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Parking assist method and parking assist device

Abstract

In a parking assist method, a surrounding image that is a color image obtained by capturing surroundings of an own vehicle is acquired, the surrounding image is converted to a first multi-gradation image in such a way that a luminance difference between a region in which a ratio of a green component is low and a region in which the ratio of the green component is high in the surrounding image increases, a feature point is extracted from the first multi-gradation image, and a relative position of the own vehicle with respect to a target parking position is calculated based on the extracted feature point.

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Background/Summary

TECHNICAL FIELD
(1) The present invention relates to a parking assist method and a parking assist device.
BACKGROUND
(2) In JP 2017-138664 A, a driving control device configured to extract a feature point from an

image in which surroundings of a target parking position was captured in the past and store the feature point, calculate a relative position of the target parking position with respect to the own vehicle, based on a position of a stored target object and a position of the target object extracted from an image in which surroundings of the own vehicle is captured at the time of autonomous parking, and cause the own vehicle to autonomously move to the target parking position, based on the calculated relative position is described.

SUMMARY

(3) When a vegetation region is included in an image obtained by capturing the surroundings of the target parking position or an image obtained by capturing the surroundings of the own vehicle, there is a risk that calculation precision of the target parking position deteriorates due to a feature point of an indistinct outline or the like being extracted in the vegetation region.

(4) An object of the present invention is to, in parking assist to assist parking of an own vehicle at a target parking position based on a feature point extracted from a captured image, improve calculation precision of the target parking position when a vegetation region is included in the captured image.

(5) According to an aspect of the present invention, there is provided a parking assist method for assisting parking of an own vehicle at a target parking position, the parking assist method including: extracting a feature point in surroundings of the target parking position from an image obtained by capturing surroundings of the own vehicle as a learned feature point and storing the learned feature point in a storage device, in advance; acquiring an image by capturing surroundings of the own vehicle when causing the own vehicle to move to the target parking position; extracting a feature point in surroundings of the own vehicle from an image of surroundings of the own vehicle as a surrounding feature point; calculating a relative position of the own vehicle with respect to the target parking position, based on a relative positional relationship between the learned feature point and the target parking position and a relative positional relationship between the surrounding feature point and the own vehicle; calculating a target travel trajectory starting from a current position of the own vehicle and reaching the target parking position, based on a relative position of the own vehicle with respect to the calculated target parking position and assisting the own vehicle in moving along the target travel trajectory; and when a target feature point, the target feature point being at least one the learned feature point and the surrounding feature point, is extracted: converting a surrounding image, the surrounding image being a color image obtained by capturing surroundings of the own vehicle, to a first multi-gradation image in such a way that in the surrounding image, a luminance difference between a region in which a ratio of a green component is low and a region in which a ratio of a green component is high increases; and extracting the target feature point from the first multi-gradation image.

(6) According to an aspect of the present invention, it is possible to, in parking assist to assist parking of an own vehicle at a target parking position based on a feature point extracted from a captured image, improve calculation precision of the target parking position when a vegetation region is included in the captured image.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a diagram illustrative of a schematic configuration example of a parking assist device;

(2) FIG. **2**A is an explanatory diagram of an example of processing of storing a learned feature point;

(3) FIG. **2**B is an explanatory diagram of an example of processing performed when parking assist is performed;

(4) FIG. **3** is a block diagram of an example of a functional configuration of a controller in FIG. **1**;

(5) FIG. **4** is a diagram illustrative of an example of a grayscale image generated from a surrounding image when illuminance around an own vehicle is greater than or equal to a predetermined threshold value;

(6) FIG. **5** is a diagram illustrative of an example of a first intermediate image generated from the surrounding image when the illuminance around the own vehicle is greater than or equal to the predetermined threshold value;

(7) FIG. **6** is a diagram illustrative of an example of a second intermediate image;

(8) FIG. **7** is a diagram illustrative of an example of a multi-gradation image obtained by a second method;

(9) FIG. **8** is a diagram illustrative of an example of a multi-gradation image obtained by a third method;

(10) FIG. **9**A is a diagram illustrative of an example of a grayscale image generated from a surrounding image when the illuminance around the own vehicle is less than the predetermined threshold value and a partially enlarged image;

(11) FIG. **9**B is a diagram illustrative of the grayscale image in FIG. **4** and a partially enlarged image;

(12) FIG. **9**C is a diagram illustrative of the multi-gradation image in FIG. **8** and a partially enlarged image;

(13) FIG. **10**A is an explanatory diagram of a first example of processing of storing a learned feature point;

(14) FIG. **10**B is an explanatory diagram of a first example of multi-gradation image generation processing;

(15) FIG. **10**C is an explanatory diagram of a second example of the multi-gradation image generation processing;

(16) FIG. **10**D is an explanatory diagram of a third example of the multi-gradation image generation processing;

(17) FIG. **10**E is an explanatory diagram of a second example of the processing of storing a learned feature point;

(18) FIG. **11**A is an explanatory diagram of a first example of processing performed when the parking assist is performed; and

(19) FIG. **11**B is an explanatory diagram of a second example of the processing performed when the parking assist is performed.

DETAILED DESCRIPTION

(20) (Configuration)

(21) FIG. **1** is now referred to. An own vehicle **1** includes a parking assist device **10** configured to assist parking of the own vehicle **1** at a target parking position. The parking assist device **10** assists the own vehicle **1** in traveling along a target travel trajectory from a current position of the own vehicle **1** to the target parking position. For example, the parking assist device **10** may perform autonomous driving in which the own vehicle **1** is controlled to autonomously travel to the target parking position along the target travel trajectory of the own vehicle **1** (that is, control to cause the own vehicle **1** to control all or some of a steering angle, driving force, and braking force thereof and autonomously perform all or a portion of travel along the target travel trajectory). Alternatively, the parking assist device **10** may assist parking of the own vehicle **1** by displaying the target travel trajectory and the current position of the own vehicle **1** on a display device that a passenger of the own vehicle **1** can visually recognize.

(22) The positioning device **11** measures the current position of the own vehicle **1**. The positioning device **11** includes, for example, a global navigation satellite system (GNSS) receiver. Human-machine interfaces (HMIs) **12** are interface devices between the parking assist device **10** and the passenger and include the display device, a speaker, a buzzer, and an operation element. A shift switch (shift SW) **13** is a switch for a driver or the parking assist device **10** to switch a shift

position. External sensors **14** detect an object existing in a predetermined distance range from the own vehicle **1**. The external sensors **14** detect a surrounding environment of the own vehicle **1**, such as a relative position between an object existing in surroundings of the own vehicle **1** and the own vehicle **1**, distance between the own vehicle **1** and the object, and a direction in which the object exists. The external sensors **14** may include, for example, a camera to capture an image of the surrounding environment of the own vehicle **1**. To cope with parking assist of the own vehicle **1** in an environment in which illuminance around the own vehicle **1** is less than a predetermined threshold value (for example, at night), a camera for day and night use that is capable of capturing an image in both a visible light region and an infrared region may be employed as the camera included in the external sensors **14**. A camera for daytime use capable of capturing an image in the visible light region and a camera capable of capturing an image in the infrared region may be individually included in the external sensors **14**. In the present embodiment, an example of a case where a camera for day and night use is employed will be described. Hereinafter, the camera in the external sensors **14** is simply referred to as "camera". The external sensors **14** may include a ranging device, such as a laser range finder, a radar, and a LiDAR. The vehicle sensors **15** detect various information (vehicle information) about the own vehicle **1**. The vehicle sensors **15** may include, for example, a vehicle speed sensor, wheel speed sensors, a triaxial acceleration sensor (G sensor), a steering angle sensor, a turning angle sensor, a gyro sensor, and a yaw rate sensor.

(23) The controller **16** is an electronic control unit that performs parking assist control of the own vehicle **1**. The controller **16** includes a processor **20** and peripheral components, such as a storage device **21**. The storage device **21** may include a semiconductor storage device, a magnetic storage device, an optical storage device, or the like. Functions of the controller **16** may be achieved by, for example, the processor **20** executing computer programs stored in the storage device **21**. A steering actuator **18***a* controls steering direction and the amount of steering of a steering mechanism in accordance with a control signal from the controller **16**. An accelerator actuator **18***b* controls accelerator opening of a drive device (an engine or a drive motor) in accordance with a control signal from the controller **16**. A brake actuator **18***c* causes a braking device to operate in accordance with a control signal from the controller **16**.

(24) An infrared projector **19** irradiates the surroundings of the own vehicle **1** with infrared light in accordance with a control signal from the controller **16** when the parking assist device **10** assists parking of the own vehicle **1** in an environment in which the illuminance around the own vehicle **1** is less than the predetermined threshold value. For example, the infrared projector may be infrared light-emitting diodes that are installed on the left-hand side and right-hand side of the own vehicle **1**, radiate infrared light obliquely downward on each of the left and right lateral sides of the own vehicle **1**, and irradiate nearby road surfaces on the left and right lateral sides of the own vehicle **1** with infrared light.

(25) Next, the parking assist control performed by the parking assist device **10** will be described. FIG. **2**A is now referred to. When the parking assist performed by the parking assist device **10** is used, the parking assist device **10** extracts a feature point from an image obtained by capturing surroundings of a target parking position **30** that is a position at which the own vehicle **1** is to be parked, and causes the storage device **21** to store the extracted feature point in advance. Hereinafter, a feature point stored in the storage device **21** is referred to as "learned feature point". In FIG. **2**A, circular marks represent learned feature points. For example, the parking assist device **10** extracts feature points in the surroundings of the target parking position **30** from a surrounding image that is obtained by capturing the surroundings of the own vehicle **1** by the camera when the own vehicle **1** is positioned in a vicinity of the target parking position **30** (for example, when the own vehicle **1** is to be parked at the target parking position **30** by manual driving). For example, the parking assist device **10** detects, as a feature point, an edge point at which luminance changes between adjacent pixels by a predetermined amount or more or a point having a characteristic shape, such as an edge and a corner of a target object like a pavement marking, a road boundary, an

obstacle, or the like, in a captured image captured by the camera. When the learned feature points are to be stored in the storage device **21**, for example, the driver operates a "parking position learning switch" that is prepared as an operation element in the HMIs **12**. Note that when the illuminance around the own vehicle **1** is less than the predetermined threshold value, learned feature points are extracted from a captured image obtained by capturing the image while the infrared projector **19** irradiates the surroundings of the own vehicle **1** with infrared light.

(26) The parking assist device **10** stores a relative positional relationship between a learned feature point and the target parking position **30**. For example, the driver may input a fact that the own vehicle **1** is positioned at the target parking position **30**, through an HMI **12**. The parking assist device **10** may calculate a relative positional relationship between a learned feature point and the target parking position **30**, based on a position of a learned feature point that is detected when the own vehicle **1** is positioned at the target parking position **30**. For example, the parking assist device **10** may store coordinates of a learned feature point and the target parking position **30** in a coordinate system with a fixed point as a reference point (hereinafter, referred to as "map coordinate system"). In this case, the parking assist device **10** may store a current position in the map coordinate system that the parking assist device **10** measures using the positioning device **11** when the own vehicle **1** is positioned at the target parking position **30**, as the target parking position **30**. Alternatively, the parking assist device **10** may store a relative position of the target parking position **30** with respect to each learned feature point in place of a position in the map coordinate system.

(27) FIG. **2B** is an explanatory diagram of an example of processing performed when the parking assist is performed. The parking assist device **10** performs the parking assist of the own vehicle **1** when the own vehicle **1** is positioned in the vicinity of the target parking position **30**. For example, the parking assist device **10** determines whether or not the driver performs a shift operation for turnabout to switch forward movement and backward movement of the own vehicle **1** when the own vehicle **1** is positioned in the vicinity of the target parking position **30**. A reference sign **31** denotes a turnabout position. The parking assist device **10** may determine that a shift operation for turnabout is performed when the shift position is changed from a drive range (D range) to a reverse range (R range) or changed from the R range to the D range, and start the parking assist. When the own vehicle **1** is positioned at a position **33** in the vicinity of the target parking position **30** and the driver operates a "parking assist activation switch" that is prepared in the HMIs **12**, the parking assist device **10** may start the parking assist.

(28) The parking assist device **10** extracts a feature point in the surroundings of the own vehicle **1** from a surrounding image that is obtained by capturing the surroundings of the own vehicle **1** with the camera. Hereinafter, a feature point in the surroundings of the own vehicle **1** that is extracted when the parking assist is performed is referred to as "surrounding feature point". In FIG. **2B**, triangular marks represents surrounding feature points.

(29) Note that when the illuminance around the own vehicle **1** is less than the predetermined threshold value when the parking assist is performed, the parking assist device **10** extracts a surrounding feature point from a captured image obtained by capturing the image with the camera while the infrared projector **19** irradiates the surroundings of the own vehicle **1** with infrared light.

(30) The parking assist device **10** matches and compares a learned feature point stored in the storage device **21** and a surrounding feature point with each other and associates the same feature points with each other.

(31) The parking assist device **10** calculates a relative position of the own vehicle **1** with respect to the target parking position **30**, based on a relative positional relationship between a surrounding feature point detected when the parking assist is performed and the own vehicle **1** and a relative positional relationship between a learned feature point associated with the surrounding feature point and the target parking position **30**. For example, the parking assist device **10** may calculate a position of the target parking position **30** in a coordinate system with reference to the current

position of the own vehicle **1** (hereinafter, referred to as "vehicle coordinate system"). For example, when coordinates of a learned feature point and the target parking position **30** in the map coordinate system are stored in the storage device **21**, the parking assist device **10** may convert the coordinates of the target parking position **30** in the map coordinate system to coordinates of the target parking position **30** in the vehicle coordinate system, based on a position of a surrounding feature point detected when the parking assist is performed and the position of the learned feature points in the map coordinate system. Alternatively, the parking assist device **10** may calculate the current position of the own vehicle **1** in the map coordinate system, based on the position of the surrounding feature point detected when the parking assist is performed and the position of the learned feature point in the map coordinate system, and calculate the relative position of the own vehicle **1** with respect to the target parking position **30** from a difference between the coordinates of the own vehicle **1** and the coordinates of the target parking position **30** in the map coordinate system. The parking assist device **10** calculates a target travel trajectory starting from the current position of the own vehicle **1** and reaching the target parking position **30**, based on the relative position of the own vehicle **1** with respect to the target parking position **30**. For example, when the position of the own vehicle **1** at a time point when the parking assist is started is the turnabout position **31**, the parking assist device **10** calculates a trajectory **32** starting from the turnabout position **31** and reaching the target parking position **30**. In addition, for example, when the position of the own vehicle **1** at a time point when the parking assist is started is the position **33** in the vicinity of the target parking position **30**, the parking assist device **10** calculates a trajectory **34** starting from the position **33** and reaching the turnabout position **31** and the trajectory **32** starting from the turnabout position **31** and reaching the target parking position **30**. The parking assist device **10** performs parking assist control of the own vehicle **1**, based on the calculated target travel trajectory.

(32) A functional configuration of the controller **16** is illustrated in FIG. **3**. A human-machine interface control unit (HMI control unit) **40** outputs a map generation command to cause a learned feature point to be stored in the storage device **21** to a map generation unit **45** when the parking position learning switch is operated. The HMI control unit **40** determines whether or not the driver performs a shift operation for turnabout and whether or not the parking assist activation switch is operated, and outputs a determination result to a parking assist control unit **41**. The parking assist control unit **41** determines whether or not the own vehicle **1** is positioned in the vicinity of the stored target parking position **30**. For example, the parking assist control unit **41** determines whether or not distance between the own vehicle **1** and the target parking position **30** is less than or equal to a predetermined distance. When the own vehicle **1** is positioned in the vicinity of the target parking position **30** and the parking assist control unit **41** detects the parking assist activation switch being operated or a shift operation for turnabout being performed, the parking assist control unit **41** sets the stored target parking position **30** as the target parking position **30** in the parking assist control and starts the parking assist control.

(33) When the parking assist control unit **41** starts the parking assist control, the parking assist control unit **41** outputs a parking position calculation command to cause the position of the target parking position **30** in the vehicle coordinate system to be calculated to a matching unit **47**. In addition, the parking assist control unit **41** outputs a travel trajectory calculation command to cause a target travel trajectory and a target vehicle speed profile in accordance with which the own vehicle **1** travels the target travel trajectory to be calculated to a target trajectory generation unit **48**. The target trajectory generation unit **48** calculates a target travel trajectory starting from the current position of the own vehicle **1** and reaching the target parking position **30** and a target vehicle speed profile and outputs the calculated target travel trajectory and target vehicle speed profile to the parking assist control unit **41**. To calculation of the target travel trajectory, a well-known method that is employed for an automated parking device can be applied. For example, the target travel trajectory can be calculated by connecting the current position of the own vehicle **1** to the target

parking position **30** by way of the turnabout position **31** with clothoid curves. In addition, for example, the target vehicle speed profile may be a vehicle speed profile that causes the own vehicle **1** to accelerate to a predetermined set speed from the current position of the own vehicle **1** and subsequently decelerate before reaching the turnabout position **31** and come to a stop at the turnabout position **31**, and accelerate to the set speed from the turnabout position **31**, decelerate before reaching the target parking position **30**, and come to a stop at the target parking position **30**.

(34) The parking assist control unit **41** outputs the target travel trajectory and information about the current position of the own vehicle **1** to the HMI control unit **40**. When the target travel trajectory includes a turnabout position, the parking assist control unit **41** outputs information about the turnabout position to the HMI control unit **40**. The HMI control unit **40** displays the target travel trajectory, the current position of the own vehicle **1**, and the turnabout position on an HMI **12**.

(35) In addition, the parking assist control unit **41** outputs a steering control command to control steering in such a way as to cause the own vehicle **1** to travel along the calculated target travel trajectory to a steering control unit **49**. In addition, the parking assist control unit **41** outputs a vehicle speed control command to control vehicle speed of the own vehicle **1** in accordance with the calculated target vehicle speed profile to a vehicle speed control unit **50**. An image conversion unit **42** converts a captured image captured by the camera to an overhead image (an around view monitoring image) that is an image viewed from a virtual viewpoint directly above the own vehicle **1**. The image conversion unit **42** generates a surrounding image as illustrated in FIGS. **2**A and **2**B by converting a captured image to an overhead image at a predetermined interval (for example, every time the own vehicle **1** travels a predetermined distance (for example, 50 cm) or travels for a predetermined time (for example, for one second)) and accumulating converted overhead images along a travel route of the own vehicle **1**. A self-position calculation unit **43** calculates the current position of the own vehicle **1** in the map coordinate system by dead reckoning based on vehicle information output from the vehicle sensors **15**.

(36) When a feature point detection unit **44** stores a learned feature point in the storage device **21**, the feature point detection unit **44** detects a learned feature point and an image feature amount of the learned feature point from a surrounding image output from the image conversion unit **42**. When the parking assist control is performed, the feature point detection unit **44** detects a surrounding feature point and an image feature amount of the surrounding feature point. Hereinafter, a learned feature point and a surrounding feature point are sometimes collectively referred to as "feature point". The feature point detection unit **44** detects a feature point and an image feature amount of the feature point from a surrounding image output from the image conversion unit **42**. For detection of a feature point and calculation of an image feature amount, various methods, such as SIFT, SURF, ORB, BRIAK, KAZE, and AKAZE, can be made use of.

(37) In a surrounding image of the own vehicle **1**, a vegetation region (that is, a region in which plants have grown) is sometimes included. There are some cases where in the vegetation region, a luminance difference is generated between a portion irradiated with light and a shadow portion not irradiated with light and a feature point having a minuscule size and an indistinct outline is extracted. Since a shadow of leaves of a plant changes due to a light source (for example, the sun), there is a risk that calculation precision of the target parking position deteriorates.

(38) In addition, in general, an image captured without radiating infrared light in an environment in which the illuminance around the own vehicle **1** is greater than or equal to the predetermined threshold value (for example, a daytime) has a characteristic that luminance of a vegetation region is lower than luminance of asphalt, and an image captured with infrared light radiated has a characteristic that the luminance of the vegetation region is higher than the luminance of asphalt. Therefore, when one of a learned feature point and a surrounding feature point is extracted from an image captured with infrared light radiated and the other of the learned feature point and the surrounding feature point is extracted from an image captured without radiating infrared light, there is a risk that the calculation precision of the target parking position deteriorates.

(39) Accordingly, when the parking assist device **10** of the embodiment extracts a learned feature point or a surrounding feature point from an image captured without irradiating the surroundings of the own vehicle **1** with infrared light in an environment in which the illuminance around the own vehicle **1** is greater than or equal to the predetermined threshold value, the parking assist device **10** converts a surrounding image to a colorless multi-gradation image in such a way that in a color surrounding image obtained by capturing the surroundings of the own vehicle **1**, a luminance value in a region in which a ratio of a green component is high increases to a higher value than a luminance value in a region in which the ratio of the green component is low, and extracts a feature point from the converted multi-gradation image.

(40) For example, the parking assist device **10** may convert a surrounding image to a multi-gradation image in such a way that a luminance value in the region in which the ratio of the green component is high is saturated (that is, the luminance value reaches an image luminance upper limit).

(41) As described above, since a vegetation region in a color surrounding image is a region in which the ratio of the green component is high, a luminance difference between a portion in which plants are irradiated with light and a shadow portion in which plants are not irradiated with light can be reduced by increasing a luminance value in the region in which the ratio of the green component is high. Since as a result, an indistinct outline feature point is less likely to be extracted in the vegetation region, the calculation precision of the target parking position can be improved. In addition, the luminance of the vegetation region can be made higher than luminance of an asphalt region in the image captured without radiating infrared light. Since because of this capability, luminance characteristics of the vegetation region and the asphalt region come to resemble each other between the image captured without radiating infrared light and the image captured with infrared light radiated, the calculation precision of the target parking position can be improved.

(42) A detection method of a feature point by the feature point detection unit **44** will be described below in detail. In an environment in which the illuminance around the own vehicle **1** is greater than or equal to the predetermined threshold value, the feature point detection unit **44** extracts a feature point from a surrounding image captured without radiating infrared light.

(43) In order to reduce a luminance difference between a portion in which plants are irradiated with light and a shadow portion in which plants are not irradiated with light, the feature point detection unit **44** converts the surrounding image to a multi-gradation image in such a way that a luminance value in a region in which the ratio of the green component is high increases to a higher value than a luminance value in a region in which the ratio of the green component is low, in the color surrounding image. The multi-gradation image is an example of a "first multi-gradation image" described in the claims.

(44) As a first method, a surrounding image may be converted to a multi-gradation image in such a way that a luminance value in the region in which the ratio of the green component is high increases. For example, the feature point detection unit **44** converts a color surrounding image to a multi-gradation image in such a way that, based on a ratio of at least two color components including, of an R component (red component) Cr, a G component (green component) Cg, and a B component (blue component) Cb in the color surrounding image, the G component Cg, a luminance value of each pixel in a region in which a ratio of the G component (green component) Cg is higher than a predetermined value is saturated (that is, the luminance value reaches the image luminance upper limit). Note that a luminance value in the region in which the ratio of Cg is higher than the predetermined value may be increased based on, instead of the image luminance upper limit, a ratio of two color components.

(45) As a second method, (1) a grayscale image (equivalent to a second multi-gradation image) of a surrounding image is generated, (2) the surrounding image is converted to a first intermediate image in such a way that a luminance value in a vegetation region decreases, (3) a second intermediate image is generated based on a luminance difference between the grayscale image and

the first intermediate image, and (4) luminance of the second intermediate image is inverted. Through the processes (1) to (4), a colorless multi-gradation image in which a luminance value in the region in which the ratio of the green component is high has increased to a higher value than a luminance value in the region in which the ratio of the green component is low is obtained.

(46) First, the feature point detection unit **44** generates a grayscale image of a surrounding image by applying ordinary (general) grayscale conversion to the surrounding image that is a color image.

(47) FIG. **4** is a diagram illustrative of an example of a grayscale image. For example, the feature point detection unit **44** may determine a luminance value of each pixel in the grayscale image by weighted-combining an R component Cr, a G component Cg, and a B component Cb of a corresponding pixel in the color surrounding image, using predetermined weighting coefficients. The grayscale image is an example of a "second multi-gradation image" described in the claims. Regions Rv enclosed by dashed lines indicate vegetation regions. An image captured without irradiating the surroundings of the own vehicle **1** with infrared light has a characteristic that the luminance of the vegetation regions Rv is lower than the luminance of the asphalt region in the surroundings of the vegetation regions Rv.

(48) Next, the feature point detection unit **44** converts the color surrounding image to a first intermediate image that is a colorless multi-gradation image. On this occasion, the feature point detection unit **44** converts the surrounding image to the first intermediate image in such a way that in the surrounding image, a luminance value in the vegetation regions in which the ratio of the G component Cg is high is reduced to a lower value than a luminance value in a region in which the ratio of the G component Cg is low.

(49) FIG. **5** is a diagram illustrative of an example of the first intermediate image. For example, the feature point detection unit **44** may generate the first intermediate image, based on a ratio of at least two color components including the G component Cg of the R component Cr, the G component Cg, and the B component Cb at each pixel in the surrounding image. For example, when a maximum value of each of the R component Cr, the G component Cg, and the B component Cb is 255, the feature point detection unit **44** may determine a luminance value Ck of each pixel in the first intermediate image, based on the equations (1) and (2) below.

[Math1]

(50)
$$k = 2. - \frac{\frac{Cg}{255}}{\frac{Cb}{255}} \quad (1)$$

$$Ck = \left\{ \begin{array}{ll} 0, & k \leq 0 \\ k \times LUMINANCEUPPERLIMIT & 0 < k < 1 \\ LUMINANCEUPPERLIMIT, & k \geq 1 \end{array} \right. \quad (2)$$

(51) Note that in the above equation, the B component Cb may be replaced by the R component Cr.

(52) Next, the feature point detection unit **44** generates a second intermediate image, based on a luminance difference between the grayscale image in FIG. **4** and the first intermediate image in FIG. **5**. For example, the feature point detection unit **44** generates a difference image obtained by subtracting a luminance value of each pixel in the grayscale image from a luminance value of a corresponding pixel in the first intermediate image, as a second intermediate image. FIG. **6** is a diagram illustrative of an example of the second intermediate image. By subtracting a luminance value of each pixel in the grayscale image from a luminance value of a corresponding pixel in the first intermediate image, a luminance difference in a region other than the vegetation regions Rv (for example, the asphalt region) is reduced in the second intermediate image.

(53) Next, the feature point detection unit **44** generates a colorless multi-gradation image in which a luminance value in the region in which the ratio of the green component is high has increased to a higher value than a luminance value in the region in which the ratio of the green component is low, by inverting the luminance of the second intermediate image. FIG. **7** is a diagram illustrative of an example of the multi-gradation image obtained by the second method. In the image in FIG. **7**, the vegetation regions Rv become bright in a substantially uniform manner (luminance becomes high in a substantially uniform manner), and the regions other than the vegetation regions Rv (for example, the asphalt region) become dark in a substantially uniform manner (luminance becomes

low in a substantially uniform manner).

(54) As a third method, using the multi-gradation image obtained by the second method (an inverted luminance image of the second intermediate image) as a third intermediate image, a multi-gradation image is generated by calculating a weighted average of each pixel value in the third intermediate image and a corresponding pixel value in the grayscale image.

(55) FIG. **8** is a diagram illustrative of an example of the multi-gradation image obtained by the third method. Adding a pixel value in the third intermediate image causes a luminance value in the vegetation regions Rv to increase to a higher value than a luminance value in the other region.

(56) In contrast, in an environment in which the illuminance around the own vehicle **1** is less than the predetermined threshold value, the feature point detection unit **44** extracts a feature point from a surrounding image captured when infrared light is radiated by the infrared projector **19**. In this case, the feature point detection unit **44** generates a grayscale image of the surrounding image by applying ordinary grayscale conversion to the surrounding image that is a color image. The feature point detection unit **44** extracts a feature point from the grayscale image. FIG. **9**A illustrates an example of the grayscale image of the surrounding image captured with infrared light radiated and an enlarged image of a boundary portion between a vegetation region Rv and the asphalt region. In the image captured with infrared light radiated, the luminance of the vegetation regions Rv is higher than the luminance of the asphalt region.

(57) FIG. **9**B is a diagram illustrative of a grayscale image of the surrounding image captured without radiating infrared light (the grayscale image in FIG. **4**) and a partially enlarged image. In the image captured without radiating infrared light, the luminance of the vegetation regions Rv is lower than the luminance of the asphalt region, differing from the image captured with infrared light radiated.

(58) FIG. **9**C is a diagram illustrative of a multi-gradation image generated in such a way that a luminance value in the vegetation regions Rv increases to a higher value than a luminance value in the other region (the multi-gradation image in FIG. **8**) and a partially enlarged image. In the multi-gradation image in FIG. **9**C, the luminance of the vegetation regions Rv is higher than the luminance of the asphalt region, and luminance characteristics of the vegetation regions Rv and the asphalt region can be made similar to luminance characteristics in the grayscale image when infrared light is radiated (FIG. **9**A).

(59) FIG. **3** is now referred to. When a learned feature point is to be stored in the storage device **21**, the driver operates the parking position learning switch and parks the own vehicle **1** at the target parking position by manual driving. The map generation unit **45** receives a map generation command from the HMI control unit **40**. The map generation unit **45** stores feature point information including a feature point output from the feature point detection unit **44**, the current position of the own vehicle **1** synchronized with the output of the feature point, and a feature amount of the feature point in the storage device **21** as a learned feature point and generates map data **46**. The map generation unit **45** may calculate a position of a feature point in the map coordinate system, based on the current position of the own vehicle **1** and store the calculated position of the feature point as feature point information.

(60) In addition, when the driver inputs a fact that the current position of the own vehicle **1** is the target parking position **30** to the parking assist device **10**, the map generation unit **45** receives the current position of the own vehicle **1** in the map coordinate system from the positioning device **11** or the self-position calculation unit **43** and stores the current position in the map data **46** as the target parking position **30**. That is, the map generation unit **45** stores relative positional relationships between the target parking position **30** and a plurality of feature points as the map data **46**.

(61) When subsequently, the parking assist control unit **41** starts the parking assist control, the matching unit **47** receives a parking position calculation command from the parking assist control unit **41**.

(62) The matching unit **47** matches the feature point information stored in the map data **46** as a learned feature point with feature point information of a surrounding feature point output from the feature point detection unit **44** when the parking assist is performed, and associates pieces of feature point information of the same feature points with each other. The matching unit **47** calculates a current relative position of the own vehicle **1** with respect to the target parking position **30**, based on a relative positional relationship between a surrounding feature point and the own vehicle **1** and a relative positional relationship between a learned feature point associated with the surrounding feature point and the target parking position **30**. For example, surrounding feature points are denoted by (x.sub.i, y.sub.i), and learned feature points each of which is associated with one of the surrounding feature points (x.sub.i, y.sub.i) are denoted by (x.sub.mi, y.sub.mi) (i=1 to N). The matching unit **47** calculates an affine transformation matrix M.sub.affine, using the following equation, based on a least-square method.

[Math2]

$$(63) \quad \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix} = [X_X^T X_X] \quad \text{Where} X_X = \begin{bmatrix} x_{m1} & y_{m1} & 1 & 0 \\ y_{m1} & -x_{m1} & 0 & 1 \\ .\text{Math.} & .\text{Math.} & .\text{Math.} & .\text{Math.} \\ x_{mN} & y_{mN} & 1 & 0 \\ y_{mN} & -x_{mN} & 0 & 1 \end{bmatrix} X_{\text{tfm}} = \begin{bmatrix} x_1 \\ y_1 \\ .\text{Math.} \\ x_N \\ y_N \end{bmatrix}$$

$$M_{\text{affine}} = \begin{bmatrix} a_1 & a_2 & a_3 \\ -a_2 & a_1 & a_4 \end{bmatrix}$$

(64) The matching unit **47** converts a position (targetx.sub.m, targety.sub.m) of the target parking position **30** in the map coordinate system, which is stored in the map data **46**, to a position (targetx, targety) in the vehicle coordinate system, using the following equation.

[Math3]

$$(65) \quad \left\{ \begin{matrix} \text{targetx} \\ \text{targety} \end{matrix} \right\} = M_{\text{affine}} \left\{ \begin{matrix} \text{targetx}_m \\ \text{targety}_m \\ 1 \end{matrix} \right]$$

(66) When the target trajectory generation unit **48** receives a travel trajectory calculation command from the parking assist control unit **41**, the target trajectory generation unit **48** calculates a target travel trajectory starting from the current position of the own vehicle **1** and reaching the target parking position **30** in the vehicle coordinate system and a target vehicle speed profile in accordance with which the own vehicle **1** travels the target travel trajectory. When the steering control unit **49** receives a steering control command from the parking assist control unit **41**, the steering control unit **49** controls the steering actuator **18***a* in such a way that the own vehicle **1** travels along the target travel trajectory. When the vehicle speed control unit **50** receives a vehicle speed control command from the parking assist control unit **41**, the vehicle speed control unit **50** controls the accelerator actuator **18***b* and the brake actuator **18***c* in such a way that vehicle speed of the own vehicle **1** changes in accordance with the target vehicle speed profile.

(67) When the own vehicle **1** reaches the target parking position **30** and the parking assist control is completed, the parking assist control unit **41** causes a parking brake **17** to operate and switches the shift position to a parking range (P range).

(68) (Operation)

(69) FIG. **10**A is an explanatory diagram of an example of processing of storing a learned feature point in an environment in which the illuminance around the own vehicle **1** is greater than or equal to the predetermined threshold value.

(70) In step S**1**, the image conversion unit **42** converts a captured image captured by the camera to an overhead image that is an image viewed from a virtual viewpoint directly above the own vehicle **1** and acquires a surrounding image. In step S**2**, the feature point detection unit **44** performs multi-

gradation image generation processing.

(71) FIG. **10**B is an explanatory diagram of a first example of the multi-gradation image generation processing. In step S**10**, the feature point detection unit **44** converts the surrounding image to a multi-gradation image in such a way that a luminance value in a region in which the ratio of the green component is high increases.

(72) FIG. **10**C is an explanatory diagram of a second example of the multi-gradation image generation processing.

(73) In step S**20**, the feature point detection unit **44** converts the surrounding image to an ordinary grayscale image. In step S**21**, the feature point detection unit **44** converts the surrounding image to a first intermediate image. In step S**22**, the feature point detection unit **44** generates a second intermediate image. In step S**23**, the feature point detection unit **44** generates a multi-gradation image by inverting luminance of the second intermediate image.

(74) FIG. **10**D is an explanatory diagram of a third example of the multi-gradation image generation processing. Processing in steps S**30** to S**32** is the same as the processing in steps S**20** to S**22** in FIG. **10**C. In step S**33**, the feature point detection unit **44** generates a third intermediate image by inverting luminance of the second intermediate image. In step S**34**, the feature point detection unit **44** generates a multi-gradation image by calculating a weighted average of the third intermediate image and the grayscale image.

(75) FIG. **10**A is now referred to. In step S**3**, the feature point detection unit **44** extracts a feature point from the multi-gradation image. In step S**4**, the feature point detection unit **44** stores the extracted feature point in the storage device **21** as a learned feature point.

(76) FIG. **10**E is an explanatory diagram of an example of processing of storing a learned feature point in an environment in which the illuminance around the own vehicle **1** is less than the predetermined threshold value.

(77) In step S**40**, the controller **16** irradiates the surroundings of the own vehicle **1** with infrared light by the infrared projector **19**. Processing in step S**41** is the same as the processing in step S**1** in FIG. **10**A. In step S**42**, the feature point detection unit **44** converts the surrounding image to an ordinary grayscale image. In step S**43**, the feature point detection unit **44** extracts a feature point from the grayscale image. Processing in step S**44** is the same as the processing in step S**4** in FIG. **10**A.

(78) FIG. **11**A is an explanatory diagram of an example of processing performed when the parking assist is performed in an environment in which the illuminance around the own vehicle **1** is greater than or equal to the predetermined threshold value. Processing in steps S**50** and S**51** is the same as the processing in steps S**1** and S**2** in FIG. **10**A. In step S**52**, the feature point detection unit **44** extracts a surrounding feature point from the multi-gradation image. In step S**53**, the parking assist control unit **41** determines whether or not distance between the own vehicle **1** and the target parking position **30** is less than or equal to a predetermined distance. When the distance is less than or equal to the predetermined distance (step S**53**: Y), the process proceeds to step S**54**. When the distance is not less than or equal to the predetermined distance (step S**53**: N), the process returns to step S**50**. In step S**54**, the parking assist control unit **41** determines whether or not the parking assist control unit **41** has detected a shift operation for turnabout. When the parking assist control unit **41** detects the shift operation (step S**54**: Y), the process proceeds to step S**56**. When the parking assist control unit **41** has not detected the shift operation (step S**54**: N), the process proceeds to step S**55**. In step S**55**, the parking assist control unit **41** determines whether or not the parking assist activation SW has been operated by the driver. When the parking assist activation SW is operated (step S**55**: Y), the process proceeds to step S**56**. When the parking assist activation SW has not been operated (step S**55**: N), the process returns to step S**50**.

(79) In step S**56**, the matching unit **47** reads in a learned feature point from the storage device **21**. In step S**57**, the matching unit **47** matches a surrounding feature point with the learned feature point. In step S**58**, the matching unit **47** calculates a target parking position **30**, based on feature

points that match with each other. In step S**59**, the target trajectory generation unit **48** calculates a target travel trajectory and a target vehicle speed profile. In step S**60**, the steering control unit **49** and the vehicle speed control unit **50** control the steering actuator **18***a*, the accelerator actuator **18***b*, and the brake actuator **18***c*, based on the target travel trajectory and the target vehicle speed profile. In step S**61**, when the parking assist control is completed, the parking assist control unit **41** causes the parking brake **17** to operate and switches the shift position to the P range.

(80) FIG. **11**B is an explanatory diagram of an example of processing performed when the parking assist is performed in an environment in which the illuminance around the own vehicle **1** is less than the predetermined threshold value.

(81) Processing in steps S**70** to S**72** is the same as the processing in steps S**40** to S**42** in FIG. **10**E. In step S**73**, the feature point detection unit **44** extracts a surrounding feature point from the grayscale image. Processing in steps S**74** to S**82** is the same as the processing in steps S**53** to S**61** in FIG. **11**A.

ADVANTAGEOUS EFFECTS OF EMBODIMENT

(82) (1) In the parking assist method, when a target feature point that is at least one of a learned feature point and a surrounding feature point is to be extracted, a surrounding image that is a color image obtained by capturing the surroundings of the own vehicle **1** is converted to a first multi-gradation image in such a way that in the surrounding image, a luminance difference between a region in which the ratio of the green component is low and a region in which the ratio of the green component is high increases, and the target feature point is extracted from the first multi-gradation image. Since because of this configuration, an indistinct feature point is less likely to be extracted in a vegetation region, the calculation precision of the target parking position can be improved. (2) One of a learned feature point and a surrounding feature point may be extracted from an image obtained by capturing the image when the surroundings of the own vehicle **1** is irradiated with infrared light, and the other of the learned feature point and the surrounding feature point may be extracted from the first multi-gradation image. Because of this configuration, even when one of the learned feature point and the surrounding feature point is extracted from an image captured with infrared light radiated and the other of the learned feature point and the surrounding feature point is extracted from an image captured without radiating infrared light, the calculation precision of the target parking position can be improved. (3) The surrounding image may be converted to the first multi-gradation image in such a way that a luminance value in the vegetation region in the surrounding image increases as a region in which the ratio of the green component is high within the surrounding image. Since because of this configuration, an indistinct feature point is less likely to be extracted in the vegetation region, the calculation precision of the target parking position can be improved. (4) The first multi-gradation image may be generated based on a ratio of at least two color components including the green component of the color components of the surrounding image that is a color image.

(83) Because of this configuration, the first multi-gradation image can be generated in such a way that a luminance value in a region in which the ratio of the green component is high increases to a higher value than a luminance value in a region in which the ratio of the green component is low. (5) A second multi-gradation image may be generated by applying grayscale conversion to the surrounding image, a first intermediate image that is a colorless multi-gradation image may be generated based on a ratio of at least two color components including the green component of the color components of the surrounding image that is a color image, a second intermediate image may be generated based on a luminance difference between the first intermediate image and the second multi-gradation image, and the first multi-gradation image may be generated by inverting luminance of the second intermediate image. Because of this configuration, the second intermediate image can be generated in such a way that a luminance difference in a region in which the ratio of the green component is low decreases. (6) A third intermediate image may be generated by inverting the luminance of the second intermediate image, and the first multi-gradation image may

be generated by calculating a weighted average of each pixel value in the third intermediate image and a corresponding pixel value in the second multi-gradation image. Because of this configuration, the first multi-gradation image can be generated in such a way that a luminance value in a region in which the ratio of the green component is high increases to a higher value than a luminance value in a region in which the ratio of the green component is low.

REFERENCE SIGNS LIST

(84) **1** Own vehicle **10** Driving assist device **16** Controller

Claims

1. A parking assist method for assisting parking of an own vehicle at a target parking position, the parking assist method comprising: extracting a feature point in surroundings of the target parking position from an image obtained by capturing surroundings of the own vehicle as a learned feature point and storing the learned feature point in a storage device, in advance; acquiring an image by capturing surroundings of the own vehicle when causing the own vehicle to move to the target parking position; extracting a feature point in surroundings of the own vehicle from an image of surroundings of the own vehicle as a surrounding feature point; calculating a relative position of the own vehicle with respect to the target parking position, based on a relative positional relationship between the learned feature point and the target parking position and a relative positional relationship between the surrounding feature point and the own vehicle; calculating a target travel trajectory starting from a current position of the own vehicle and reaching the target parking position, based on a relative position of the own vehicle with respect to the calculated target parking position and assisting the own vehicle in moving along the target travel trajectory; and when a target feature point, the target feature point being at least one the learned feature point and the surrounding feature point, is extracted: converting a surrounding image, the surrounding image being a color image obtained by capturing surroundings of the own vehicle, to a first multi-gradation image in such a way that in the surrounding image, a luminance difference between a region in which a ratio of a green component is low and a region in which a ratio of a green component is high increases; and extracting the target feature point from the first multi-gradation image.

2. The parking assist method according to claim 1, further comprising extracting at least one of the learned feature point and the surrounding feature point from an image obtained by capturing the image when surroundings of the own vehicle are irradiated with infrared light and extracts another of the learned feature point and the surrounding feature point from the first multi-gradation image.

3. The parking assist method according to claim 1, further comprising converting the surrounding image to the first multi-gradation image in such a way that a luminance value in a vegetation region in the surrounding image increases as a region in which a ratio of a green component is high within the surrounding image.

4. The parking assist method according to claim 1, further comprising generating the first multi-gradation image, based on a ratio of at least two color components including a green component of respective color components of the surrounding image, the surrounding image being a color image.

5. The parking assist method according to claim 1, further comprising: generating a second multi-gradation image by applying grayscale conversion to the surrounding image; generating a first intermediate image, the first intermediate image being a colorless multi-gradation image, based on a ratio of at least two color components including a green component of respective color components of the surrounding image, the surrounding image being a color image; generating a second intermediate image, based on a luminance difference between the first intermediate image and the second multi-gradation image; and generating the first multi-gradation image by inverting luminance of the second intermediate image.

6. The parking assist method according to claim 1, further comprising: generating a second multi-

gradation image by applying grayscale conversion to the surrounding image; generating a first intermediate image, the first intermediate image being a colorless multi-gradation image, based on a ratio of at least two color components including a green component of respective color components of the surrounding image, the surrounding image being a color image; generating a second intermediate image, based on a luminance difference between the first intermediate image and the second multi-gradation image; generating a third intermediate image by inverting luminance of the second intermediate image; and generating the first multi-gradation image by calculating a weighted average of each pixel value in the third intermediate image and a corresponding pixel value in the second multi-gradation image.

7. A parking assist device comprising: an image capturing device configured to capture surroundings of an own vehicle; a storage device; and a controller configured to: extract a feature point in surroundings of a target parking position from an image obtained by capturing surroundings of the own vehicle as a learned feature point and store the learned feature point in a storage device, in advance; acquire an image by capturing surroundings of the own vehicle when causing the own vehicle to move to the target parking position; extract a feature point in surroundings of the own vehicle from an image of surroundings of the own vehicle as a surrounding feature point; calculate a relative position of the own vehicle with respect to the target parking position, based on a relative positional relationship between the learned feature point and the target parking position and a relative positional relationship between the surrounding feature point and the own vehicle; calculate a target travel trajectory starting from a current position of the own vehicle and reaching the target parking position, based on a relative position of the own vehicle with respect to the calculated target parking position; and assist the own vehicle in moving along the target travel trajectory, wherein when the controller extracts a target feature point, the target feature point being at least one of the learned feature point and the surrounding feature point, the controller: converts a surrounding image, the surrounding image being a color image obtained by capturing surroundings of the own vehicle, to a first multi-gradation image in such a way that in the surrounding image, a luminance difference between a region in which a ratio of a green component is low and a region in which a ratio of a green component is high increases, and extracts the target feature point from the first multi-gradation image.