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Display device for enabling a user to visually recognize an image as a virtual image

Abstract

A display device includes a controller that determines the mode of inclination of a display object that is an image shaped to point to one direction, and a drawing unit that projects light representing the display object in the mode of inclination determined by the controller onto a windshield to cause the light to be reflected off the windshield toward a user in the vehicle to enable the user to visually recognize the display object in the mode of inclination as a virtual image through the windshield. The controller determines the mode of inclination of the display object that points to the one direction as a navigation direction, by controlling yaw and roll angles of the display object depending on the attribute of a path point that is set on the path to navigate the vehicle to a destination.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) This is a continuation application of PCT International Application No. PCT/JP2021/031521 filed on Aug. 27, 2021, designating the United States of America, which is based on and claims priority of Japanese Patent Application No. 2020-146228 filed on Aug. 31, 2020.

FIELD
(1) The present disclosure relates to a display device for enabling a user to visually recognize an image as a virtual image.
BACKGROUND
(2) Display devices have conventionally been proposed in which light representing an image is projected onto and reflected off a translucent plate-like display medium while showing a background through the display medium to a user so as to enable the user to visually recognize the image as a virtual image. Such display devices use so-called augmented reality (AR) and are capable of displaying, in a real background, an image related to the background. In particular, in fields such as automobile-related fields, so-called head-up displays (HUDs) have been developed that display an image indicating speed or various types of warnings as a virtual image in front of a windshield during driving (see, for example, Patent Literature (PTL) 1).
(3) The use of such a display device enables a driver as the user to see driving-related images (e.g., a map, a speed meter, or a navigation direction), i.e., display objects, without large eye movements while seeing the outside world ahead. The driver is thus able to drive more carefully.
CITATION LIST
Patent Literature
(4) PTL 1: International Publication No. 2015/118859
SUMMARY
(5) However, the display device which is the head-up display of the above PTL 1 can be improved upon.
(6) In view of this, the present disclosure provides a display device capable of improving upon the above related art.
(7) A display device according to one aspect of the present disclosure includes a control circuit that determines a mode of inclination of a display object that is an image shaped to point to one

direction; and a projector that projects light representing the display object in the mode of inclination determined by the control circuit onto a display medium provided in a vehicle, to cause the light to be reflected off the display medium toward a user in the vehicle to enable the user to visually recognize the display object in the mode of inclination as a virtual image through the display medium. The control circuit determines the mode of inclination of the display object that points to the one direction as a navigation direction, by controlling a yaw angle and a roll angle of the display object in accordance with an attribute of a path point that is set on a path for navigation of the vehicle to a destination.
(8) Note that these general and specific aspects may be achieved by a system, a method, an integrated circuit, a computer program, or a computer-readable recording medium such as a CD-ROM, or may be achieved by any combination of a system, a method, an integrated circuit, a computer program, and a computer-readable recording medium. The recording medium as referred to herein may be a non-transitory recording medium.
(9) The display device according to one aspect of the present disclosure is capable of improving upon the above related art.
(10) Further advantages and effects of one aspect of the present disclosure become apparent from the specification and the drawings. These advantages and/or effects are each implemented by features described in some embodiments and in the specification and drawings, but not all of them have to be implemented necessarily in order to achieve one or more of the same features.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a diagram showing an example of use of a display device according to an embodiment.
(2) FIG. **2** is a diagram showing one example of the interior of a vehicle that includes the display device according to the embodiment.
(3) FIG. **3** is a block diagram illustrating a functional configuration of the display device according to the embodiment.
(4) FIG. **4** is a diagram showing one example of a display object according to the embodiment.
(5) FIG. **5** is a diagram showing a specific example of a display object overlaid on a road surface by the display device according to the embodiment.
(6) FIG. **6** is a diagram showing another specific example of a display object overlaid on a road surface by the display device according to the embodiment.
(7) FIG. **7** is a diagram showing an example of comparison between a conventional display object and a display object overlaid on a road surface by the display device according to the embodiment.
(8) FIG. **8** is a diagram showing another example of comparison between a conventional display object and a display object overlaid on a road surface by the display device according to the embodiment.
(9) FIG. **9**A is a diagram showing one example of controlling the yaw angle of a display object according to the embodiment.
(10) FIG. **9**B is a diagram showing one example of a method of determining a path point according to the embodiment.
(11) FIG. **10** is a diagram showing one example of controlling the roll angle of a display object according to the embodiment.
(12) FIG. **11** is a diagram showing one example of controlling the position of a display object according to the embodiment.
(13) FIG. **12** is a diagram showing one example of controlling the shape of a display object according to the embodiment.

(14) FIG. **13** is a diagram showing one example of controlling the design of a display object according to the embodiment.
(15) FIG. **14** is a diagram showing another example of controlling the design of a display object according to the embodiment.
(16) FIG. **15** is a diagram showing one example of controlling the movement of a display object according to the embodiment.
(17) FIG. **16** is a diagram showing one example of controlling the height of a display object according to the embodiment.
(18) FIG. **17** is a diagram showing a more specific example of controlling the height of a display object according to the embodiment.
(19) FIG. **18** is a diagram showing another example of controlling the height of a display object according to the embodiment.
(20) FIG. **19** is a diagram showing one example of controlling an offset in the yaw angle of a display object according to the embodiment.
(21) FIG. **20** is a flowchart showing processing operations of the display device according to the embodiment.

DESCRIPTION OF EMBODIMENT

(22) (Underlying Knowledge Forming Basis of the Present Disclosure)
(23) The inventors of the present disclosure have found the following possible problems with the display device according to PTL 1 described in the “Background Art”.
(24) The display device according to PTL 1 displays guidance for vehicle navigation. That is, the display device overlays a display object such as an arrow on a road surface. The displayed guidance is expressed as AR, and the display object displayed as guidance may have, for example, a long carpet-like shape.
(25) The display object displayed as guidance may, however, extend off a driving lane when navigation uses a low-precision map or a sensor with low detection accuracy. In other words, overlay misregistration may occur. There is also a possibility that the long display object as a whole may not fit in a display range and may be lost in part. Such overlay misregistration and loss are likely to give a feeling of discomfort to a user. Besides, the feeling of discomfort may mislead the user or the vehicle.
(26) To solve the problems described above, a display device according to one aspect of the present disclosure includes a controller that determines a mode of inclination of a display object that is an image shaped to point to one direction; and a drawing unit that projects light representing the display object in the mode of inclination determined by the controller onto a display medium provided in a vehicle, to cause the light to be reflected off the display medium toward a user in the vehicle to enable the user to visually recognize the display object in the mode of inclination as a virtual image through the display medium. The controller determines the mode of inclination of the display object that points to the one direction as a navigation direction, by controlling a yaw angle and a roll angle of the display object in accordance with an attribute of a path point that is set on a path for navigation of the vehicle to a destination. Please note that the controller may be configured as a control circuit, and the drawing unit may be configured as a projector.
(27) Since the yaw and roll angles of the display object are controlled in accordance with the attribute of the path point, it is possible to display the display object like a bird or plane view to lead the vehicle to the destination. This allows the display object to be formed not into a long carpet-like shape but into a short shape such as an arrowhead pointing to one direction. As a result, it is possible to reduce the occurrence of overlay misregistration or loss of the display object and alleviate user discomfort caused by the overlay misregistration or loss of the display object while appropriately notifying the user of the navigation direction by the one direction pointed to by the display object.
(28) The controller may further control a lateral position of the display object visually recognized

in accordance with a direction from the vehicle to the path point, the lateral position being a position in a breadth direction of the vehicle.
(29) This reduces the occurrence of overlay misregistration. The lateral position of the display object is also controlled, for example, such that the direction from the vehicle to the display object is oriented closer to the travel direction of the vehicle than to the direction from the vehicle to the path point. The control reduces the possibility that, even if the display object is displayed within a predetermined range in the lateral position, the display object sticks to the boundary of this range or suddenly moves off this boundary.
(30) The controller may control the lateral position of the display object to allow the display object to be visually recognized within a predetermined range in the breadth direction of the vehicle.
(31) This reduces the possibility that the display object becomes lost or invisible.
(32) The controller further may control a position of the path point in accordance with a travelling speed of the vehicle.
(33) Accordingly, the display object can provide the user with an appropriate navigation direction depending on the travelling speed. For example, in the case where the travelling speed of the vehicle is high, the display object points to a direction to a far path point as the navigation direction. This enables the user who makes a right or left turn at a given intersection to have sufficient lead time to prepare for the right or left turn. In the case where the travelling speed of the vehicle is low, the display object points to a direction to a path point close to the vehicle as the navigation direction. This prevents the display object from pointing to a right or left turn direction when there is another intersection immediately before a target intersection.
(34) When controlling the position of the path point, the controller may determine a first point on the path depending on the travelling speed of the vehicle, when there is a variable section between a current location of the vehicle and the first point and when a difference between a travel direction of the vehicle and a path direction at a second point located immediately before the variable section is outside a predetermined range, the variable section being a section in which an absolute value for a rate of change in the path direction at each point on the path is greater than a threshold value, may determine the second point as the position of the path point; and when the difference falls within the predetermined range, may determine the first point as the position of the path point.
(35) In the case where there is a variable section, either one of the first point and the second point located before and after the variable section is determined as the position of the path point, depending on the travel direction of the vehicle. This reduces the possibility that the display object points to an inappropriate navigation direction as the travel direction of the vehicle.
(36) The controller may further control a depth position of the display object visually recognized in accordance with a travelling speed of the vehicle, the depth position being a position in a travel direction of the vehicle.
(37) This reduces the occurrence of overlay misregistration. Moreover, as the travelling speed of the vehicle becomes higher, a position farther from the vehicle is determined as the depth position, and as the travelling speed of the vehicle becomes lower, a position closer to the vehicle is determined as the depth position. This avoids the display object from being overlaid on a vehicle travelling ahead, for example when the vehicle is travelling slowly on a relatively congested road. The user as a driver tends to focus on a far point when the travelling speed of the vehicle is high, and tends to focus on a near point when the travelling speed of the vehicle is low. This reduces user's eye movements to see the display object and allows the user to drive carefully.
(38) The controller may limit the depth position of the display object to allow the display object to be visually recognized within a predetermined range in an up-down direction of the vehicle.
(39) This reduces the possibility that the display object becomes lost or invisible.
(40) The display device may further include a first input unit that acquires reliability information indicating reliability of the navigation. The controller may control either a height of the display object visually recognized from a road surface or a dynamic design of the display object in

accordance with the reliability information acquired by the first input unit.
(41) For example, in the case where the reliability of the navigation is low, overlay misregistration may occur in the display object, or the one direction pointed to by the display object may be shifted from an appropriate navigation direction. However, the display device according to one aspect of the present disclosure controls the height or dynamic design of the display object when the reliability of the navigation is low. As one specific example, the display object may be displayed at apparently a high position, or the display object may blink on and off. This alleviates user discomfort caused by overlay misregistration or the aforementioned shift in the one direction.
(42) The controller may further control a height of the display object visually recognized from a road surface in accordance with a distance from a current location of the vehicle to a right/left turn point on the path.
(43) Accordingly, it is possible to appropriately notify the user of the right/left turn point. Besides, in the case where the height of the display object is controlled to move the display object from a high position to a low position as the vehicle approaches the right/left turn point, it is possible to prompt the user to slow down the vehicle. That is, it is possible to prompt the user to drive carefully.
(44) The attribute of the path point may be a tangential direction at the path point on the path, and when determining the mode of inclination of the display object, the controller may control the yaw angle of the display object to cause the one direction to coincide with the tangential direction. Alternatively, the attribute of the path point may be a position of the path point, and when determining the mode of inclination of the display object, the controller may control the yaw angle of the display object to cause the one direction coincide with a direction from the vehicle to the path point.
(45) Accordingly, the one direction pointed to by the display object is oriented in the tangential direction or in the direction from the vehicle toward the path point. Therefore, it is possible to notify the user of an appropriate navigation direction for directing the vehicle to the path point by the one direction pointed to by the display object.
(46) The controller may further apply an offset to the yaw angle and the roll angle of the display object when a traffic lane different from a driving lane of the vehicle is recommended as a recommended traffic lane in the navigation.
(47) Accordingly, in the case where the one direction pointed to by the display object is oriented to the recommended traffic lane as a result of the application of an offset, it is possible to prompt the user to drive on the recommended traffic lane.
(48) The controller may further change a shape of the display object in accordance with the yaw angle of the display object.
(49) Accordingly, even if the depth position of the display object is far from the vehicle, the visibility of the display object can be improved by changing the shape of the display object.
(50) When determining the mode of inclination of the display object, the controller may further control a pitch angle of the display object in accordance with the yaw angle of the display object.
(51) Accordingly, even if the depth position of the display object is far from the vehicle, the visibility of the display object can be improved by controlling the pitch angle of the display object.
(52) The controller may further control a design of the display object in accordance with a distance from a current location of the vehicle to a right/let turn point located ahead of the path point on the path. Alternatively, the controller may further control a design of the display object in accordance with an expected arrival time from a current location of the vehicle to a right/left turn point located ahead of the path point on the path.
(53) Accordingly, it is possible to notify the user of the navigation direction to the right/left turn point by the mode of inclination of the display object and to appropriately notify the user of the timing of a right or left turn at the right/left turn point by controlling the design of the display object. That is, even if the navigation direction to the right/left turn point is different from the right

or left turn direction at the right/left turn point, it is possible to appropriately notify the user of both the navigation direction and the right or left turn direction at the same time.
(54) The controller may further move the display object in the navigation direction when a distance from a current location of the vehicle to a right/left turn point on the path is less than or equal to a threshold value. Alternatively, the controller may further move the display object in the navigation direction when an expected arrival time from a current location of the vehicle to a right/left turn point on the path is less than or equal to a threshold value.
(55) This allows the user to more easily notice the right/left turn point and to know the timing of a right or left turn at the right/left turn point.
(56) The display device may further include a second input unit that acquires sensing information indicating an approach of another vehicle from a sensor that detects the approach of the other vehicle to the vehicle. The controller may further control a design of the display object in accordance with the sensing information acquired by the second input unit.
(57) Accordingly, the attention of the user can be attracted to the approach of other vehicles by controlling the design of the display object. For example, in the case where the vehicle changes its traffic lane, it is possible to attract the attention of the user to the approach of other vehicles.
(58) These general and specific aspects may be realized by a system, a method, an integrated circuit, a computer program, or a computer-readable recording medium such as a CD-ROM, or may be realized by any combination of a system, a method, an integrated circuit, a computer program, or a computer-readable recording medium. Moreover, the recording medium as referred to herein may be a non-transitory recording medium.
(59) Hereinafter, one embodiment will be described in detail with reference to the drawings.
(60) The embodiment described below illustrates one generic or specific example of the present disclosure. Numerical values, shapes, materials, constituent elements, the arrangement and positions of constituent elements, the form of connection of constituent elements, steps, a sequence of steps, and so on in the following embodiment are merely one example, and do not intend to limit the scope of the present disclosure. Among the constituent elements in the following embodiment, those that are not recited in any one of the independent claims which define the generic concept of the present disclosure are described as arbitrary constituent elements.
(61) Note that each drawing is a schematic diagram and does not necessarily provide precise depiction. Substantially the same constituent elements are given the same reference signs throughout the drawings, and their detailed description is omitted or simplified.
Embodiment
(62) [Overall Configuration]
(63) FIG. **1** is a diagram showing an example of use of a display device according to an embodiment of the present disclosure.
(64) Display device **100** according to the present embodiment is configured as a head-up display (HUD) and mounted on vehicle **2**. As one specific example, display device **100** may be built in dashboard **2***b* of vehicle **2**.
(65) Display device **100** projects video image light representing display object **10** onto windshield **2***a* of vehicle **2**. As a result, the video image light is reflected off windshield **2***a* and transmitted to, for example, user **1** who is the driver of vehicle **2**. Accordingly, user **1** visually recognizes display object **10** as a virtual image through windshield **2***a*. That is, display device **100** allows user **1** to visually recognize display object **10** as a virtual image. Note that allowing user **1** to visually recognize display object **10** as a virtual image in this way is hereinafter also referred to as displaying display object **10**, and the operation of projecting the video image light representing the display object is synonymous with the operation of displaying display object **10**. Windshield **2***a* is one example of a display medium. In the present embodiment, the display medium is windshield **2***a*, but when vehicle **2** includes a combiner, display device **100** may project video image light onto the combiner that serves as the display medium.

(66) Windshield **2***a* is a translucent plate-like display medium. Thus, display device **100** allows user **1** to visually recognize display object **10** as a virtual image while showing a background such as a road surface through windshield **2***a* to user **1**. That is, AR achieves display of display object **10** in a real background.
(67) Display object **10** is an image shaped to point to one direction. As one specific example, display object **10** is a three-dimensional image like an arrowhead. Note that the one direction is the direction of the tip end of the arrowhead and hereinafter also referred to as a pointed direction. The pointed direction of display object **10** is oriented to the direction of guiding vehicle **2** to a destination, i.e., a navigation direction.
(68) Therefore, the use of display device **100** allows a driver as user **1** to see display object **10** while seeing the outside world ahead and without large eye movements. Thus, the driver is able to drive more carefully while grasping the navigation direction.
(69) FIG. **2** is a diagram showing one example of the interior of vehicle **2** that includes display device **100** according to the present embodiment.
(70) Display device **100** that is put in dashboard **2***b* out of sight projects video image light onto windshield **2***a*. For example, as a result of the projection of the video image light by display device **100**, display object **10** appears as a virtual image within display range d**1** of windshield **2***a*.
(71) FIG. **3** is a block diagram illustrating a functional configuration of display device **100** according to the present embodiment.
(72) Display device **100** includes input unit **110**, controller **120**, and drawing unit **130**.
(73) Input unit **110** acquires vehicle-related information from each of navigation device **21**, vehicle control device **22**, and sensor **23**, all of which are mounted on vehicle **2**.
(74) Navigation device **21** is a device for navigating vehicle **2** to a destination, using a satellite positioning system such as a global positioning system (GPS). Navigation device **21** outputs vehicle position information that indicates the current location of vehicle **2**, path information that indicates the path from the current location of vehicle **2** to the destination, and vehicle azimuth information that indicates the travel direction of vehicle **2** as the aforementioned vehicle-related information.
(75) Vehicle control device **22** may be configured as, for example, an electronic control unit (ECU) mounted on vehicle **2** and output vehicle speed information that indicates the travelling speed of vehicle **2** as the aforementioned vehicle-related information.
(76) Sensor **23** detects objects such as people or other vehicles around vehicle **2** and outputs sensing information that indicates the result of the detection as the aforementioned vehicle-related information. For example, sensor **23** may detect objects such as people or other vehicles by light detection and ranging (LiDAR).
(77) Controller **120** determines a display form of display object **10**, using the vehicle-related information acquired by input unit **110**. Specifically, controller **120** includes position processor **121**, inclination processor **122**, design processor **123**, shape processor **124**, and path-point determiner **125**.
(78) Path-point determiner **125** determines a path point on the path indicated by the aforementioned path information and notifies position processor **121** and inclination processor **122** of the determined path point.
(79) Position processor **121** determines the position of display object **10** visually recognized by user **1**, using the path point determined by path-point determiner **125**. This position is a position in a three-dimensional space and includes a lateral position in the breadth direction of vehicle **2**, a depth position in the travel direction of vehicle **2**, and a height from the road surface.
(80) Inclination processor **122** determines the mode of inclination of display object **10**, using the path point determined by path-point determiner **125**. The mode of inclination is determined by the yaw, roll, and pitch angles of display object **10**.
(81) Design processor **123** determines the design of display object **10**. Note that the design of

display object **10** according to the present embodiment refers to coloration or brightness of display object **10** and includes a dynamic change in coloration or brightness.
(82) Shape processor **124** determines the shape of display object **10**. Note that the shape of display object **10** according to the present embodiment is defined by the overall length or width of display object **10**. The overall length refers to the length of display object **10** in the pointed direction indicated by display object **10**, and the width refers to the length of display object **10** in the direction perpendicular to the pointed direction. Shape processor **124** determines the shape of display object **10** by changing the ratio between the overall length and the width.
(83) Controller **120** outputs display-form information that indicates the form of display including the aforementioned position, the aforementioned mode of inclination, the aforementioned design, and the aforementioned shape to drawing unit **130**.
(84) Drawing unit **130** acquires the display-form information from controller **120** and draws display object **10** in accordance with the display-form information. For example, drawing unit **130** may include a light source and an optical system and generate video image light representing display object **10** in the form of display indicated by the display-form information so as to allow user **1** to visually recognize display object **10** in the form of display. Then, drawing unit **130** projects the video image light onto windshield **2***a*. As a result, object **10** with the determined mode of inclination, the determined design, and the determined shape is visually recognized at the determined position by user **1**. That is, as to the mode of inclination, drawing unit **130** projects the video image light representing display object **10** in the mode of inclination determined by inclination processor **122** of controller **120** onto windshield **2***a* mounted on vehicle **2** so as to cause the video image light to be reflected off windshield **2***a* toward user **1** in vehicle **2** and to allow user **1** to visually recognize display object **10** in the mode of inclination as a virtual image through windshield **2***a*.
(85) FIG. **4** is a diagram showing one example of display object **10** according to the present embodiment. Note that (a) in FIG. **4** shows the top view of display object **10**, (b) in FIG. **4** shows the perspective view of display object **10**, and (c) in FIG. **4** shows the position of display object **10** in the travel direction of vehicle **2** and in the height direction.
(86) As illustrated in (a) and (b) in FIG. **4**, display object **10** is formed into a flat plate-like and approximately V or inverted V shape. Inclination processor **122** of controller **120** determines the mode of inclination of display object **10** by controlling yaw angle ψ, roll angle φ, and pitch angle θ of display object **10**.
(87) Yaw angle ψ is the angle of rotation of display object **10** about a yaw axis extending in the thickness direction of display object **10** as a central axis. For example, in the case where the pointed direction of display object **10** coincides with the travel direction of vehicle **2**, yaw angle ψ of display object **10** is 0°.
(88) Roll angle φ is the angle of rotation of display object **10** about a roll axis extending in the pointed direction of display object **10** as a central axis. For example, in the case where display object **10** is arranged along a horizontal plane, roll angle φ of display object **10** is 0°.
(89) Pitch angle θ is the angle of rotation of display object **10** about a pitch axis extending in a direction perpendicular to the yaw axis and the roll shaft as a central axis. For example, in the case where display object **10** is arranged along a horizontal plane, pitch angle θ of display object **10** is 0°.
(90) As illustrated in (c) in FIG. **4**, position processor **121** of controller **120** determines position y of display object **10** in the travel direction of vehicle **2** on the basis of, for example, the vehicle speed information. Position y is indicated as the distance from vehicle **2** in the travel direction. Position processor **121** further determines position z as the height of display object **10**. Position z is indicated as the height from the road surface on which vehicle **2** is travelling.
(91) [Display Example of Display Object]
(92) FIG. **5** is a diagram showing a specific example of display object **10** overlaid on a road surface

by display device **100** according to the present embodiment.
(93) For example, when vehicle **2** is approaching a T-junction, display device **100** determines the mode of inclination of display object **10** such that the pointed direction of display object **10** coincides with the navigation direction of vehicle **2**. Then, display device **100** projects video image light representing display object **10** in the determined mode of inclination onto windshield **2***a* so as to allow user **1** to visually recognize display object **10**.
(94) In the example illustrated in FIG. **5**, inclination processor **122** of controller **120** determines a rightward navigation direction on the basis of the aforementioned information including the vehicle position information, the path information, and the vehicle azimuth information. Then, inclination processor **122** sets yaw angle ψ of display object **10** at, for example, −90° so that the pointed direction of display object **10** coincides with the navigation direction. Inclination processor **122** further sets roll angle φ of display object **10** at, for example, 90° according to yaw angle ψ.
(95) Such display object **10** is overlaid and displayed on the road surface of the T-junction in order to appear as a virtual image through windshield **2***a*.
(96) FIG. **6** is a diagram showing another specific example of display object **10** overlaid on a road surface by display device **100** according to the present embodiment.
(97) Even in the case where vehicle **2** is travelling on a road other than an intersection such as a T-junction, display device **100** determines the mode of inclination of display object **10** such that the pointed direction of display object **10** coincides with the navigation direction of vehicle **2** as illustrated in FIG. **6**. Then, display device **100** overlays and displays display object **10** in the determined mode of inclination on the road surface.
(98) FIG. **7** is a diagram showing an example of comparison between a conventional display object and display object **10** overlaid on a road surface by display device **100** according to the present embodiment. Specifically, (a) in FIG. **7** shows one example of a display object overlaid on the road surface by a conventional display device, and (b) in FIG. **7** shows one example of display object **10** overlaid on the road surface by display device **100**.
(99) As illustrated in (a) in FIG. **7**, the conventional display device displays long carpet-like display object **90** overlaid on the road surface. The longitudinal direction of display object **90** coincides with the navigation direction. In other words, display object **90** is arranged along the path to a destination. Here, the navigation direction or the path may include errors if the navigation device uses a low-precision map or low-precision positioning. As a result, long display object **90** may deviate from the road surface as illustrated in (a) in FIG. **7**. That is, overlay misregistration is likely to occur. Accordingly, display object **90** may hold the possibility of misleading the user and the possibility of causing user discomfort.
(100) On the other hand, display device **100** according to the present embodiment displays arrowhead-shaped display object **10** overlaid on the road surface as illustrated in (b) in FIG. **7**. Thus, even if the navigation direction or the path includes errors, it is possible to avoid misleading user **1** and to alleviate discomfort felt by user **1**
(101) FIG. **8** is a diagram showing another example of comparison between a conventional display object and display object **10** overlaid on a road surface by display device **100** according to the present embodiment. Specifically, (a) in FIG. **8** shows another example of the display object overlaid on the road surface by a conventional display device, and (b) in FIG. **8** shows another example of display object **10** overlaid on the road surface by display device **100**.
(102) As illustrated in (a) in FIG. **8**, the conventional display device displays long carpet-like display object **90** overlaid on the road surface. Such display object **90** is displayed only within display range **91**. Thus, in the case where part of display object **90** extends off display range **91** as illustrated in (a) in FIG. **8**, that part is not displayed and display object **90** that is lost in part is displayed within display range **91**. As a result, display object **90** may hold the possibility of misleading the user and the possibility of causing user discomfort.
(103) On the other hand, display device **100** according to the present embodiment displays

arrowhead-shaped display object **10** overlaid on the road surface as illustrated in (b) in FIG. **8**. Accordingly, display object **10** is easily contained in display range d**1**, and the possibility of losing part of display object **10** is reduced. As a result, display object **10** can avoid misleading user **1** and alleviate discomfort felt by user **1**.

(104) [Yaw and Roll Angle Control of Display Object]

(105) FIG. **9**A is a diagram showing one example of controlling the yaw angle of display object **10** according to the present embodiment. Note that (a) in FIG. **9**A shows one example of controlling yaw angle ψ, and (b) in FIG. **9**A shows another example of controlling yaw angle ψ, different from the example illustrated in (a) in FIG. **9**A.

(106) First, path-point determiner **125** of controller **120** determines a path point. This path point is a point that is set on the path to navigate vehicle **2** to a destination. Path-point determiner **125** controls the position of the path point on the path indicated by the aforementioned path information, depending on the travelling speed of vehicle **2**. A specific method of determining the position of the path point will be described later with reference to FIG. **9**B.

(107) In this determination of the path point, path-point determiner **125** may determine the path point nonlinearly relative to the travelling speed, or may determine the path point linearly relative to the travelling speed. In the case where the travelling speed of vehicle **2** is used in the control of display object **10**, each constituent element included in controller **120**, such as path-point determiner **125**, may use the travelling speed indicated by the aforementioned vehicle speed information as the travelling speed of vehicle **2**, and in the case where the distance from vehicle **2** is measured, each constituent element may use the current location of vehicle **2** indicated by the aforementioned vehicle position information as a reference position for the distance.

(108) Next, inclination processor **122** determines the mode of inclination of display object **10** that points to the pointed direction as the navigation direction, by controlling yaw angle ψ and roll angle φ of display object **10** on the basis of the attribute of the determined path point. Specifically, inclination processor **122** controls yaw angle ψ on the basis of the attribute of the path point and controls roll angle φ in accordance with controlled yaw angle ψ.

(109) In the determination of yaw angle ψ, inclination processor **122** determines yaw angle ψ of display object **10** on the basis of the attribute of the path point as in the example illustrated in (a) or (b) in FIG. **9**A. For example, the attribute of the path point may be the tangential direction at the path point on the path as illustrated in (a) in FIG. **9**A. Note that inclination processor **122** determines this tangential direction as the aforementioned navigation direction. This navigation direction may be a direction expressed using the north direction as a reference. In the determination of the mode of inclination of display object **10**, inclination processor **122** controls yaw angle ψ of display object **10** such that the pointed direction of display object **10** coincides with the tangential direction serving as the navigation direction.

(110) Alternatively, the attribute of the path point may be the position of the path point as illustrated in (b) in FIG. **9**A. In the determination of the mode of inclination of display object **10**, inclination processor **122** controls yaw angle ψ of display object **10** such that the pointed direction of display object **10** coincides with a direction from vehicle **2** toward the path point. In this case, inclination processor **122** determines the direction from vehicle **2** to the path point as the navigation direction. This direction from vehicle **2** to the path point is hereinafter also referred to as a “path-point direction”.

(111) FIG. **9**B is a diagram showing one example of the method of determining a path point according to the present embodiment. Note that (a) in FIG. **9**B shows an example of determining a second point on the path as the position of the path point, and (b) in FIG. **9**B shows an example of determining a first point on the path as the position of the path point.

(112) For example, it is assumed, as illustrated in (a) in FIG. **9**B, that vehicle **2** is travelling on a gentle right curve in the road and then approaches a sharp left curve in the road along the path. In this case, path-point determiner **125** first determines a position corresponding to the travelling

speed of vehicle **2** on the path as the first point. For example, as the travelling speed of vehicle **2** becomes higher, path-point determiner **125** determines, as the first point, a position on the path that is away by a longer distance from vehicle **2** along the path, and as the travelling speed of vehicle **2** becomes lower, path-point determiner **125** determines, as the first point, a position on the path that is away by a shorter distance from vehicle **2** along the path.

(113) Here, if a path direction that is the tangential direction at the first point on the path is used as the navigation direction, since the path direction is a leftward direction, yaw angle ψ of display object **10** is controlled such that the pointed direction of display object **10** is directed to the left. However, in the case where vehicle **2** is approaching a gentle right curve in the road, the display of such display object **10** pointing to the leftward direction may mislead user **1** or cause user discomfort. Note that the aforementioned possibility of misleading the user or causing user discomfort lies not only in the case where the vehicle is travelling on a sharp curve such as a sharp left curve, but also in the case where the vehicle makes a right or left turn at a right/left turn point on the path. The right/left turn point is a point of intersection that allows a right or left turn.

(114) Thus, path-point determiner **125** according to the present embodiment identifies a section including a sharp curve or a right/left turn point on the path and also uses this section to determine the position of the path point, instead of determining the position of the path point through simple use of the travelling speed of vehicle **2**. In such a section including a sharp curve or a section in which vehicle **2** makes a right or left turn at a right/left turn point, the rate of change in the path direction is high. Therefore, path-point determiner **125** uses the rate of change in the path direction and identifies a section in which the absolute value for the rate of change is greater than a threshold value, as a variable section. Note that the rate of change in the path direction is the amount of change in the tangential direction on the path per unit length of the path. The unit length may, for example, be 100 m, and the amount of change in the tangential direction may be 45°. That is, the variable section is a section including a sharp curve or a section including a point of intersection for a right or left turn, and is also a section in which the tangential direction changes by 45° or more within the range of 100 m along the path.

(115) Specifically, path-point determiner **125** determines the first point on the path depending on the travelling speed of vehicle **2**. Then, path-point determiner **125** determines whether there is a variable section between the current location of vehicle **2** and the first point, the variable section being a section in which the absolute value for the rate of change in the path direction at each point on the path is greater than a threshold value. In the case where it is determined that there is a variable section, path-point determiner **125** sets a second point immediately before the variable section on the path. Then, path-point determiner **125** determines either the first point or the second point as the position of the path point depending on a difference between the path direction at the second point and the travel direction of vehicle **2**.

(116) For example, in the case where the difference between the path direction at the second point and the travel direction of vehicle **2** is out of a predetermined range as illustrated in (a) in FIG. **9**B, path-point determiner **125** determines the second point as the position of the path point. This enables directing the pointed direction of display object **10** to the right and appropriately guiding user **1** or vehicle **2** along a right curve.

(117) On the other hand, in the case where vehicle **2** is travelling on the right curve in the road and approaching the second point, the travel direction of vehicle **2** becomes closer to the path direction at the second point as illustrated in (b) in FIG. **9**B. Thus, in the case where the difference between the path direction at the second point and the travel direction of vehicle **2** is within the predetermined range, path-point determiner **125** determines the first point as the position of the path point. This enables directing the pointed direction of display object **10** to the left and appropriately guiding user **1** or vehicle **2** along a sharp left curve. Or, it is possible to appropriately guide user **1** or vehicle **2** in a left-turn direction at a right/left turn point. Note that the aforementioned predetermined range may, for example, be 10°.

(118) While FIG. **9**B shows one example of the case in which a gentle curve, a sharp curve opposite to the direction of the gentle curve, and a right or left turn are sequential along the path, the present disclosure is also applicable to other cases. For example, even if the path is curved in only one direction, it is possible to direct the pointed direction of display object **10** to an appropriate direction and it is possible to avoid misleading user **1** or vehicle **2** and to alleviate user discomfort. Although the path direction in the example illustrated in FIG. **9**B is the tangential direction on the path, the path direction may be the direction from vehicle **2** toward the path point, i.e., the path-point direction.
(119) In this way, path-point determiner **125** according to the present embodiment controls the position of the path point depending on the travelling speed of vehicle **2**. Since this path point is used to present the navigation direction by display object **10**, display object **10** is capable of presenting an appropriate navigation direction responsive to the travelling speed to user **1**. Specifically, path-point determiner **125** determines the first point on the path depending on the travelling speed of vehicle **2**. Then, in the case where it is determined that there is a variable section between the current location of vehicle **2** and the first point, the variable section being a section in which the absolute value for the rate of change in the path direction at each point on the path is greater than the threshold value, and where the difference between the travel direction of vehicle **2** and the path direction at the second point located immediately before the variable section is out of the predetermined range, path-point determiner **125** determines the second point as the position of the path point. On the other hand, in the case where the above difference is within the predetermined range, path-point determiner **125** determines the first point as the position of the path point.
(120) Therefore, in the case where there is a variable section, either one of the first and second points before and after the variable section that depends on the travel direction of vehicle **2** is determined as the position of the path point. Accordingly, it is possible to reduce the possibility that display object **10** points to an inappropriate navigation direction relative to the travel direction of vehicle **2**.
(121) FIG. **10** is a diagram showing one example of controlling the roll angle of display object **10** according to the present embodiment. Note that (a) in FIG. **10** shows display object **10** when viewed from a yaw-axis direction, (b) in FIG. **10** shows display object **10** when viewed from a direction perpendicular to the roll axis, and (c) in FIG. **10** shows display object **10** when viewed from a roll-axis direction.
(122) Inclination processor **122** of controller **120** determines yaw angle ψ of display object **10**, for example as illustrated in (a) in FIG. **10**, i.e., as illustrated in the example illustrate in FIG. **9**A. Inclination processor **122** determines roll angle φ in accordance with yaw angle ψ of display object **10** as illustrated in (b) and (c) in FIG. **10**. Specifically, as yaw angle ψ increases, inclination processor **122** determines a larger role angle φ. For example, in the case where display object **10** rotates counterclockwise about the yaw axis as a central axis, yaw angle ψ increase. At this time, roll angle φ increases to cause display object **10** to be inclined in the vertical direction as illustrated in (b) in FIG. **10**.
(123) In this way, as illustrated in FIGS. **9**A to **10**, inclination processor **122** according to the present embodiment determines the mode of inclination of display object **10** pointing to the pointed direction as the navigation direction, by controlling yaw angle ψ and roll angle φ of display object **10** on the basis of the attribute of the path point. Thus, display object **10** can be displayed like a bird or plane view to lead vehicle **2** to the destination. Accordingly, display object **10** can be formed not into a long carpet-like shape but into a short shape pointing to one direction such as an arrowhead. As a result, it is possible reduce the occurrence of overlay misregistration or loss of display object **10** and alleviate discomfort felt by user **1** due to the overlay misregistration or loss of display object **10** while appropriately notifying user **1** of the navigation direction by the one direction pointed to by display object **10**. Moreover, since roll angle φ is also controlled, even if

display object **10** extends off the road when vehicle **2** is travelling on a curve or the like in the road, it is possible to alleviate discomfort felt on the extension off of display object **10** by user **1**.

(124) Inclination processor **122** also controls yaw angle ψ of display object **10** such that the pointed direction coincides with the tangential direction as illustrated in (a) in FIG. **9**A. Or, inclination processor **122** controls yaw angle ψ of display object **10** such that the pointed direction coincides with the direction from vehicle **2** toward the path point as illustrated in (b) in FIG. **9**A. Accordingly, it is possible to notify user **1** of an appropriate navigation direction for directing vehicle **2** to the path point by the pointed direction of display object **10**.

(125) [Position Control of Display Object]

(126) FIG. **11** is a diagram showing one example of controlling the position of display object **10** according to the present embodiment. Note that (a) in FIG. **11** indicates the positional relationship between vehicle **2** and display object **10** when viewed from above vehicle **2**, and (b) in FIG. **11** shows the position of display object **10** visually recognized in display range d**1** of windshield **2***a*.

(127) First, position processor **121** of controller **120** identifies the position of the path point determined by path-point determiner **125** on the basis of the notification from path-point determiner **125**.

(128) Then, position processor **121** of controller **120** determines a plane position (x, y) of display object **10** as illustrated in (a) in FIG. **11**. The plane position (x, y) refers to the position of display object **10** arranged in a plane. The plane may be a road surface on which vehicle **2** is travelling, or may be a tangent plane to the road surface. Position y in plane position (x, y) indicates a position along a longitudinal axis that is an axis along the travel direction of vehicle **2** that is one of two axes arranged along the above plane and orthogonal to each other. That is, position y is a depth position of visually recognized display object **10** in the travel direction of vehicle **2**. Positon x in plane position (x, y) indicates a position along a lateral axis that is orthogonal to the longitudinal axis and that is one of the two axes arranged along the above plane. That is, position x is a lateral position of visually recognized display object **10** in the breadth direction of vehicle **2**. Hereinafter, the breadth direction is also referred to as the lateral direction or the lateral axial direction. Note that position processor **121** may use the travel direction indicated by the aforementioned vehicle azimuth information as the travel direction of vehicle **2**.

(129) Specifically, position processor **121** controls position y depending on the travelling speed of vehicle **2**. For example, as the travelling speed of vehicle **2** becomes higher, position processor **121** determines position y that is farther away from vehicle **2**, and as the travelling speed of vehicle **2** becomes lower, positon processor **121** determines position y that is closer to vehicle **2**. In the determination of position y, position processor **121** may determine position y nonlinearly relative to the travelling speed, or may determine position y linearly relative to the travelling speed.

(130) As to position x, position processor **121** controls position x depending on the direction from vehicle **2** to the path point. Specifically, position processor **121** identifies angle α between the travel direction of vehicle **2** and the path-point direction from vehicle **2** to the path point. Then, position processor **121** calculates angle β that is 1/n times of angle α and identifies a direction that forms angle β with the travel direction of vehicle **2**. Note that this direction forming angle β is a direction inclined from the travel direction toward to the path-point direction. Then, position processor **121** determines the lateral axial position of a point located at position y from among points on a straight line along the direction forming angle β. Referring to the aforementioned 1/n times, n is a real number greater than one and may, for example, be three. Alternatively, position processor **121** may calculate 1/n times of the distance in the lateral axial direction from vehicle **2** to the path point and determine, as position x, a point that is away by the aforementioned 1/n-fold distance to the path point from vehicle **2** in the lateral axial direction. Moreover, position processor **121** may determine angle β or position x linearly relative to the lateral axial distance from angle α or vehicle **2** to the path point.

(131) In the determination of the plane position (x, y) of display object **10**, position processor **121**

limits the plane position (x, y) of display object **10** such that display object **10** does not extend off display plane range d**2** in the aforementioned plane. As illustrated in (b) in FIG. **11**, display plane range d**2** is the range corresponding to display range d**1** of windshield **2***a*. The length of display plane range d**2** in the travel direction corresponds to the length of display range d**1** in the up-down direction, and the length of display plane range d**2** in the lateral direction corresponds to the length of display range d**1** in the lateral direction. As a result, it can be said that position processor **121** limits plane position (x, y) of display object **10** such that display object **10** does not extend off display range d**1**. That is, position processor **121** limits position x of display object **10** such that display object **10** becomes visually recognizable within a predetermined range in the breadth direction of vehicle **2**. Position processor **121** also limits position y of display object **10** such that display object **10** becomes visually recognizable within a predetermined range in the up-down direction of vehicle **2**.
(132) In this way, position processor **121** according to the present embodiment controls the lateral position, i.e., position x, of display object **10** depending on the direction from vehicle **2** to the path point. Accordingly, it is possible to reduce the possibility that display object **10** sticks to a boundary at the lateral edge of display range d**1** or suddenly moves off the boundary as a result of controlling n in the aforementioned 1/n times. Note that the situation in which display object **10** sticks to the boundary refers to a situation in which display object **10** does not depart from the boundary for a certain period of time while vehicle **2** is travelling.
(133) Position processor **121** also limits the lateral position of display object **10** such that display object **10** becomes visually recognizable within display range d**1**. This reduces the possibility that the left or right portion of display object **10** becomes lost or that display object **10** becomes invisible.
(134) Position processor **121** also controls the depth position, i.e., position y, of display object **10** depending on the travelling speed of vehicle **2**. For example, as the travelling speed of vehicle **2** becomes lower, a position closer to vehicle **2** is determined as the depth position. This reduces the possibility that, when vehicle **2** is travelling slowly on a relatively congested road, display object **10** is overlaid on a vehicle travelling ahead.
(135) Position processor **121** also limits the depth position of display object **10** such that display object **10** becomes visually recognizable within display range d**1**. This reduces the possibility that the upper or lower portion of display object **10** becomes lost or that display object **10** becomes invisible.
(136) [Shape or Pitch Angle Control of Display Object]
(137) FIG. **12** is a diagram showing one example of controlling the shape of display object **10** according to the present embodiment.
(138) As illustrated in (a) to (c) in FIG. **12**, shape processor **124** of controller **120** changes the shape of display object **10** depending on yaw angle ψ. For example, shape processor **124** changes overall length L of display object **10**. For example, in the case where yaw angle ψ is 0° as illustrated in (a) in FIG. **12**, shape processor **124** sets overall length L to L1, and in the case where yaw angle ψ is 45° as illustrated in (b) in FIG. **12**, shape processor **124** sets overall length L to L2 (L2<L1). In the case where yaw angle ψ is 90°, shape processor **124** sets overall length L to L3 (L3<L2). This change in overall length L changes the ratio between overall length L and the width and consequently changes the shape of display object **10**.
(139) For example, in the case where display object **10** is at far position y, user **1** visually recognizes display object **10** in a direction closer to the horizontal direction. Thus, if the shape of display object **10** is not changed in such a case, display object **10** visually recognized by user **1** in display range d**1** has a short width in the up-down direction. That is, display object **10** looks like collapsed in the longitudinal direction. As a result, user **1** has difficulty in grasping the pointed direction of display object **10**.
(140) In view of this, shape processor **124** according to the present embodiment increases overall

length L of display object **10** as yaw angle ψ approaches 0° as illustrated in FIG. **12**. This shortens the width in the up-down direction of display object **10** visually recognized by user **1** even if display object **10** is at far position y. Thus, it is possible to reduce the possibility that display object **10** looks like collapsed.
(141) Alternatively, inclination processor **122** of controller **120** may control pitch angle θ of display object **10** to reduce the possibility that display object **10** looks like collapsed. That is, in the determination of the mode of inclination of display object **10**, inclination processor **122** further controls pitch angle θ of display object **10** depending on yaw angle ψ of display object **10**. For example, inclination processor **122** increases pitch angle θ of display object **10** as yaw angle ψ of display object **10** approaches 0°. That is, pitch angle θ is controlled such that the pointed direction of display object **10** becomes closer to the vertical direction.
(142) Although, in the aforementioned example, controller **120** controls the shape or pitch angle θ of display object **10** depending on yaw angle ψ, the shape or pitch angle θ of display object **10** may also be controlled not only depending on yaw angle ψ but also depending on position y. For example, in the case where the distance from vehicle **2** to position y is greater than or equal to a threshold value, controller **120** may control the shape or pitch angle θ of display object **10** depending on yaw angle ψ.
(143) In this way, controller **120** according to the present embodiment controls the shape or pitch angle θ of display object **10** depending on yaw angle ψ of display object **10**. This improves visibility of display object **10** even if the depth position, i.e., position y, of display object **10** is far from vehicle **2**.
(144) [Design Control of Display Object]
(145) FIG. **13** is a diagram showing one example of controlling the design of display object **10** according to the present embodiment.
(146) For example, as illustrated in (a) in FIG. **13**, vehicle **2** may travel on a road curved to the left along the path indicated by the path information and then make a right turn at a right/left turn point. In this case, design processor **123** of controller **120** controls the design of display object **10** depending on the distance from the current location of vehicle **2** to the right/left turn point that is located forward of the path point on the path. For example, design processor **123** measures the distance along path from the current location of vehicle **2** indicated by the vehicle position information to the right/left turn point indicated by the path information. Then, if the path information indicates to make a right turn at the right/left turn point when the distance to the right/left turn point becomes less than or equal to the threshold value, design processor **123** changes the color or brightness of the right half of display object **10**. As one specific example, design processor **123** may change the color of the right half of display object **10**, the overall color of which is green, to yellow. Alternatively, design processor **123** may change the color of part of the right half of display object **10**, i.e., the color of the right end, to yellow. As another alternative, design processor **123** may display another object **10***a* indicating a right turn around display object **10** as illustrated in (b) in FIG. **13**, or may cause object **10***a* to blink on and off. Note that object **10***a* indicates a right or left turn from the relative positional relation between display object **10** and object **10***a*. The threshold value for the distance to the right/left turn point may, for example, be 300 m.
(147) Accordingly, it is possible to indicate the navigation direction for guiding vehicle **2** to the left curve by controlling yaw angle ψ of display object **10** to direct the pointed direction of display object **10** to the left, and it is also possible to appropriately notify user **1** of the presence of a right turn following the left curve by changing the design of display object **10**.
(148) Alternatively, design processor **123** may control the design of display object **10** depending on an expected arrival time from the current location of vehicle **2** to the right/left turn point that is located forward of the path point on the path. For example, design processor **123** may measure the distance along the path from the current location of vehicle **2** indicated by the vehicle position

information and the right/left turn point indicated by the path information and calculate the expected arrival time by dividing the measured distance by the travelling speed of vehicle **2** indicated by the vehicle speed information. Then, if the path information indicates to make a right turn at the right/left turn point when the expected arrival time up to the right/left turn point becomes less than or equal to a threshold value, design processor **123** changes the color or brightness of the right half of display object **10**. Although, in the example illustrated in FIG. **13**, the left curve is followed by the right turn, the directions of the curve and the turn may be reversed. A case is also possible in which a right or left turn is followed by a curve, or two curves are sequential, or a right turn and a left turn are sequential. The threshold value for the expected arrival time may, for example, be in the range of 10 seconds to one minute.
(149) In this way, it is possible, according to the present embodiment, to notify user **1** of the navigation direction to the right/left turn point by the mode of inclination of display object **10** and to appropriately notify user **1** of a right or left turn at the right/left turn point by controlling the design of display object **10**. That is, even if the navigation direction to the right/left turn point is different from the right- or left-turn direction at the right/left turn point, it is possible to appropriately notify user **1** of both of the navigation direction and the right- or left-turn direction at the same time. That is, even if the pointed direction of display object **10** is directed to the left in order to guide vehicle **2** along the road curved to the left, it is possible to appropriately notify user **1** of the need to make a right turn at the next right/left turn point.
(150) FIG. **14** is a diagram showing another example of controlling the design of display object **10** according to the present embodiment.
(151) For example, in the case where vehicle **2** is travelling on a road with a plurality of traffic lanes as illustrated in (a) in FIG. **14**, another vehicle **3** is approaching vehicle **2**. At this time, design processor **123** notifies user **1** of the approach of other vehicle **3** by controlling the color of display object **10**.
(152) Specifically, input unit **110** of display device **100** acquires sensing information indicating the approach of other vehicle **3** from sensor **23** that detects the approach of other vehicle **3** to vehicle **2**. Note that the function of acquiring such sensing information is part of the function of input unit **110**, and it can also be said that input unit **110** includes a second input unit that achieves this function.
(153) Design processor **123** of controller **120** controls the design of display object **10** in accordance with the sensing information acquired by input unit **110**. For example, the sensing information indicates that other vehicle **3** is approaching from the right side of vehicle **2**. In this case, design processor **123** changes the color or brightness of the right end of display object **10**. As one specific example, design processor **123** may change the color of this right end from green to red. Alternatively, design processor **123** may cause this right end to blink on and off in red. As another alternative, design processor **123** may cause the color of the entire or part of the right half of display object **10** other than the right end of display object **10** to change or blink on and off. As yet another alternative, design processor **123** may display object **10***a* for attracting attention of user **1** around display object **10** as illustrated in (b) in FIG. **14**, or may cause object **10***a* to blink on and off.
(154) In this way, it is possible, according to the present embodiment, to attract attention of user **1** to the approach of other vehicle **3** by controlling the design of display object **10**. For example, it is possible to attract attention of user **1** to the approach of other vehicle **3** in cases such as where vehicle **2** changes the traffic lane or where vehicle **2** enters a rendezvous point of the traffic lanes.
(155) [Movement Control of Display Object]
(156) FIG. **15** is a diagram showing one example of controlling the movement of display object **10** according to the present embodiment.
(157) For example, vehicle **2** may travel along the path indicated by the path information and make a left turn at a right/left turn point as illustrated in (a) in FIG. **15**. In this case, position processor

121 of controller **120** moves display object **10** in the navigation direction when the distance along the path from the current location of vehicle **2** to the right/left turn point becomes less than or equal to a threshold value. Note that moving display object **10** in the navigation direction can also be said as moving display object **10** in the pointed direction. In the example illustrated in (a) in FIG. **15**, position processor **121** moves display object **10** to the left.
(158) Alternatively, position processor **121** may move display object **10** in the navigation direction when the expected arrival time from the current location of vehicle **2** to the right/left turn point on the path becomes less than or equal to a threshold value. For example, position processor **121** may measure the distance along the path between the current location of vehicle **2** indicated by the vehicle position information and the right/left turn point indicated by the path information and calculate the expected arrival time by dividing the measured distance by the travelling speed of vehicle **2** indicated by the vehicle speed information. Then, design processor **123** moves display object **10** in the navigation direction when the expected arrival time to the right/left turn point becomes less than or equal to the threshold value.
(159) This enables user **1** to easily notice a right or left turn at the right/left turn point.
(160) Alternatively, position processor **121** may repeatedly move display object **10** in the navigation direction as illustrated in (b) in FIG. **15**, instead of moving it only once. For example, position processor **121** may return display object **10** to the original position after having moved display object **10** in the navigation direction, and then move display object **10** again in the navigation direction.
(161) In this way, it is possible, according to the present embodiment, by allow user **1** to easily notice the right/left turn point as well as to notify user **1** of the timing of the right or left turn at the right/left turn point by moving display object **10** in the navigation direction.
(162) [Height or Design Control of Display Object]
(163) FIG. **16** is a diagram showing one example of controlling the height of display object **10** according to the present embodiment.
(164) Position processor **121** of controller **120** controls the height, i.e., position z, of display object **10** depending on the reliability of navigation by navigation device **21**.
(165) For example, input unit **110** of display device **100** acquires reliability information indicating the reliability of navigation from navigation device **21**. Note that the function of acquiring such reliability information is part of the function of input unit **110**, and it can also be said that input unit **110** includes a first input unit that archives this function.
(166) The reliability information is information generated by navigation device **21** and may be included in the aforementioned vehicle-related information. The reliability of navigation corresponds to the accuracy of the path set by navigation device **21** and the accuracy of the current location of vehicle **2** and the travel direction thereof detected by navigation device **21**. For example, navigation device **21** may identify the reliability of navigation of vehicle **2** on the basis of, for example, the intensity of receiving GPS signals from a satellite and generate reliability information indicating the identified reliability. As one specific example, in the case where the intensity of receiving GPS signals is low, navigation device **21** may generate reliability information indicating low reliability, and in the case where the intensity of receiving GPS signals is high, navigation device **21** may generate reliability information indicating high reliability. Alternatively, navigation device **21** may identify the reliability of navigation depending on the type of a map used to navigate vehicle **2** and generate reliability information indicating the identified reliability. For example, in the case where a high-precision map is used in navigation, navigation device **21** may generate reliability information indicating relatively high reliability, and in the case where an ordinary map is used in navigation, navigation device **21** may generate reliability information indicating relatively low reliability. Note that navigation device **21** may switch the use of a high-precision map and an ordinary map depending on the travelling point of vehicle **2**, and for example, may use the high-precision map when vehicle is travelling on a highway.

(167) Then, position processor **121** controls the height of visually recognized display object **10** from the road surface depending on the reliability information acquired by input unit **110**. For example, as the reliability indicated by the reliability information becomes lower, position processor **121** may determine higher position z as the height of display object **10**, and as the reliability indicated by the reliability information becomes higher, position processor **121** may determine lower position z as the height of display object **10**.
(168) FIG. **17** is a diagram showing a more specific example of controlling the height of display object **10** according to the present embodiment. Note that (a) in FIG. **17** shows one example of display object **10** that has not undergone height control based on reliability, and (b) in FIG. **17** shows one example of display object **10** that has undergone height control based on reliability.
(169) For example, in the case where the reliability of navigation is low and the height of display object **10** is not controlled depending on the reliability, display object **10** may be overlaid but deviates from the road surface as illustrated in (a) in FIG. **17**. That is, overlay misregistration may occur. Besides, the pointed direction of display object **10** may also deviate from the actual navigation direction. However, position processor **121** according to the present embodiment displays display object **10** at a high position as illustrated in (b) in FIG. **17** when the reliability of navigation is low. Display object **10** that is displayed apparently at a high position above the road surface is hardly recognized as overlay misregistration by user **1**. Besides, the deviation in the pointed direction of display object **10** is also hardly recognized by user **1**. Accordingly, it is possible to alleviate discomfort felt by user **1** due to the overlay misregistration and the deviation in the pointed direction.
(170) Although, in the examples illustrated in FIGS. **16** and **17**, the height of display object **10** is controlled depending on the reliability information, i.e., depending on the reliability of navigation, other control may be performed. For example, design processor **123** of controller **120** may control the dynamic design of visually recognized display object **10** depending on the reliability information. For example, design processor **123** may cause display object **10** to blink on and off when the reliability indicated by the reliability information is lower than or equal to a threshold value. The blinking cycle may, for example, be 0.5 seconds. This creates a period of time during which display object **10** is not displayed. Thus, it is possible to alleviate user discomfort caused by overlay misregistration of display object **10**. Note that, in the case where the reliability is indicated by a numerical value from 0 to 1, the threshold value for the reliability may, for example, be 0.5.
(171) In this way, controller **120** according to the present embodiment controls either the height of visually recognized display object **10** or the dynamic design of display object **10** depending on the reliability information. Accordingly, it is possible to alleviate discomfort felt by user **1** due to overlay misregistration or a deviation in the pointed direction of display object **10**.
(172) FIG. **18** is a diagram showing another example of controlling the height of display object **10** according to the present embodiment.
(173) As illustrated in FIG. **18**, position processor **121** of controller **120** may control the height of visually recognized display object **10** from the road surface depending on the distance along the path from the current location of vehicle **2** to a right/left turn point on the path. For example, position processor **121** may lower the height of display object **10**, i.e., position z, when vehicle **2** approaches a right/left turn point and the distance to the right/left turn point becomes shorter. More specifically, position processor **121** may lower the height of display object **10** as the distance from vehicle **2** to the right/left turn point becomes shorter, or may lower the height of display object **10** when the distance becomes less than or equal to a threshold value.
(174) In this way, the present embodiment allows user **1** to more easily notice a right or left turn at the right/left turn point. It is also possible to prompt user **1** to slow down vehicle **2**, i.e., it is possible to prompt user **1** to drive carefully.
(175) [Offset Control of Display Object]
(176) FIG. **19** is a diagram showing one example of controlling offsets of yaw angle ψ and roll

angle φ of display object **10** according to the present embodiment.
(177) In the case where navigation recommends traffic lane **32** different from traffic lane **31** on which vehicle **2** is travelling as a recommended traffic lane, inclination processor **122** of controller **120** applies offsets to yaw angle ψ and roll angle φ of display object **10**. Note that (a) in FIG. **19** shows an example of not applying offsets to display object **10**, and (b) in FIG. **19** shows an example of applying offsets to display object **10**.
(178) For example, in the case where the path information indicates to make a right or left turn at a right/left turn point that is located forward of travelling vehicle **2** and the road on which vehicle **2** is travelling includes multiple traffic lanes, navigation device **21** detects a traffic lane for the right or left turn as a recommended traffic lane. For example, in the case where the path information indicates to make a right turn, a right traffic lane is detected as a recommended traffic lane, and in the case where the path information indicates to make a left turn, a left traffic lane is detected as a recommended traffic lane. Then, navigation device **21** outputs recommended-traffic-lane information indicating the recommended traffic lane. Input unit **110** of display device **100** acquires this recommended-traffic-lane information as the vehicle-related information.
(179) For example, in the case where input unit **110** does not acquire the recommended-traffic-lane information, inclination processor **122** does not apply offsets to display object **10** as illustrated in (a) in FIG. **19**. However, in the case where input unit **110** has acquired the recommended-traffic-lane information, inclination processor **122** applies offsets to display object **10** as illustrated in (b) in FIG. **19**. For example, the recommended-traffic-lane information may indicate traffic lane **32** as the recommended traffic lane. Thus, in the case where inclination processor **122** has determined from the vehicle position information that vehicle **2** is travelling on traffic lane **31** and has determined that the recommended traffic lane is not traffic lane **31** but traffic lane **32**, inclination processor **122** applies, to display object **10**, offsets for directing the pointed direction to traffic lane **32**. As one specific example of applying offsets, inclination processor **122** may add an offset of ±2° to yaw angle ψ of display object **10** and add an offset of the angle corresponding to the offset of ±2° to roll angle φ of display object **10**. As a result, in the example illustrated in FIG. **19**, display object **10** is displayed inclined by 2° toward traffic lane **32**. Note that inclination processor **122** may apply offsets to display object **10**, irrespective of whether or not the traffic lane on which vehicle **2** is travelling is the recommended traffic lane. In this case, even if the traffic lane on which vehicle **2** is travelling cannot be identified, it is possible to apply offsets to display object **10**. The offset angle of roll angle φ may or may not be equal to the offset angle of yaw angle ψ.
(180) In this way, it is possible, according to the present embodiment, to direct the pointed direction of display object **10** to the recommended traffic lane by the application of offsets and to prompt user **1** to travel on the recommended traffic lane. Note that the offsets may be fixed angles, or may be variable angles. For example, as the travelling speed of vehicle **2** becomes higher, inclination processor **122** may apply smaller offsets, and as the travelling speed of vehicle **2** becomes lower, inclination processor **122** may larger offsets.
(181) [Flowchart of Processing Operations]
(182) FIG. **20** is a flowchart illustrating processing operations of display device **100** according to the embodiment.
(183) First, display device **100** acquires the vehicle-related information from navigation device **21**, vehicle control device **22**, and sensor **23** (step S**11**). Then, display device **100** determines a path point from the path indicated by the path information included in the vehicle-related information (step S**12**). Then, display device **100** determines the mode of inclination of display object **10** by controlling yaw angle ψ and roll angle φ of display object **10** on the basis of, for example, the attribute of the path point (step S**13**). At this time, display device **100** may determine the mode of inclination by further controlling pitch angle θ.
(184) Then, display device **100** determines the position (x, y, z) of display object **10** on the basis of the path point and the current location of vehicle **2** (step S**14**), determines the design of display

object **10** (step S**15**), and further determines the shape of display object **10** (step S**16**).
(185) Next, display device **100** applies video image light representing display object **10** in the mode of inclination determined in step S**13** and having the position, design, and shape determined in step S**14** to S**16**, toward windshield **2** (step S**17**). As a result, user **1** visually recognizes display object **10** through windshield **2***a*.
(186) Here, display device **100** determines whether to end display of display object **10** (step S**18**). For example, in cases such as where vehicle **2** is parked, where the engine of vehicle **2** is stopped, or where display device **100** has received an instruction to stop display, display device **100** determines to end the display of display object **10** (Yes in step S**18**). Otherwise, display device **100** determines not to end the display of display object **10** (No in step S**18**) and repeatedly executes the processing from step S**11**. In the case where the processing in step S**11** is repeated, the latest vehicle-related information is acquired at this time. Thus, it is possible to update the mode of inclination, position, design, and shape of display object **10** at any time in accordance with the latest vehicle-related information.
Other Embodiments
(187) While the display device according to one or more aspects of the present disclosure has been described based on the embodiment, the present disclosure is not intended to be limited to this embodiment. The present disclosure may also include other variations obtained by making various modifications conceivable by those skilled in the art to the embodiment, without departing from the scope of the present disclosure.
(188) For example, although controller **120** according to the embodiment described above includes position processor **121**, inclination processor **122**, design processor **123**, and shape processor **124**, controller **120** may not include each of these processing units other than inclination processor **122**. Although inclination processor **122** controls yaw angle ψ, roll angle φ, and pitch angle θ of display object **10**, pitch angle θ may be fixed.
(189) In the above-described embodiment, each constituent element may be configured as dedicated hardware, or may be realized by executing a software program suitable for each constituent element. Each constituent element may also be realized by a program execution unit such as a central processing unit (CPU) or a processor reading out and executing a software program recorded on a hard disk or a recording medium such as a semiconductor memory. Here, the software program for realizing display device **100** or the like according to the above-described embodiment may cause a computer to execute each step included in, for example, the flowchart illustrated in FIG. **20**.
(190) Note that the present disclosure also includes the following cases.
(191) (1) At least one of the devices described above is specifically a computer system configured by, for example, a microprocessor, a read only memory (ROM), a random access memory (RAM), a hard disk unit, a display unit, a keyboard, and a mouse. The RAM or the hard disk unit stores computer programs. At least one of the devices described above achieves its function as a result of the microprocessor operating in accordance with the computer programs. Here, the computer programs are configured by combining a plurality of instruction codes indicating commands to the computer in order to achieve predetermined functions.
(192) (2) Some or all of the constituent elements that configure at least one of the devices described above may be configured with one system LSI (large scale integration). The system LSI is a super-multi-function LSI manufactured by integrating a plurality of structural units on a single chip, and is specifically a computer system configured to include a microprocessor, a ROM, a RAM, and so on. The RAM stores computer programs. The system LSI achieves its function as a result of the microprocessor operating in accordance with the computer programs.
(193) (3) Some or all of the constituent elements that configure at least one the devices described above may be configured as an IC card detachable from the device or as a stand-alone module. The IC card or the module is a computer system configured by a microprocessor, a ROM, a RAM, and

so on. The IC card or the module may include the aforementioned super-multi-function LSI. The IC card or the module achieves its function as a result of the microprocessor operating in accordance with the computer programs. The IC card or the module may also be tamper-resistant.
(194) (4) The present disclosure may be realized as the method described above. The present disclosure may also be realized as a computer program for causing a computer to execute the method, or as digital signals consisting of computer programs.
(195) The present disclosure may also be realized as a computer-readable recording medium having computer programs or digital signals recorded thereon, examples of which include a flexible disc, a hard disk, a Compact Disc (CD)-ROM, a DVD, a DVD-ROM, a DVD-RAM, a Blu-ray (registered trademark) Disc (BD), and a semiconductor memory. As another alternative, the present disclosure may also be realized as digital signals recorded on such a recording medium.
(196) The present disclosure may also be realized by computer programs or digital signals transmitted via, for example, a telecommunication line, a wireless or wired communication line, a network represented by the Internet, or data broadcasting.
(197) The present disclosure may also be realized by another independent computer system by transmitting programs or digital signals recorded on a recording medium or by transmitting programs or digital signals via, for example, a network.
Further Information about Technical Background to this Application
(198) The disclosures of the following patent applications including specification, drawings, and claims are incorporated herein by reference in their entirety: Japanese Patent Application No. 2020-146228 filed on Aug. 31, 2020, and PCT International Application No. PCT/JP2021/031521 filed on Aug. 27, 2021.
INDUSTRIAL APPLICABILITY
(199) The display device according to the present disclosure achieves the effect of alleviating user discomfort on display objects and may be applicable to, for example, a vehicle-mounted head-up display.

Claims

1. A display device comprising: a control circuit that determines a mode of inclination of a display object that is an image shaped to point to one direction, and that further determines a position of the display object visually recognized by a user in a vehicle; and a projector that projects light representing the display object in the mode of inclination determined by the control circuit onto a display medium provided in the vehicle, to cause the light to be reflected off the display medium toward the user in the vehicle to enable the user to visually recognize the display object in the mode of inclination as a virtual image through the display medium, wherein the control circuit determines the mode of inclination of the display object that points to the one direction as a navigation direction, by controlling a yaw angle and a roll angle of the display object in accordance with an attribute of a path point that is set on a path for navigation of the vehicle to a destination, wherein the attribute includes a direction of the path at the path point or a position of the path point, wherein a depth position of the display object in a traveling direction of the vehicle is placed between a current position of the vehicle on the path and the path point, and wherein the control circuit moves a lateral position of the display object in a lateral direction of the vehicle towards a right/left turn direction indicated by the navigation direction when a distance from a current location of the vehicle to a right/left turn point, which is a point of intersection that allows a right or left turn on the path, is less than or equal to a first threshold value.
2. The display device according to claim 1, wherein the control circuit further controls the lateral position of the display object visually recognized in accordance with a direction from the vehicle to the path point, the lateral position being a position in the lateral direction of the vehicle.
3. The display device according to claim 2, wherein the control circuit controls the lateral position

of the display object to allow the display object to be visually recognized within a predetermined range in the lateral direction of the vehicle.

4. The display device according to claim 1, wherein the control circuit further controls a position of the path point in accordance with a travelling speed of the vehicle.

5. The display device according to claim 1, wherein the control circuit further controls the depth position of the display object visually recognized in accordance with a traveling speed of the vehicle, the depth position being a position in the travel direction of the vehicle.

6. The display device according to claim 5, wherein the control circuit limits the depth position of the display object to allow the display object to be visually recognized within a predetermined range in an up-down direction of the vehicle.

7. The display device according to claim 1, further comprising: a first input unit that acquires reliability information indicating reliability of navigation which is determined based on an accuracy of the path set by a navigation device in the vehicle or the accuracy of the current location and the travel direction of the vehicle detected by the navigation device, wherein the control circuit controls either a height of the display object visually recognized from a road surface or a dynamic design of the display object in accordance with the reliability information acquired by the first input unit.

8. The display device according to claim 1, wherein the control circuit further controls a height of the display object visually recognized from a road surface to be lower as a distance from the current location of the vehicle to the right/left turn point on the path becomes shorter.

9. The display device according to claim 1, wherein a surface including a width direction of the vehicle, is defined as a first plane, wherein the attribute of the path point is a tangential direction at the path point on the first plane, and when determining the mode of inclination of the display object, the control circuit controls the yaw angle of the display object to cause the one direction to coincide with the tangential direction on the first plane.

10. The display device according to claim 1, wherein the attribute of the path point is a position of the path point, and when determining the mode of inclination of the display object, the control circuit controls the yaw angle of the display object to cause the one direction coincide with a direction from the vehicle to the path point.

11. The display device according to claim 1, wherein the control circuit further changes a shape of the display object in accordance with the yaw angle of the display object.

12. The display device according to claim 1, wherein, when determining the mode of inclination of the display object, the control circuit further controls a pitch angle of the display object in accordance with the yaw angle of the display object.

13. The display device according to claim 1, wherein the control circuit further controls a color or a brightness of the display object in accordance with the distance from the current location of the vehicle to the right/left turn point located ahead of the path point on the path.

14. The display device according to claim 1, wherein the control circuit further controls a color or a brightness of the display object in accordance with an expected arrival time from the current location of the vehicle to the right/left turn point located ahead of the path point on the path.

15. The display device according to claim 1, wherein the control circuit further moves the lateral position of the display object in the lateral direction of the vehicle towards the right/left turn direction indicated by the navigation direction when an expected arrival time from the current location of the vehicle to the right/left turn point on the path is less than or equal to a second threshold value.

16. The display device according to claim 1, further comprising: a second input unit that acquires sensing information indicating an approach of an other vehicle from a sensor that detects the approach of the other vehicle to the vehicle, wherein the control circuit further controls a design of the display object in accordance with the sensing information acquired by the second input unit.