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(54) **VEHICLE TRAVEL SUPPORT SYSTEM AND VEHICLE TRAVEL SUPPORT METHOD**

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CPC ***B60W 30/12*** (2013.01)

(57) **ABSTRACT**

In a vehicle travel support system or a vehicle travel support method, a control apparatus estimates a travel path of a vehicle on the basis of the present position of the vehicle and map information, acquires from a map information storage apparatus a curve radius that is of a curve included in the travel path and that is contained in the map information, performs a vehicle turning support or a deceleration support prior to entry to the curve on the basis of a start point of the curve which is detected on the basis of front images, and performs the vehicle turning support for the curve by using the curve radius contained in the map information.

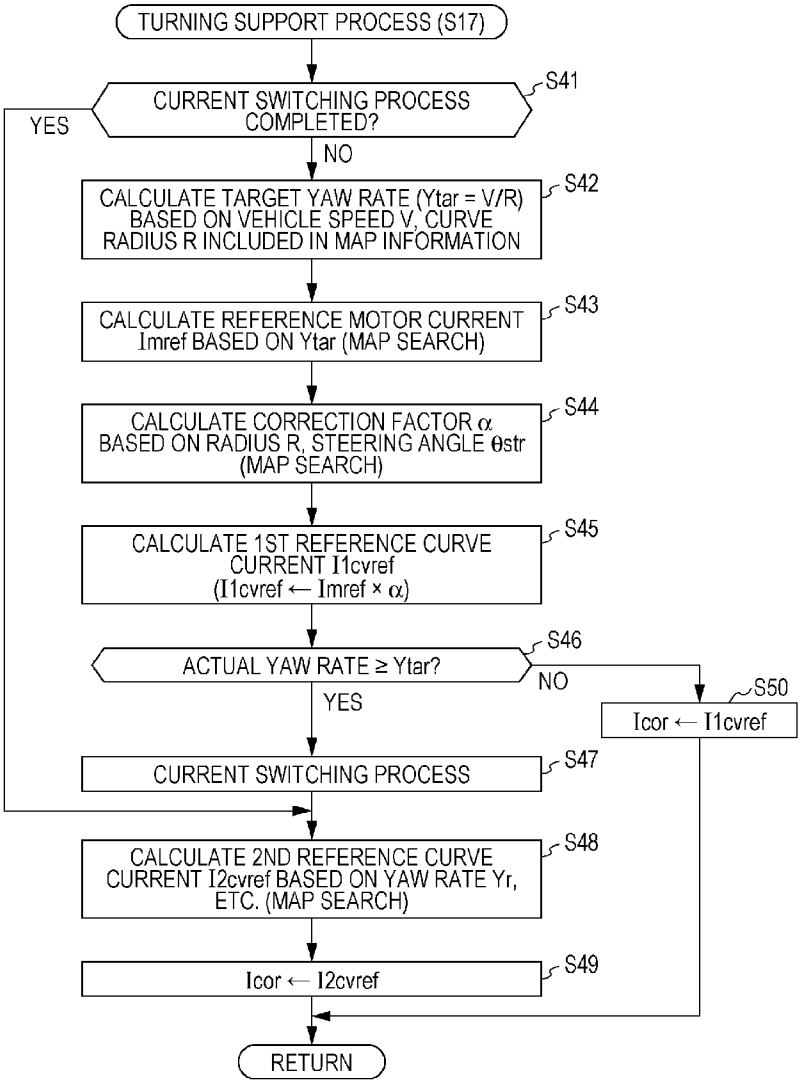
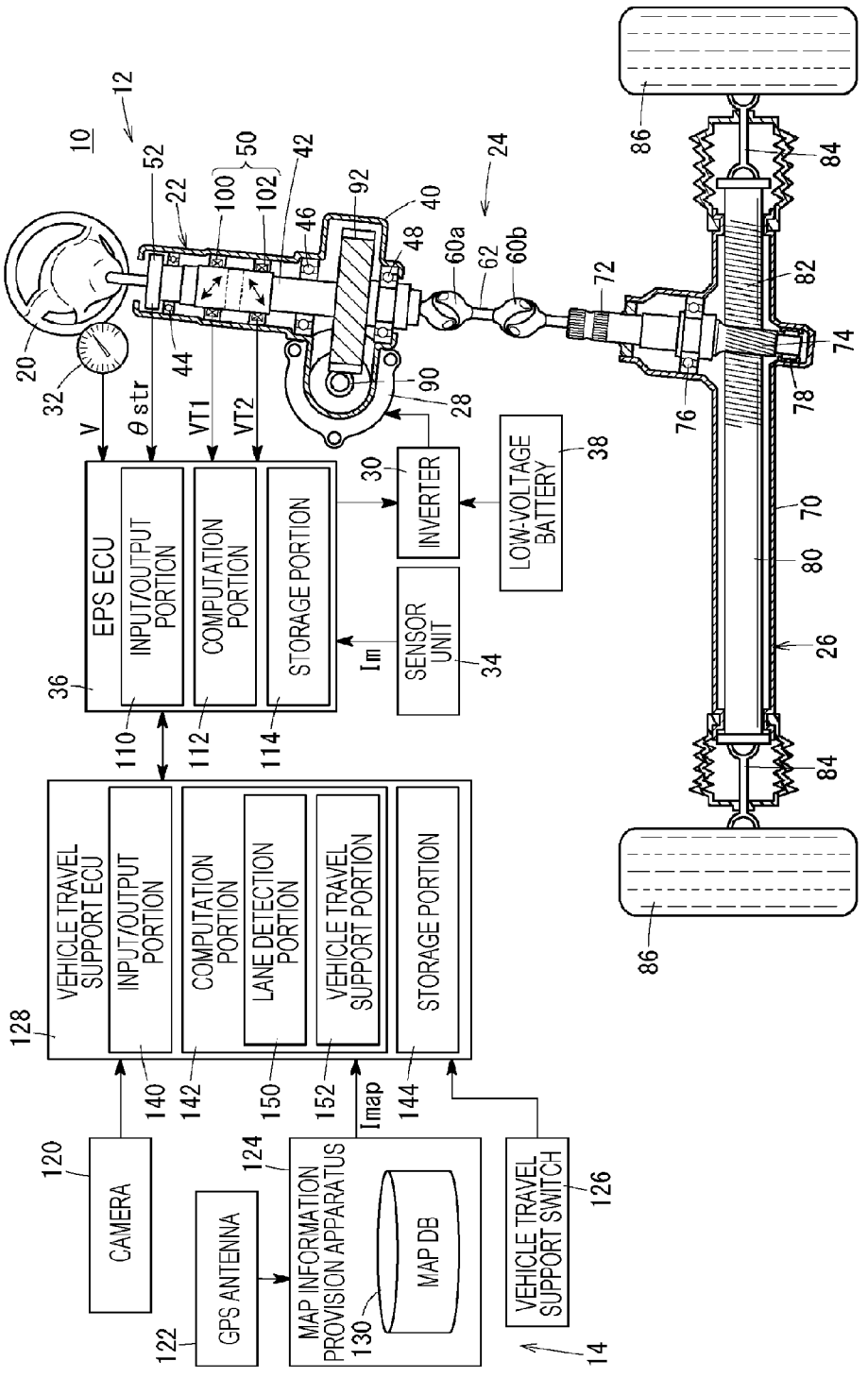


FIG. 1


10
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42
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60a
60b
62
70
72
74
76
78
80
82
84
86
90
92
100
102
110
112
114
120
122
124
126
128
130
140
142
144
150
152
V
θstr
VT1
VT2
Im
Imap
EPS ECU
INPUT/OUTPUT PORTION
COMPUTATION PORTION
STORAGE PORTION
INVERTER
SENSOR UNIT
LOW-VOLTAGE BATTERY
VEHICLE TRAVEL SUPPORT ECU
INPUT/OUTPUT PORTION
COMPUTATION PORTION
LANE DETECTION PORTION
VEHICLE TRAVEL SUPPORT PORTION
STORAGE PORTION
CAMERA
GPS ANTENNA
MAP INFORMATION PROVISION APPARATUS
MAP DB
VEHICLE TRAVEL SUPPORT SWITCH
14

FIG. 2

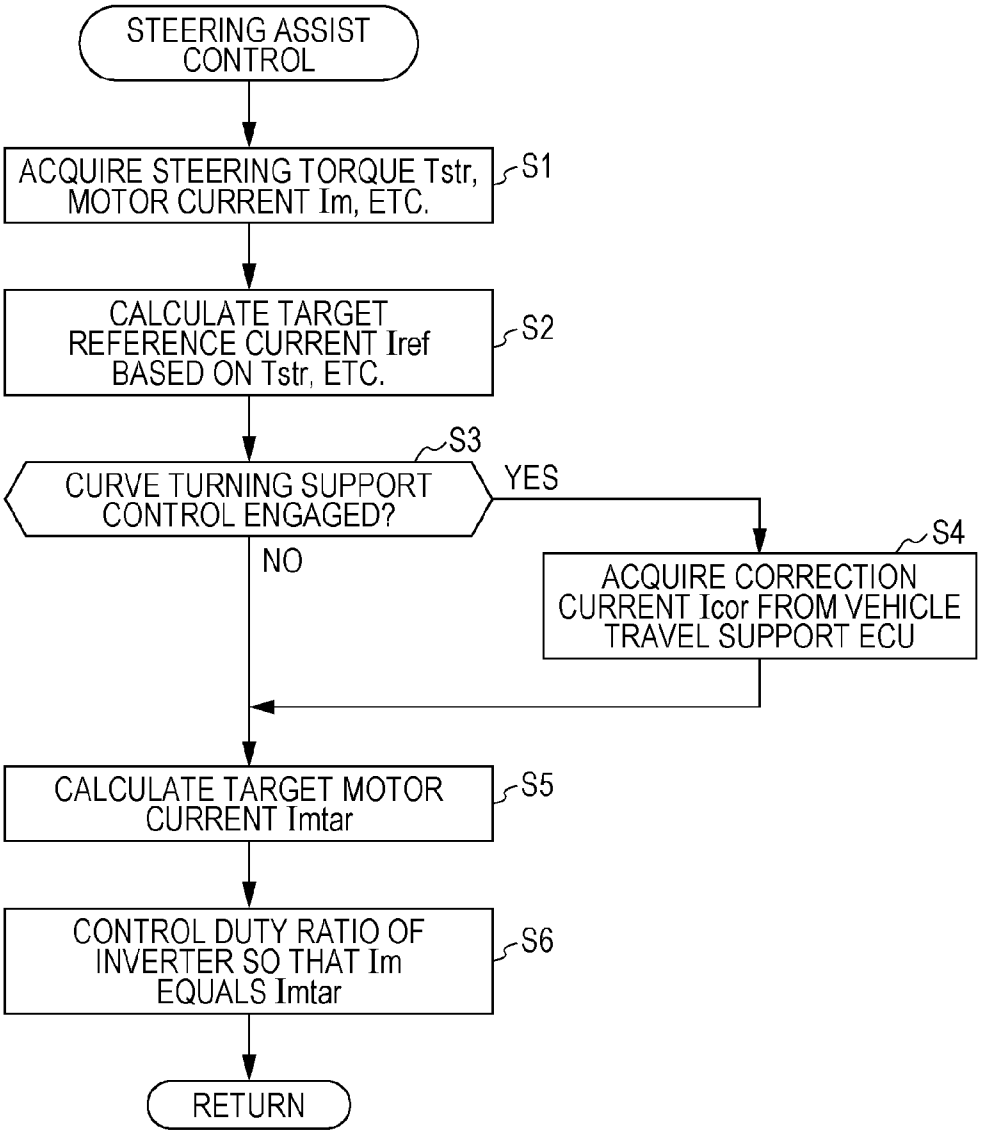

STEERING ASSIST CONTROL
ACQUIRE STEERING TORQUE Tstr, MOTOR CURRENT Im, ETC.
S1
CALCULATE TARGET REFERENCE CURRENT Iref BASED ON Tstr, ETC.
S2
S3
CURVE TURNING SUPPORT CONTROL ENGAGED?
YES
NO
S4
ACQUIRE CORRECTION CURRENT Icor FROM VEHICLE TRAVEL SUPPORT ECU
CALCULATE TARGET MOTOR CURRENT Imtar
S5
CONTROL DUTY RATIO OF INVERTER SO THAT Im EQUALS Imtar
S6
RETURN

FIG. 3

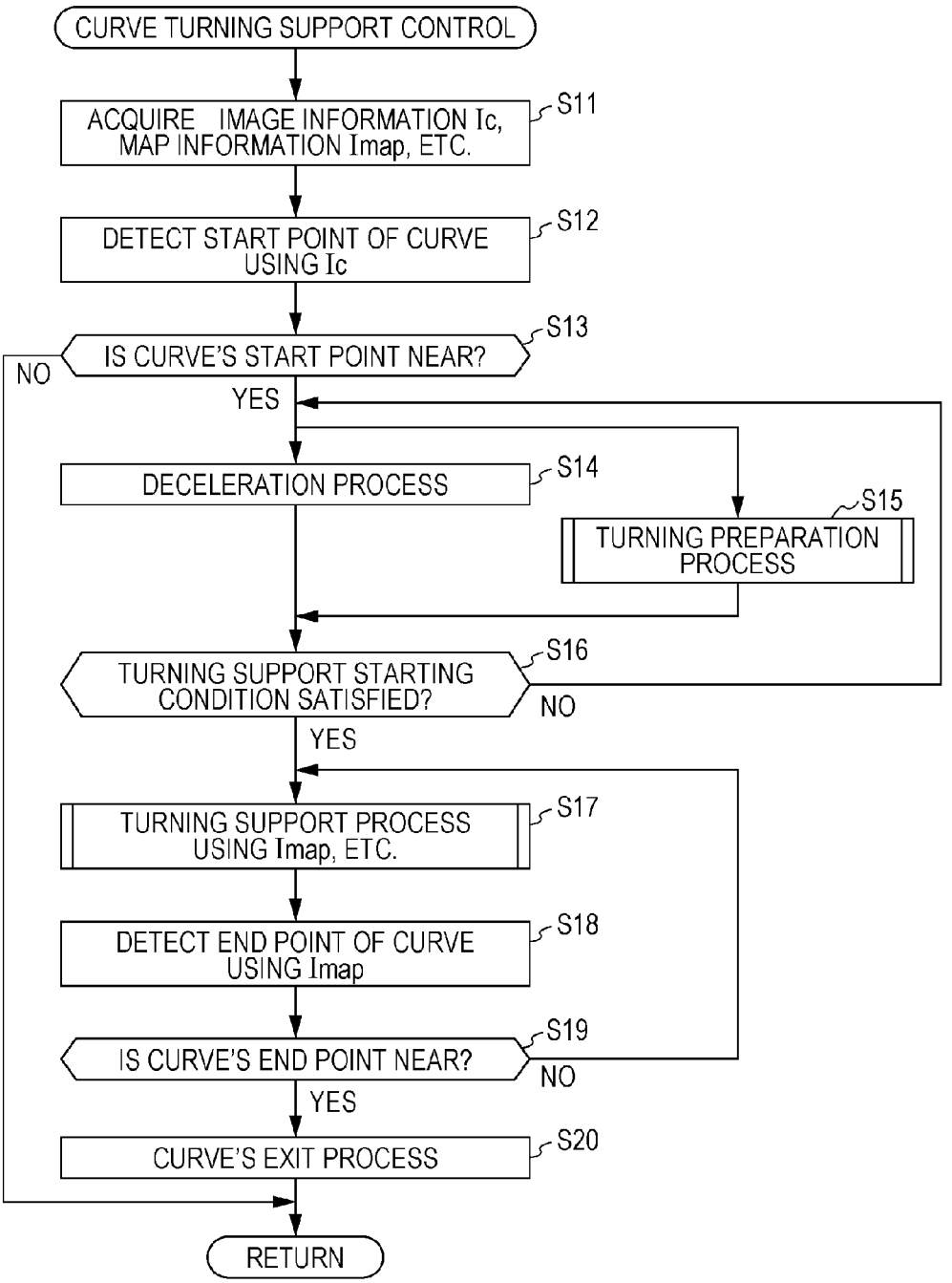

CURVE TURNING SUPPORT CONTROL
ACQUIRE IMAGE INFORMATION Ic, MAP INFORMATION Imap, ETC.
S11
DETECT START POINT OF CURVE USING Ic
S12
IS CURVE'S START POINT NEAR?
S13
NO
YES
DECELERATION PROCESS
S14
TURNING PREPARATION PROCESS
S15
TURNING SUPPORT STARTING CONDITION SATISFIED?
S16
NO
YES
TURNING SUPPORT PROCESS USING Imap, ETC.
S17
DETECT END POINT OF CURVE USING Imap
S18
IS CURVE'S END POINT NEAR?
S19
NO
YES
CURVE'S EXIT PROCESS
S20
RETURN

FIG. 4

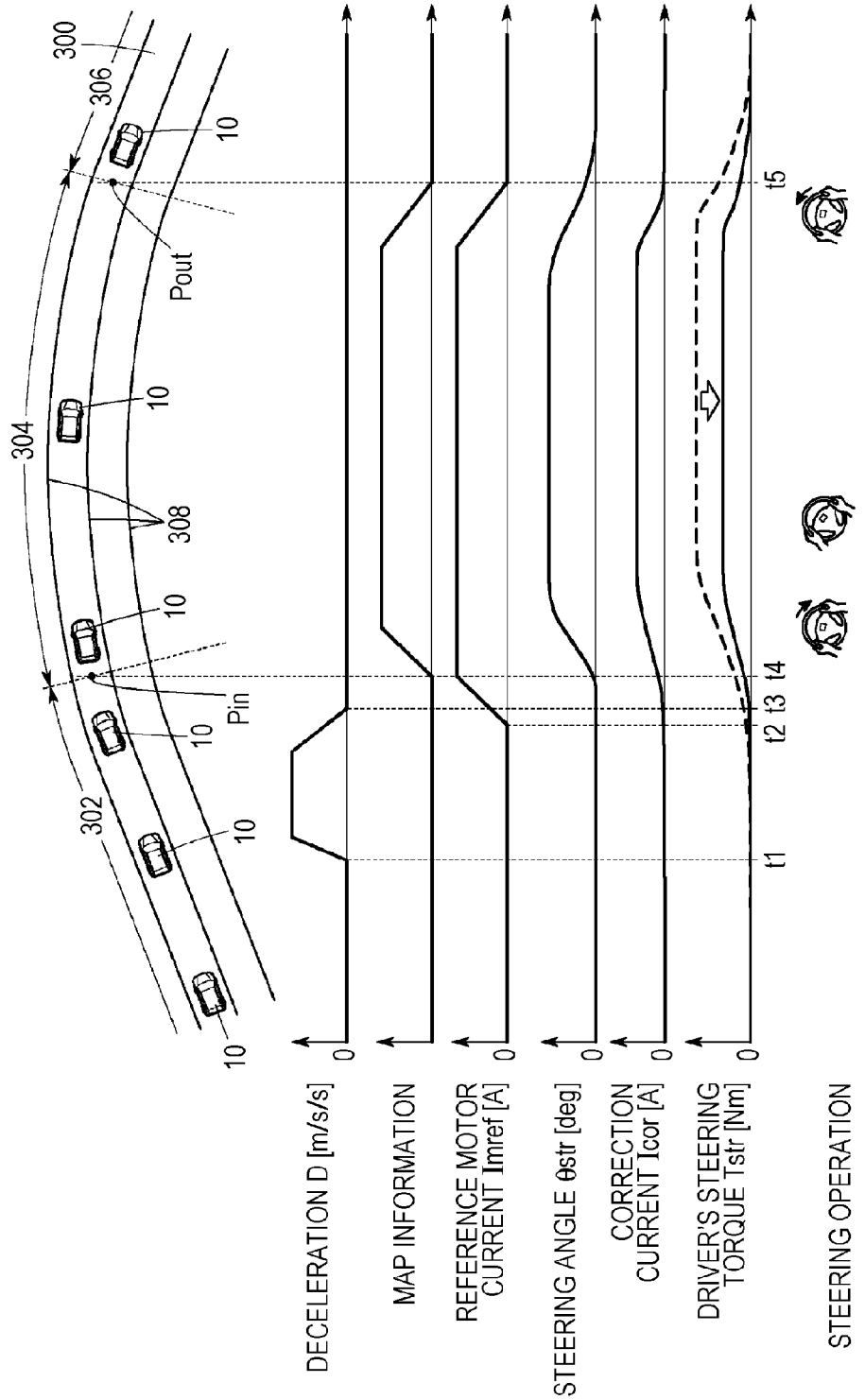

300
306
304
302
308
10
Pout
Pin
DECELERATION D [m/s/s]
MAP INFORMATION
REFERENCE MOTOR CURRENT Imref [A]
STEERING ANGLE θstr [deg]
CORRECTION CURRENT Icor [A]
DRIVER'S STEERING TORQUE Tstr [Nm]
STEERING OPERATION
0
t1
t2
t3
t4
t5

FIG. 5

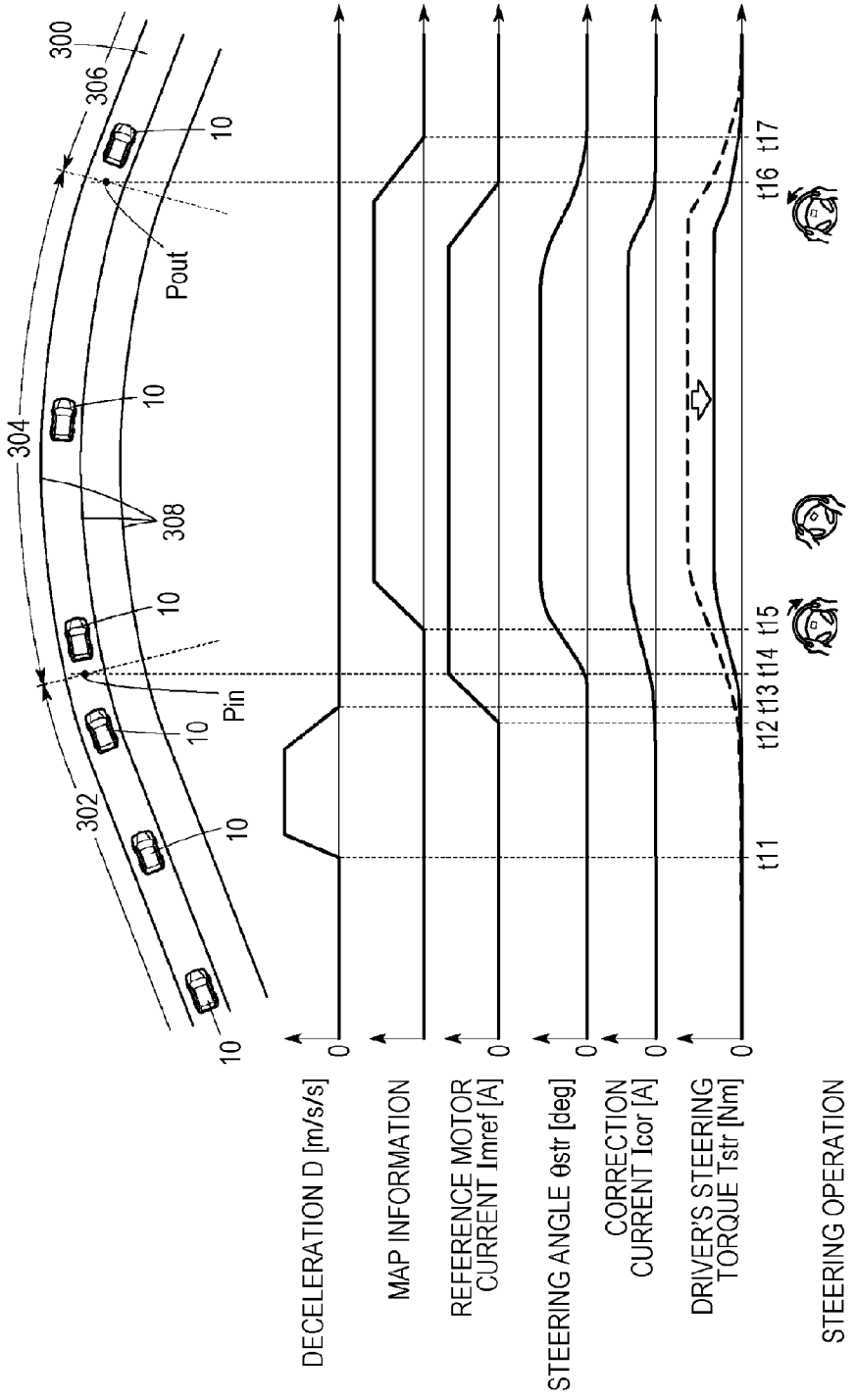

300
306
304
302
308
Pout
Pin
10
DECELERATION D [m/s/s]
MAP INFORMATION
REFERENCE MOTOR CURRENT Imref [A]
STEERING ANGLE θstr [deg]
CORRECTION CURRENT Icor [A]
DRIVER'S STEERING TORQUE Tstr [Nm]
STEERING OPERATION
0
t11
t12
t13
t14
t15
t16
t17

FIG. 6

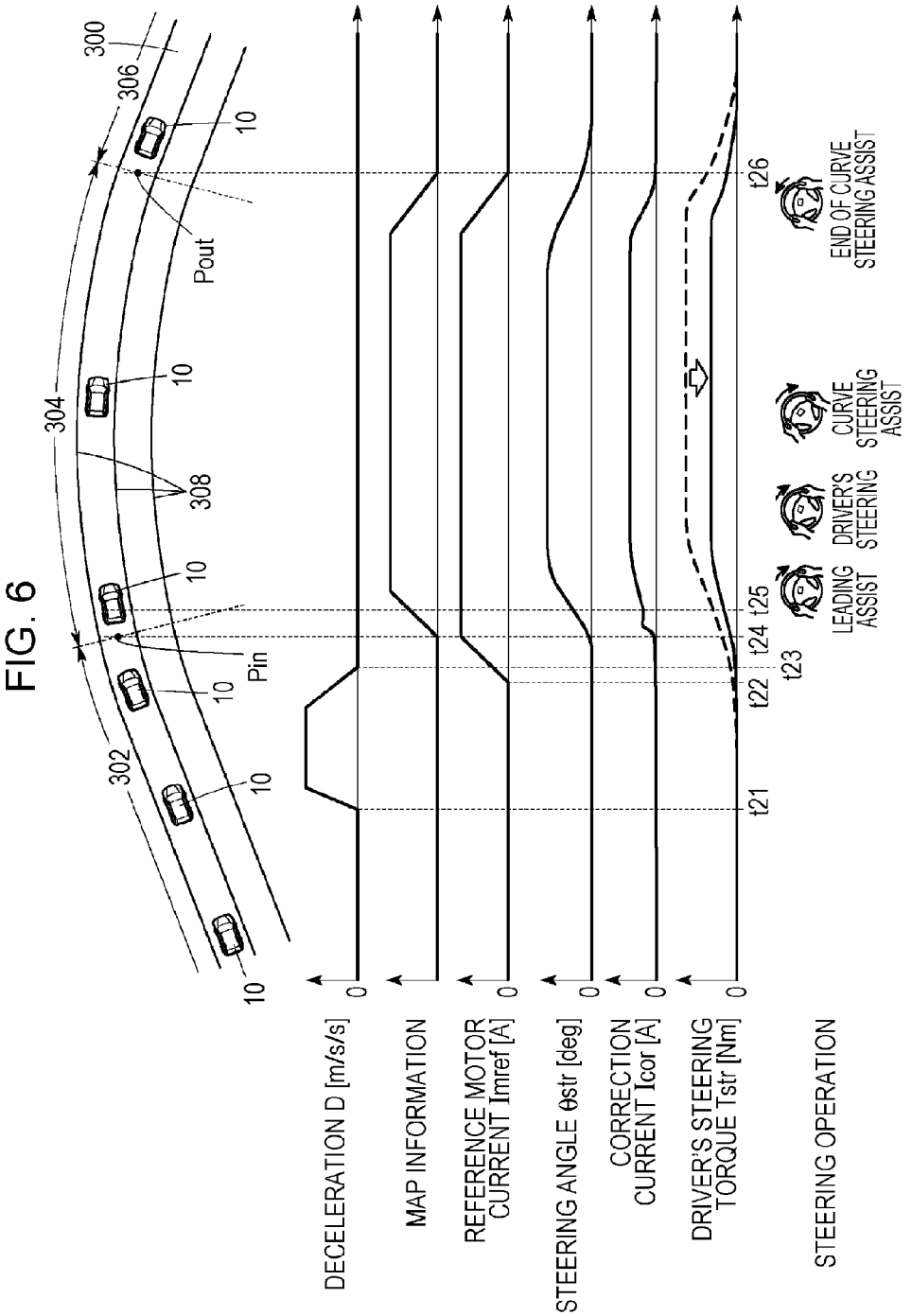

300
306
304
302
308
10
Pout
Pin
DECELERATION D [m/s/s]
MAP INFORMATION
REFERENCE MOTOR CURRENT Imref [A]
STEERING ANGLE θstr [deg]
CORRECTION CURRENT Icor [A]
DRIVER'S STEERING TORQUE Tstr [Nm]
STEERING OPERATION
0
t21
t22
t23
t24
t25
t26
LEADING ASSIST
DRIVER'S STEERING
CURVE STEERING ASSIST
END OF CURVE STEERING ASSIST

FIG. 7

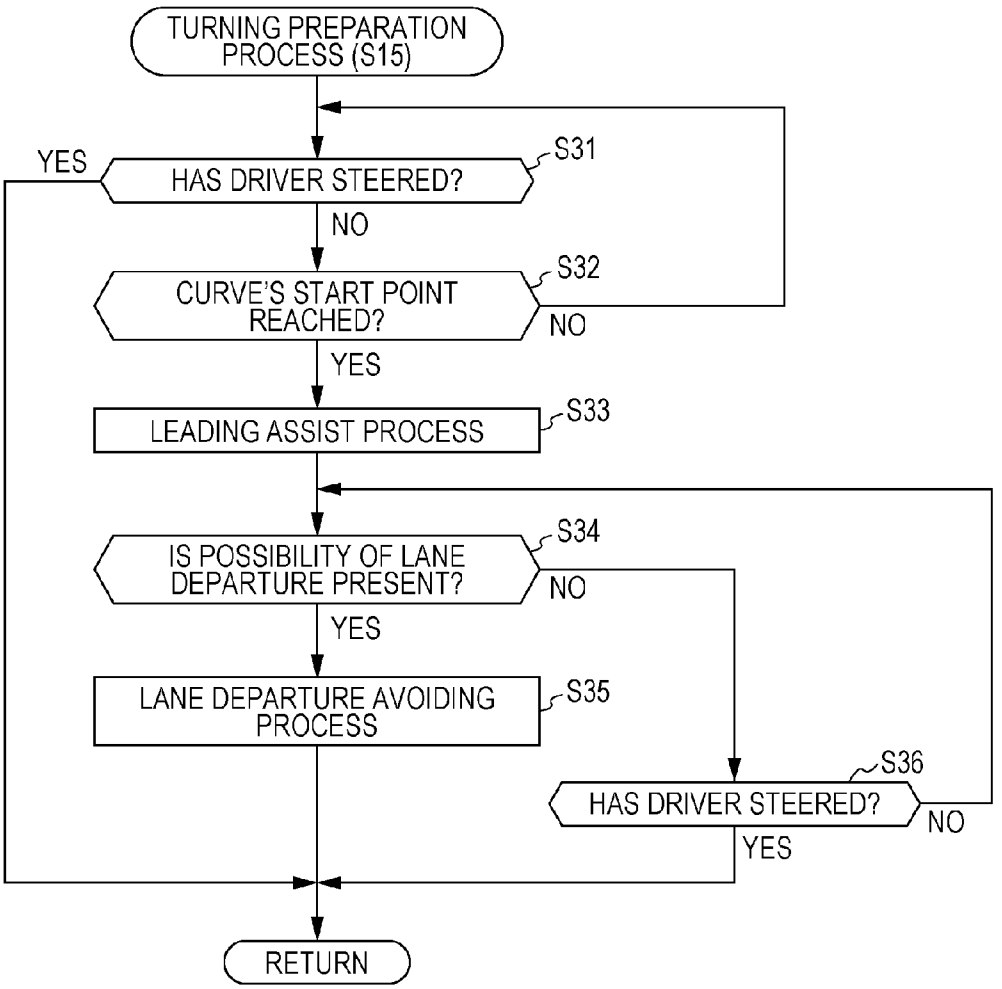
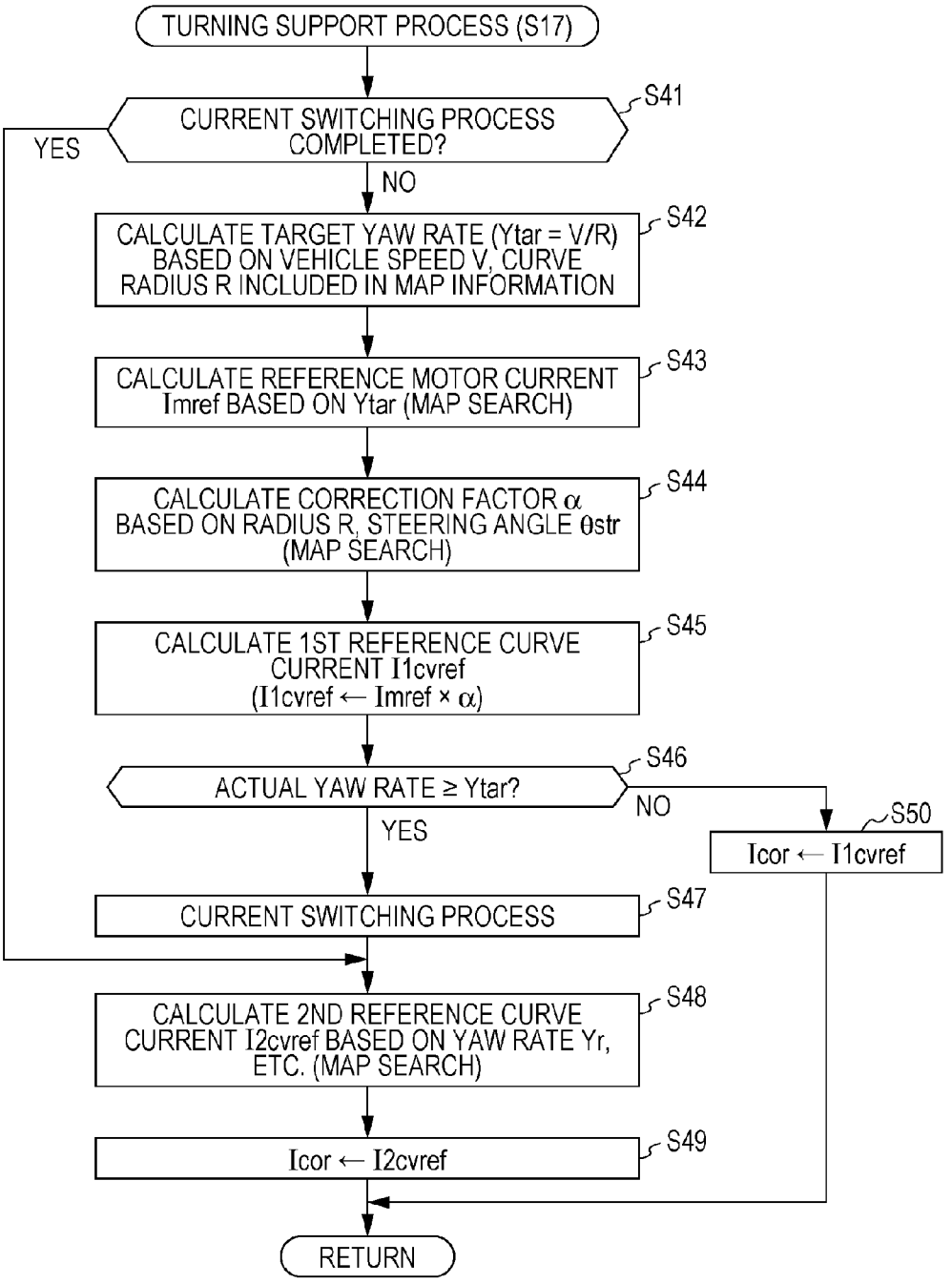

TURNING PREPARATION PROCESS (S15)
HAS DRIVER STEERED?
S31
YES
NO
CURVE'S START POINT REACHED?
S32
NO
YES
LEADING ASSIST PROCESS
S33
IS POSSIBILITY OF LANE DEPARTURE PRESENT?
S34
NO
YES
LANE DEPARTURE AVOIDING PROCESS
S35
HAS DRIVER STEERED?
S36
NO
YES
RETURN

FIG. 8


TURNING SUPPORT PROCESS (S17)
S41
CURRENT SWITCHING PROCESS COMPLETED?
YES
NO
S42
CALCULATE TARGET YAW RATE (Ytar = V/R) BASED ON VEHICLE SPEED V, CURVE RADIUS R INCLUDED IN MAP INFORMATION
S43
CALCULATE REFERENCE MOTOR CURRENT Imref BASED ON Ytar (MAP SEARCH)
S44
CALCULATE CORRECTION FACTOR α BASED ON RADIUS R, STEERING ANGLE θstr (MAP SEARCH)
S45
CALCULATE 1ST REFERENCE CURVE CURRENT I1cvref (I1cvref ← Imref × α)
S46
ACTUAL YAW RATE ≥ Ytar?
NO
YES
S50
Icor ← I1cvref
S47
CURRENT SWITCHING PROCESS
S48
CALCULATE 2ND REFERENCE CURVE CURRENT I2cvref BASED ON YAW RATE Yr, ETC. (MAP SEARCH)
S49
Icor ← I2cvref
RETURN

VEHICLE TRAVEL SUPPORT SYSTEM AND VEHICLE TRAVEL SUPPORT METHOD

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] The present application claims priority under 35 U.S.C. §119 to Japanese Patent Application No. 2015-024465, filed Feb. 10, 2015, entitled "Vehicle Travel Support System and Vehicle Travel Support Method." The contents of this application are incorporated herein by reference in their entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to a vehicle travel support system and a vehicle travel support method that perform vehicle travel support by using steering assist torque produced by an actuator.

BACKGROUND

[0003] Japanese Unexamined Patent Application Publication No. 2012-027760 discloses a system that performs lane keeping support and lane departure warning (see paragraph and the abstract). According to Japanese Unexamined Patent Application Publication No. 2012-027760, a lane detection unit 10 detects a lane on the basis of an image taken by an image pickup unit 2 (paragraph [0012] in the publication). A lane keeping support unit 11 calculates a steering angle needed in order to keep the vehicle in the present lane and operates a steering motor 5 via a power steering control unit 6 (paragraph [0012]). A lane departure warning apparatus 12 determines a possibility of the vehicle departing from the lane on the basis of lane information detected by the lane detection unit 10, and produces an alarm to the driver if it is determined that the vehicle is to depart from the lane (paragraph [0012]). According to Japanese Unexamined Patent Application Publication No. 2012-027760, if a curve radius from the navigation apparatus 13 is equal to or less than a pre-set value, the lane departure warning apparatus 12 notifies the driver by voice or the like that the lane keeping support or the lane departure warning will become invalid (paragraph [0013]).

[0004] Japanese Patent No. 4654208 discloses a lane departure prevention system or the like that acquires information about the environment around a host vehicle by using a vehicle-mounted camera 3a and supports in the driving of the host vehicle and produces alarms to occupants of the vehicle (paragraph [0010]).

[0005] Neither Japanese Unexamined Patent Application Publication No. 2012-027760 nor Japanese Patent No. 4654208 provides any consideration that focuses on the vehicle travel support during a turn along a curve.

[0006] Accordingly, the present application describes a vehicle travel support system and a vehicle travel support method capable of more suitably performing the vehicle travel support when the vehicle turns a curve.

[0007] A vehicle travel support system according to a first aspect of the disclosure includes an image pickup apparatus that takes a front image of a view ahead of a vehicle, a lane detection apparatus that detects a lane indicated on a travel path of the vehicle from the front image acquired by the image pickup apparatus, a position detection apparatus that detects a present position of the vehicle, a map information storage apparatus that stores map information, an actuator that generates a steering assist force, and a control apparatus that assists in keeping the vehicle in the lane or avoiding departure of the vehicle from the lane by causing the actuator to generate the steering assist force. The control apparatus estimates the travel path of the vehicle based on the present position of the vehicle and the map information, acquires, regarding a curve included in the travel path, a curve radius contained in the map information from the map information storage apparatus, performs at least one of a vehicle turning support and a deceleration support prior to entry to the curve, based on a start point of the curve which is detected based on the front image, and performs the vehicle turning support for the curve by using the curve radius contained in the map information.

[0008] According to the first aspect of the disclosure, the vehicle turning support or the deceleration support prior to entry to the curve is performed on the basis of the start point of the curve which is detected on the basis of front images taken by the image pickup apparatus and the vehicle turning support for the curve is performed by using the curve radius contained in the map information. Therefore, it becomes possible to perform a suitable deceleration support or a suitable vehicle turning support with reference to the start point of the curve detected with high accuracy by using front images and perform a highly accurate vehicle turning support for a curve based on the map information.

[0009] The control apparatus may start the vehicle turning support for the curve which uses the curve radius, when steering is performed by a driver of the vehicle. Therefore, it becomes possible to perform a vehicle turning support that reflects tastes of the driver. Furthermore, it also becomes possible to prevent a sense of strangeness about the steering assist force from being given to the driver.

[0010] In the foregoing vehicle travel support system, the control apparatus may compute a first steering assist force that is the steering assist force that reflects at least one of a target yaw rate and a target lateral acceleration that are based on the curve radius and vehicle speed and also computes a second steering assist force that is the steering assist force that reflects the vehicle speed and at least one of vehicle yaw rate and lateral acceleration, and may start the vehicle turning support based on the first steering assist force, subsequently change the steering assist force gradually or stepwise from the first steering assist force to the second steering assist force, and then perform the vehicle turning support using the second steering assist force. Thus, it is possible to perform a smooth transition from the first steering assist force that reflects the curve radius to the second steering assist force that reflects the vehicle yaw rate.

[0011] The control apparatus may cause the steering assist force to be generated by using as a reference a start point of the curve which is detected based on the front image. Thus, even if the driver does not perform steering or the amount of steering performed is small, the steering assist force is generated so that the vehicle can smoothly turn the curve.

[0012] The control apparatus, while performing the vehicle turning support for the curve by using the curve radius contained in the map information, may reduce the steering assist force so that the vehicle turning support ends at an end point of the curve which is detected based on the front image. Thus, the vehicle turning support for the curve which uses the radius of the curve contained in the map information can be ended in accordance with the end point of the curve detected on the basis of front images. Therefore, the vehicle turning support can be highly accurately ended.

[0013] A vehicle travel support system according to a second aspect of the disclosure includes a position detection apparatus that detects a present position of a vehicle, a map information storage apparatus that stores map information, an actuator that generates a steering assist force, and a control apparatus that assists in keeping the vehicle in a lane or avoiding departure of the vehicle from the lane by causing the actuator to generate the steering assist force. The control apparatus estimates a travel path of the vehicle based on the present position of the vehicle and the map information, acquires, regarding a curve included in the travel path, a curve radius contained in the map information from the map information storage apparatus, performs at least one of a deceleration support and a vehicle turning support based on a current that maintains at least one of a vehicle yaw rate and a lateral acceleration that occur on the vehicle, and performs the vehicle turning support for the curve by using the curve radius contained in the map information.

[0014] According to the second aspect of the disclosure, at least one of the vehicle turning support and the deceleration support based on the current that maintains at least one of the lateral acceleration and the vehicle yaw rate is performed and the vehicle turning support for the curve by using the curve radius thereof contained in the map information is performed. Therefore, it becomes possible to perform the vehicle turning support or the deceleration support that maintains the lateral acceleration of the vehicle yaw rate and perform a highly accurate vehicle turning support for a curve based on the map information.

[0015] The control apparatus may cause the steering assist force to be generated before the vehicle enters the curve. This makes it possible to notify the driver in advance that the vehicle turning support will be performed for the curve.

[0016] The control apparatus may determine a delay of an actual steering timing at which steering is performed by a driver of the vehicle from a reference steering timing that is a steering timing set with reference to a start point of the curve and may advance a start timing of starting the steering assist force prior to entry to the curve, according to the delay of the actual steering timing. Therefore, the timing of starting the steering assist force prior to entry to the curve can be adjusted according to the skill of the driver.

[0017] In the foregoing vehicle travel support system, if the vehicle has passed a steering-requiring position set with reference to the start point of the curve contained in the map information while the driver does not operate the steering wheel, the control apparatus determines from the front image that there is departure of the vehicle from the lane or possibility of departure of the vehicle from the lane, then the control apparatus may cause the steering assist force to be generated in order to avoid or recover from departure of the vehicle from the lane. Thus, in the determination regarding departure of the vehicle from the lane based on front images, the use of the information about the start point of the curve contained in the map information makes it possible to highly accurately determine the need for a lane departure avoidance or recovery process.

[0018] According to a third aspect of the disclosure, there is provided a vehicle travel support method that uses a vehicle travel support system that includes an image pickup apparatus that takes a front image of a view ahead of a vehicle, a lane detection apparatus that detects a lane indicated on a travel path of the vehicle from the front image acquired by the image pickup apparatus, a position detection apparatus that detects a present position of the vehicle, a map information storage apparatus that stores map information, an actuator that generates a steering assist force, and a control apparatus that assists in keeping the vehicle in the lane or avoiding departure of the vehicle from the lane by causing the actuator to generate the steering assist force. The vehicle travel support method includes causing the control apparatus to estimate the travel path of the vehicle based on the present position of the vehicle and the map information, acquire, regarding a curve included in the travel path, a curve radius contained in the map information from the map information storage apparatus, perform a vehicle turning support or a deceleration support prior to entry to the curve, based on a start point of the curve which is detected based on the front image, and perform the vehicle turning support for the curve by using the curve radius contained in the map information, when steering is performed by a driver of the vehicle.

[0019] According to a fourth aspect of the disclosure, there is provided a vehicle travel support method that uses a vehicle travel support system that includes an image pickup apparatus that takes a front image of a view ahead of a vehicle, a lane detection apparatus that detects a lane indicated on a travel path of the vehicle from the front image acquired by the image pickup apparatus, a position detection apparatus that detects a present position of the vehicle, a map information storage apparatus that stores map information, an actuator that generates a steering assist force, and a control apparatus that assists in keeping the vehicle in the lane or avoiding departure of the vehicle from the lane by causing the actuator to generate the steering assist force. The vehicle travel support method includes causing the control apparatus to estimate the travel path of the vehicle based on the present position of the vehicle and the map information, acquire, regarding a curve included in the travel path, a curve radius contained in the map information from the map information storage apparatus, and reduce, while performing the vehicle turning support for the curve by using the curve radius contained in the map information, the steering assist force so that the vehicle turning support ends at an end point of the curve which is detected based on the front image.

[0020] According to this disclosure, during the vehicle turning support for a curve by using the curve radius contained in the map information, the steering assist force is reduced so that the vehicle turning support will end at the end point of the curve which is detected on the basis of front images. Therefore, it becomes possible to perform a highly accurate vehicle turning support for a curve based on the map information and end the vehicle turning support at an appropriate timing with reference to the end point of the curve which is detected with high accuracy by using front images.

[0021] According to the disclosure, it becomes possible to more suitably perform the vehicle travel support when the vehicle turns a curve. It also becomes possible to prevent a sense of strangeness about the steering assist force from being given to the driver of the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The advantages of the disclosure will become apparent in the following description taken in conjunction with the following drawings.

[0023] FIG. **1** is a general construction diagram of a vehicle equipped with a vehicle travel support system according to an embodiment of the present disclosure.

[0024] FIG. **2** is a flowchart of a steering assist control in the embodiment.

[0025] FIG. **3** is a flowchart of a curve turning support control in the embodiment.

[0026] FIG. **4** is a diagram showing a first example of various numerical values involved in execution of the curve turning support control in the embodiment, together with a travel path of the vehicle.

[0027] FIG. **5** is a diagram showing a second example of the various numerical values involved in execution of the curve turning support control in the embodiment, together with a travel path of the vehicle.

[0028] FIG. **6** is a diagram showing a third example of the various numerical values involved in execution of the curve turning support control in the embodiment, together with a travel path of the vehicle.

[0029] FIG. **7** is a flowchart of a vehicle turning preparation process (details of step S**15** in FIG. **3**) in the embodiment.

[0030] FIG. **8** is a flowchart of the vehicle turning support process (details of step S**17** in FIG. **3**) in the embodiment.

DETAILED DESCRIPTION

A. One Embodiment

A1. Description of Overall Construction

A1-1. Overall Construction

[0031] FIG. **1** is a general construction diagram of a vehicle **10** equipped with a vehicle travel support system **14** (hereinafter, also referred to as "support system **14**") according to an embodiment of the present disclosure. As shown in FIG. **1**, the vehicle **10** has an electric power steering apparatus **12** (hereinafter, referred to as "EPS apparatus **12**") as well as the support system **14**.

A1-2. EPS Apparatus **12**

A1-2-1. Overview of EPS Apparatus **12**

[0032] The EPS apparatus **12** includes a steering wheel **20**, a steering column **22**, an intermediate joint **24**, a steering gear box **26**, an motor **28** for the EPS apparatus **12** (hereinafter, also referred to as "EPS motor **28**"), an inverter **30** (hereinafter, also referred to as "EPS inverter **30**"), a vehicle speed sensor **32**, a sensor unit **34**, an electric power steering electronic control unit **36** (hereinafter, referred to as "EPS ECU **36**" or "ECU **36**"), and a low-voltage battery **38** (hereinafter, also referred to as "battery **38**").

[0033] The steering column **22** includes a casing **40**, a steering shaft **42** supported within the casing **40** by the bearings **44**, **46** and **48**, a torque sensor **50**, and a steering angle sensor **52**.

[0034] The intermediate joint **24** includes two universal joints **60***a* and **60***b* and a shaft portion **62** disposed between the two universal joints **60***a* and **60***b*.

[0035] The steering gear box **26** includes a casing **70**, a pinion shaft **72** provided with a pinion **74** of a rack-and-pinion mechanism and supported by bearings **76** and **78**, a rack shaft **80** having rack teeth **82** of the rack-and-pinion mechanism, and tie rods **84**.

A1-2-2. Manual Steering System

[0036] One end of the steering shaft **42** is fixed to the steering wheel **20** and the other end thereof is connected to the universal joint **60***a*. The universal joint **60***a* connects the other end of the steering shaft **42** and one end of the shaft portion **62**. The universal joint **60***b* connects the other end of the shaft portion **62** and one end of the pinion shaft **72**. The pinion **74** of the pinion shaft **72** and the rack teeth **82** formed on the rack shaft **80** movable back and force in a vehicle width direction mesh with each other. Two opposite ends of the rack shaft **80** are connected to left and right front wheels **86** (steering road wheels) via the tie rods **84**.

[0037] Therefore, the steering torque Tstr (rotation force) caused by a driver operating the steering wheel **20** is transferred to the pinion shaft **72** via the steering shaft **42** and the intermediate joint **24**. Then, the steering torque Tstr is converted into thrust by the pinion **74** of the pinion shaft **72** and the rack teeth **82** of the rack shaft **80**, and the rack shaft **80** is displaced in a vehicle width direction. As the rack shaft **80** is displaced, the tie rods **84** steer the front wheels **86**, whereby vehicle **10** can change its direction.

[0038] The steering shaft **42**, the intermediate joint **24**, the pinion shaft **72**, the rack shaft **80**, and the tie rods **84** constitute a manual steering system that transfers the driver's steering action on the steering wheel **20** directly to the front wheels **86**.

A1-2-3. Steering Assist System

A1-2-3-1. Assist Drive System

[0039] The EPS motor **28** is connected to the steering shaft **42** via a worm gear **90** and a worm wheel gear **92**. That is, an output shaft of the EPS motor **28** is connected to the worm gear **90**. Furthermore, the worm wheel gear **92** in mesh with the worm gear **90** is formed elastically and integrally with the steering shaft **42**.

[0040] In this embodiment, the EPS motor **28** is, for example, of a three-phase alternating-current brushless type. However, the EPS motor **28** may also be of another type such as a three-phase alternating-current brush type, a single-phase alternating-current type, or a direct-current type. The EPS motor **28** is supplied with electric power from the low-voltage battery **38** via the EPS inverter **30** that is controlled by the EPS ECU **36**. Thus, the EPS motor **28** generates drive force Fm (hereinafter, also referred to as "motor drive force Fm" or "steering assist force Fm") commensurate with the supplied electric power. The motor drive force Fm is transferred to the rack shaft **80** via the output shaft of the EPS motor **28**, the worm gear **90**, the steering shaft **42** (the worm wheel gear **92**), the intermediate joint **24**, and the pinion shaft **72**. The EPS motor **28**, the worm gear **90**, and the steering shaft **42** (the worm wheel gear **92**) constitute an assist drive system that generates drive force for steering (the steering assist force Fm).

[0041] The steering assist force Fm in this embodiment can include a component of input amplification force Famp and a component of vehicle travel support force Fda. The input amplification force Famp is a drive force that amplifies the input torque from the driver to the steering wheel **20** (the steering torque Tstr), acting in the same direction as the steering torque Tstr, so as to assist the driver in steering. As described later, a drive force that acts in the opposite direction to the input amplification force Famp can also be generated. The vehicle travel support force Fda is a drive force that is

generated and used independently of the steering torque Tstr in order to assist in the traveling of the vehicle **10** (particularly, the turning along a curve **304** (FIG. **4**)).

A1-2-3-2. Assist Control System

[0042] The torque sensor **50**, the vehicle speed sensor **32**, the EPS inverter **30**, the sensor unit **34**, and the EPS ECU **36** constitute an assist control system that controls the assist drive system. The assist drive system, the assist control system, and the low-voltage battery **38** combined will be collectively termed the steering assist system as well below. In this embodiment, the output of the EPS motor **28** is controlled by a so-called vector control that uses the d-axis and the q-axis.

(a) Feed-Forward System Sensors

[0043] The torque sensor **50** is a magnetostriction type sensor having high bending and torsional rigidities which is obtained by treating the steering shaft **42** directly with magnetostriction plating. The torque sensor **50** includes a first detection element **100** and a second detection element **102** of the magnetostriction type. Each of the first detection element **100** and the second detection element **102** is a magnetostriction film. The first detection element **100** outputs to the EPS ECU **36** a voltage (rightward-direction torque voltage VT**1**) commensurate with the torque (rightward-direction torque Tsr) in a clockwise direction when the steering wheel **20** is viewed from the driver side. The second detection element **102** outputs to the EPS ECU **36** a voltage (leftward-direction torque voltage VT**2**) commensurate with the torque (leftward-direction torque Tsl) in the counterclockwise direction when the steering wheel **20** is viewed from the driver side.

[0044] The vehicle speed sensor **32** detects the vehicle speed V [km/h] and outputs it to the EPS ECU **36**. The steering angle sensor **52** detects a steering angle θstr [degree] that indicates the amount of steering of the steering wheel **20**, and outputs it to the EPS ECU **36**. The rightward-direction torque voltage VT**1**, the leftward-direction torque voltage VT**2**, the vehicle speed V, and the steering angle θstr are used for the feed-forward control by the EPS ECU **36**.

(b) EPS Inverter **30**

[0045] The EPS inverter **30** has a three-phase bridge type construction, performs a direct-current/alternating-current conversion of converting the direct current from the low-voltage battery **38** into three-phase alternating current, and supplies the alternating current to the EPS motor **28**.

(c) Feedback System Sensors

[0046] The sensor unit **34** detects q-axis current that is a torque current component in the vector control (hereinafter, referred to as "motor current Im"). In this embodiment, the motor current Im is defined to be positive in value when the rotation direction of the motor **28** is a first direction (e.g., such a direction as to turn the vehicle **10** in the rightward direction) and negative in value when the rotation direction of the motor **28** is a second direction (e.g., such a direction as to turn the vehicle **10** in the leftward direction). However, if the first direction and the second direction can be separately determined, the motor current Im may be controlled as being positive in value.

[0047] The sensor unit **34** includes a current sensor (not shown in the drawings) that detects an electric current having at least two phases of the U, V and W phases in the winding wire (not shown) of the EPS motor **28**, a resolver (not shown) that detects the electrical angle θ that is the rotation angle of an output shaft (not shown) or an outer rotor (not shown) of the EPS motor **28**, and a q-axis current computation portion that computes a q-axis current (motor current Im) on the basis of the current having at least two phases and the electrical angle. Incidentally, the function of the q-axis current computation portion may also be realized by the EPS ECU **36**.

(d) EPS ECU **36**

[0048] As shown in FIG. **1**, the EPS ECU **36** has a hardware construction that includes an input/output portion **110**, a computation portion **112**, and a storage portion **114**. The EPS ECU **36** controls the output of the EPS motor **28** via the EPS inverter **30** on the basis of output values of various sensors. The computation portion **112** executes a steering assist control that controls the steering assist force Fm (=the motor drive force Fm) for assisting the driver in steering.

A1-2-3-3. Low-voltage Battery **38**

[0049] The low-voltage battery **38** is an electricity storage apparatus capable of outputting low voltage (12 volt in this embodiment) and may be, for example, a secondary cell such as a lead storage battery.

A1-3. Vehicle Travel Support System **14**

[0050] A shown in FIG. **1**, the vehicle travel support system **14** includes a front camera **120** (hereinafter, also referred to as "camera **120**"), a GPS antenna **122**, a map information provision apparatus **124**, a vehicle travel support switch **126**, and a vehicle travel support electronic control unit **128** (hereinafter, referred to as "vehicle travel support ECU **128**" or "ECU **128**").

[0051] The camera **120** is mounted at an inward side of the windshield in front of a rearview mirror, and captures white lines at both sides of a road surface ahead of the vehicle **10** (lane lines **308** (FIG. **4**)) as images (front images If) when the vehicle travel support switch **126** is on. The camera **120** outputs image information Ic regarding the front images If to the vehicle travel support ECU **128**.

[0052] The GPS antenna **122** receives signals from a plurality of GPS satellites present in the sky above the vehicle **10** (GPS signals) and outputs the GPS signals to the map information provision apparatus **124**.

[0053] The map information provision apparatus **124** specifically determines the present position Pc of the vehicle **10** on the basis of output of the GPS antenna **122** and provides the EPS ECU **36** with information regarding the present position Pc and its surroundings (hereinafter, also referred to as "map information Imap"). The map information Imap includes not only the present position Pc but also a radius R of the curve **304** (hereinafter, also referred to as "curve radius R"), the distance Lin to an entrance of the curve **304** (hereinafter, also referred to as "starting point distance Lin"), and the distance Lout to an exit of the curve **304** (hereinafter, also referred to as "ending point distance Lout").

[0054] The map information Imap is stored in a map information database **130** (hereinafter, referred to as "map DE **130**") of the map information provision apparatus **124**. The map information provision apparatus **124** specifically determines the present position Pc of the vehicle **10** on the basis of the GPS signal received by the GPS antenna **122**. Then, the map information provision apparatus **124** reads the map

information Imap from the map DE **130** on the basis of the present position Pc, and provides the information to the EPS ECU **36**.

[0055] The vehicle travel support ECU **128** has a hardware construction that includes an input/output portion **140**, a computation portion **142**, and a storage portion **144**. The ECU **128** detects from front images If (camera images) acquired by the camera **120** the lane lines **308** (the white lines or boundary lines) at both sides of the vehicle **10** (FIGS. **4** to **6**). Then, the ECU **128** controls the EPS motor **28** so as to assist the vehicle **10** in traveling, for example, along the middle between the two lane lines **308**. Incidentally, FIGS. **4** to **6** show a case in which the vehicle **10** keeps left.

[0056] The computation portion **142** performs overall control of the vehicle travel support system **14** and includes a lane detection portion **150** and a vehicle travel support portion **152**. The lane detection portion **150** detects the lane lines **308** marked on a travel path **300** (FIGS. **4** to **6**) of the vehicle **10** from the image information Ic (front images If) acquired by the camera **120**. The vehicle travel support portion **152** executes a vehicle travel support control of assisting so as to keep the vehicle **10** between the lane lines **308**. Note that, in this embodiment, the vehicle travel support control is executed, with the vehicle speed V being in the range of, for example 30 to 120 [km/h].

A2. Various Controls

A2-1. Summary

[0057] Next, controls by the EPS ECU **36** and the vehicle travel support ECU **128** in this embodiment will be described. The EPS ECU **36** executes the steering assist control. The vehicle travel support ECU **128** executes the vehicle travel support control that includes a curve turning support control. The curve turning support control is a control of assisting the vehicle **10** in turning along the curve **304** by adjusting the vehicle travel support force Fda.

A2-2. Steering Assist Control

[0058] FIG. **2** is a flowchart of the steering assist control in this embodiment. As stated above, the steering assist control controls the steering assist force Fm for assisting the driver in steering. The steering assist force Fm can contain a component of the input amplification force Famp and a component of the vehicle travel support force Fda. The steering assist force Fm is exhibited as a torque and acts in the same direction as the driver's steering torque Tstr. Alternatively, as described later, the steering assist force Fm may be set in the opposite direction to the driver's steering torque Tstr and caused to act as a counterforce. The EPS ECU **36** repeatedly performs the process shown in FIG. **2** in a predetermined first operation cycle (e.g., a cycle of several microseconds to several hundred milliseconds).

[0059] In step S**1** in FIG. **2**, the EPS ECU **36** acquires the steering torque Tstr, the motor current Im, etc. Necessary values other than the steering torque Tstr and the motor current Im include, for example, values necessary to generate the steering assist force Fm in the related-art EPS apparatus **12** (e.g., vehicle yaw rate Yr or lateral acceleration G).

[0060] In step S**2**, the EPS ECU **36** calculates a target reference current Iref on the basis of the steering torque Tstr or the like. The target reference current Iref is a value of the motor current Im which corresponds to the input amplification force Famp and, basically, increases in absolute value if the steering torque Tstr increases in absolute value. Note that, for calculation of the target reference current Iref, a so-called inertia control, a damper control, etc., may be used.

[0061] In step S**3**, the EPS ECU **36** communicates with the vehicle travel support ECU **128** and determines whether the vehicle travel support ECU **128** is executing the curve turning support control. If the curve turning support control is not being executed (NO in S**3**), the process proceeds to step S**5**.

[0062] If the curve turning support control is being executed (YES in S**3**), the process proceeds to step S**4**, in which the EPS ECU **36** acquires from the vehicle travel support ECU **128** a correction current Icor for correcting the target reference current Iref. The correction current Icor is a correction value of the motor current Im which is used for the curve turning support control by the vehicle travel support ECU **128**, and corresponds to the vehicle travel support force Fda. Details of the correction current Icor will be described later with reference to FIG. **3** and the like.

[0063] After step S**3** or S**4**, the EPS ECU **36** calculates a target motor current Imtar in step S**5**. Specifically, if the EPS ECU **36** has not acquired the correction current Icor from the vehicle travel support ECU **128**, the EPS ECU **36** sets the target reference current Iref directly as the target motor current Imtar (Imtar←Iref). If the EPS ECU **36** has acquired the correction current Icor from the vehicle travel support ECU **128**, the EPS ECU **36** adds the correction current Icor to the target reference current Iref to set a target motor current Imtar (Imtar←Iref+Icor).

[0064] In step S**6**, the EPS ECU **36** changes the output of the motor **28** by controlling the duty ratio of the inverter **30** so that the motor current Im becomes equal to the target motor current Imtar.

A2-3. Curve Turning Support Control

A2-3-1. Overall Flow of Curve Turning Support Control

[0065] FIG. **3** is a flowchart of the curve turning support control in the embodiment. FIGS. **4** to **6** show first to third examples of various numerical values involved in execution of the curve turning support control in the embodiment, together with the travel path **300** of the vehicle **10**. As stated above, the curve turning support control is a control of assisting the vehicle **10** in turning along the curve **304** by adjusting the vehicle travel support force Fda. The vehicle travel support force Fda is exhibited as a torque and is in the same direction as the driver's steering torque Tstr. Alternatively, as stated later, the steering assist force Fm may be in the opposite direction to the driver's steering torque Tstr and caused to act as a counterforce. The vehicle travel support ECU **128** repeatedly performs the process shown in FIG. **3** in a predetermined second operation cycle (e.g., a cycle of several microseconds to several hundred milliseconds).

[0066] In FIGS. **4** to **6**, the vehicle **10** is traveling on the travel path **300**. The travel path **300** includes a straight path **302**, the curve **304**, and a straight path **306**. Furthermore, the travel path **300** includes the lane lines **308** that are white lines at both sides of the travel path **300**. Furthermore, in each of FIGS. **4** to **6**, an interrupted line regarding the driver's steering torque Tstr represents a characteristic in a comparative example in which the turning support process in the embodiment is not performed.

[0067] In step S**11** in FIG. **3**, the vehicle travel support ECU **128** acquires the image information Ic (including front

images If), the map information Imap, etc. Necessary values other than the image information Ic and the map information Imap include, for example, the vehicle speed V, the steering angle θstr, and the vehicle yaw rate Yr (or lateral acceleration G).

[0068] In step S**12**, the ECU **128** detects the start point Pin (entrance) of the curve **304** by using front images if from the image information Ic. For example, the ECU **128** performs edge detection within the front images If to detect the lane lines **308**. Then, the ECU **128** calculates tangent lines to the lane lines **308** and detects as the start point Pin of the curve **304** a point where the slope of the tangent line to the lane lines **308** becomes equal to or greater than a first angle threshold value.

[0069] In step S**13**, the ECU **128** determines whether the start point Pin of the curve **304** has come near (time t**1** in FIG. **4**, time t**11** in FIG. **5**, and time t**21** in FIG. **6**). Concretely, the ECU **128** determines whether the distance L**1** to the start point Pin has become equal to less than a distance threshold value THl**1**. If the start point Pin is not near (NO in S**13**), the ECU **128** ends the present process and returns to step S**11**. If the start point Pin is near (YES in S**13**), the ECU **128** executes a deceleration process in step S**14** and executes a turning preparation process in step S**15**.

[0070] The deceleration process is a process of decelerating the vehicle **10** so that the vehicle speed V will become equal to a target curve-turning vehicle speed Vcvtar when the vehicle **10** reaches the start point Pin. The target curve-turning vehicle speed Vcvtar is a target value of the vehicle speed V calculated on the basis of the radius R of the curve **304** and the speed limit. As for the deceleration process, the ECU **128** sets a target deceleration Dtar from a relation between the distance L**1** to the start point Pin and the vehicle speed V, and decelerates the vehicle **10** so that the actual deceleration D (absolute value) becomes equal to or greater than a target deceleration Dtar (absolute value). To decelerate the vehicle **10**, the ECU **128** uses a friction brake apparatus (not shown) (and/or engine brake and/or regenerative brake).

[0071] Furthermore, in the deceleration process, the ECU **128** may cause generation of a counterforce to an accelerator pedal (not shown) (pedal counterforce) in order to notify the driver of a deceleration timing. Note that the occurrence of positive decelerations D from time t**1** to t**3** in FIG. **4**, from time t**11** to t**13** in FIG. **5**, from time t**21** to t**23** in FIG. **6** are results of the deceleration process but may instead be caused by the driver's spontaneous operation.

[0072] In addition, in the deceleration process, when the driver does not perform deceleration operation or the deceleration operation performed by the driver is not sufficient, automatic brake may be engaged.

[0073] The turning preparation process in step S**15** is a process that the vehicle **10** performs before starting to turn. Details of the turning preparation process will be described with reference to FIG. **7**.

[0074] In step S**16**, the ECU **128** determines whether a turning support starting condition has been satisfied. Examples of the turning support starting condition that can be used include a condition that the driver has operated the steering wheel **20**, a condition that the vehicle **10** has reached the start point Pin of the curve **304**, a condition that the vehicle **10** has reached a predetermined distance set with reference to the start point Pin.

[0075] When the turning support starting condition is not satisfied (NO in S**16**), steps S**14** and S**15** are repeated. When the turning support starting condition is satisfied (YES in S**16**), the process proceeds to step S**17**.

[0076] In step S**17**, the ECU **128** executes a turning support process of assisting in the turning of the vehicle **10** along the curve **304** (at time t**4** in FIG. **4**, time t**14** in FIG. **5**, and time t**24** in FIG. **6**). Details of the turning support process will be described later with reference to FIG. **8**.

[0077] Subsequently, in step S**18**, the ECU **128** detects the end point Pout (exit) of the curve **304** by using front images if from the image information Ic. Specifically, the ECU **128** performs edge detection within the front images If to detect the lane lines **308**. Then, the ECU **128** calculates tangent lines to the lane lines **308**, and detects as the end point Pout of the curve **304** a point where the slope of a tangent line to the lane lines **308** becomes equal to or less than a second angle threshold value.

[0078] In step S**19**, the ECU **128** determines whether the vehicle **10** has come near the end point Pout of the curve **304**. Concretely, the ECU **128** determines whether the distance L**2** to the end point Pout has become equal to or less than a distance threshold value THl**2**. When the end point Pout is not near (NO in S**19**), the process returns to step S**17**. When the end point Pout is near (YES in S**19**), the process proceeds to step S**20**.

[0079] In step S**20**, the ECU **128** executes an exit process for exiting the curve **304**. In the exit process, the ECU **128** reduces the steering assist force Fm (the vehicle travel support force Fda) so that the vehicle turning support process ends at the end point Pout of the curve **304** detected on the basis of the image information Ic (front images If). Thus, it becomes possible to end the vehicle turning support for the curve **304** which uses information about the radius R included in the map information Imap in accordance with the end point Pout of the curve **304** detected on the basis of the image information Ic. Therefore, the vehicle turning support process can be ended with high accuracy.

A2-3-2. Turning Preparation Process

[0080] FIG. **7** is a flowchart of the turning preparation process in the embodiment (illustrating details of step S**15** in FIG. **3**). As in the foregoing, the turning preparation process is a process that is performed before the vehicle **10** starts turning (or before the driver starts operating the steering wheel **20**).

[0081] In step S**31** in FIG. **7**, the vehicle travel support ECU **128** determines whether there has been an operation performed on the steering wheel **20** by the driver in order to turn the curve **304**. When there has been an operation performed on the steering wheel **20** by the driver (YES in S**31**), the ECU **128** ends the present process. If there has not been an operation on the steering wheel **20** by the driver (NO in S**31**), the ECU **128** proceeds to step S**32**.

[0082] In step S**32**, the ECU **128** determines whether the vehicle **10** has reached the start point Pin (entrance) of the curve **304**. If the vehicle **10** has not reached the start point Pin (NO in S**32**), the process returns to step S**31**. If the vehicle **10** has reached the start point Pin (YES in S**32**), it means that the driver has not operated the steering wheel **20** although the driver ought to have started operating the steering wheel **20**. In this case, the process proceeds to step S**33**.

[0083] In step S**33**, the ECU **128** executes a leading assist process of prompting the driver to operate the steering wheel **20**. In the leading assist process, the motor **28** is operated even when the driver has not operated the steering wheel **20**. This

causes the vehicle **10** to gently generate the steering assist force Fm (the vehicle travel support force Fda) (during the period from t**24** to t**25** in FIG. **6**).

[0084] In step S**34**, the ECU **128** determines whether there is possibility of the vehicle **10** departing from the lane lines **308**. This determination is performed on the basis of, for example, the slope of the movement track of the vehicle **10** relative to the lane lines **308**, the vehicle speed V, etc.

[0085] If there is a possibility of the vehicle **10** departing from the lane lines **308** (YES in S**34**), the ECU **128** executes in step S**35** a lane departure avoiding process for avoiding departure of the vehicle **10** from the lane lines **308**. In the lane departure avoiding process, the ECU **128** sets a correction current Icor that generates a steering assist force Fm needed in order to avoid departure from the lane lines **308**.

[0086] Referring back to step S**34**, if there is not a possibility of the vehicle **10** departing from the lane lines **308** (NO in S**34**), the ECU **128** determines in step S**36** whether there is an operation of the steering wheel **20** performed by the driver. If there is no operation of the steering wheel **20** performed by the driver (NO in S**36**), the process returns to step S**34**. If there has been an operation of the steering wheel **20** performed by the driver (YES in S**36**), it means that the turning support starting condition has been satisfied, so that the ECU **128** ends the present execution of the turning preparation process.

A2-3-3. Vehicle Turning Support Process

[0087] FIG. **8** is a flowchart of the vehicle turning support process in the embodiment (illustrating details of step S**17** in FIG. **3**). As in the foregoing, the turning support process is a process of assisting in the turning of the vehicle **10** along the curve **304**.

[0088] In step S**41**, the ECU **128** determines whether the current switching process that is executed stepwise in step S**47** described below has been completed. Details of the current switching process will be described later in conjunction with step S**47**.

[0089] When the current switching process is not completed (NO in S**41**), the ECU **128** calculates in step S**42** the target yaw rate Ytar on the basis of the curve radius R contained in the map information Imap and the vehicle speed V from the vehicle speed sensor **32**. Concretely, the value obtained by dividing the vehicle speed V by the radius R is set as the target yaw rate Ytar (Ytar=V/R).

[0090] In step S**43**, the ECU **128** calculates the reference motor current Imref on the basis of the target yaw rate Ytar. The reference motor current Imref is a current necessary to generate the steering assist force Fm (the vehicle travel support force Fda) necessary to achieve the target yaw rate Ytar (from time t**2** to t**5** in FIG. **4**, from time t**12** to t**16** in FIG. **5**, and from time t**22** to t**26** in FIG. **6**). The greater the target yaw rate Ytar (absolute value), the greater the reference motor current Imref is made. The reference motor current Imref can be set by using a map (reference motor current map) (not shown) that is stored in the storage portion **144**.

[0091] In step S**44**, the ECU **128** calculates the correction factor α on the basis of the curve radius R and the steering angle θstr. The correction factor α is a factor for reflecting effects of the curve radius R and the steering angle θstr in the target yaw rate Ytar. For example, the smaller the curve radius R is (the sharper the curve **304** is), the greater the correction factor α is made. Furthermore, the greater the steering angle θstr is, the greater the correction factor α is made. The correction factor α can be set by using a map (correction factor map) (not shown).

[0092] In step S**45**, the ECU **128** calculates a first reference curve current I**1**cvref by multiplying the reference motor current Imref by the correction factor α (I**1**cvref←Imref×α). Note that since the first reference curve current I**1**cvref is used immediately after the turning support starting condition is satisfied (YES in S**16** in FIG. **3**), the calculation of the first reference curve current I**1**cvref may be included in the turning preparation process (FIG. **7**) as a part of the process (e.g., between steps S**31** and S**32**).

[0093] In step S**46**, the ECU **128** determines whether the vehicle yaw rate Yr is equal to or greater than the target yaw rate Ytar. When the vehicle yaw rate Yr is equal to or greater than the target yaw rate Ytar (YES in S**46**), the ECU **128** executes an electric current switching process in step S**47**. The current switching process a process of switching from the first reference curve current I**1**cvref to a second reference curve current I**2**cvref stepwise. Note that if the lateral acceleration G is used instead of the vehicle yaw rate Yr, the lateral acceleration G is compared with a target lateral acceleration Gtar.

[0094] In step S**48**, the ECU **128** calculates the second reference curve current I**2**cvref on the basis of the vehicle yaw rate Yr and the like. Specifically, during the switching from the target vaw rate Ytar to the vehicle yaw rate Yr in the current switching process (S**47**), the ECU **128** calculates the second reference curve current I**2**cvref by using a value for the switching. When the current switching process (S**47**) has been completed, the ECU **128** calculates the second reference curve current I**2**cvref on the basis of the vehicle yaw rate Yr.

[0095] The second reference curve current I**2**cvref is a current necessary to generate the steering assist force Fm (the vehicle travel support force Fda) that accords with the vehicle yaw rate Yr and the like. The greater the vehicle yaw rate Yr (absolute value) and the like, the greater the second reference curve current I**2**cvref is made. The second reference curve current I**2**cvref can be set by using a map (second reference curve current map) (not shown) that is stored in the storage portion **144**.

[0096] In step S**49**, the ECU **128** sets the second reference curve current I**2**cvref as a correction current Icor.

[0097] Referring back to step S**46**, when the vehicle yaw rate Yr is not equal to or greater than the target yaw rate Ytar (NO in S**46**), the ECU **128** sets, in step S**50**, the first reference curve current I**1**cvref as the correction current Icor.

A3. Effects of the Embodiment

[0098] As described above, according to this embodiment, the deceleration process prior to the entry to the curve **304** (a deceleration support in S**14** in FIG. **3**) and the turning preparation process (a turning support in S**15**) are performed on the basis of the start point Pin of the curve **304** (FIGS. **4** to **6**) detected on the basis of front images If taken by the camera **120** (the image pickup apparatus), and the vehicle turning support process (a turning support in S**17**) for turning the curve **304** is performed by using the information on the radius R of the curve **304** contained in the map information Imap. This makes it possible to perform a suitable deceleration support and a suitable vehicle turning support with reference to the start point Pin of the curve **304** detected with highly accuracy by using the front images If and perform a highly accurate vehicle turning support for the curve **304** based on

the map information Imap. Therefore, this embodiment can be suitably used, for example, in the case where portions of the lane lines **308** of the curve **304** are not clear or the case where the radius R of the curve **304** is so small that the radius R cannot be highly accurately detected merely from the image information ic.

[0099] There are cases where the present position Pc detected by the GPS antenna **122** and the map information provision apparatus **124** has an error and use of the present position Pc and the map information Imap combined will result in an erroneous deviation of the start point Pin of the curve **304** (see the map information from time t**15** to t**17** in FIG. **5**). In this embodiment, the start point Pin of the curve **304** is detected on the basis of the front images If, so that the vehicle turning support process can be started at an appropriate timing.

[0100] In addition, by performing the vehicle turning support in accordance with the shape of the curve **304**, it becomes possible to inhibit a phenomenon in which the steering torque Tstr that needs to be applied differs between the time of turning the steering wheel **20** and the time of returning the steering wheel **20** as in the common power steering characteristic (i.e., a characteristic based on the target reference current Iref). Therefore, it becomes easy to maintain or correct the steering angle during the turning along the curve **304**. Incidentally, a reason why turning the steering wheel **20** and returning the steering wheel **20** require different steering torques Tstr is that self-aligning torque occurs when the vehicle **10** turns. Due to the self-aligning torque, returning the steering wheel **20** requires less steering torque Tstr than turning the steering wheel **20**.

[0101] In this embodiment, the vehicle travel support ECU **128** (the control apparatus) starts the vehicle turning support (S**17** in FIG. **3**) for the curve **304** which uses the radius R of the curve **304**, when the driver has operated the steering wheel **20** (YES in S**16** in FIG. **3** and YES in S**36** in FIG. **7**). Thus, it becomes possible to perform a vehicle turning support in which the driver's taste is reflected. It also becomes possible to avoid giving the driver a sense of strangeness about the steering assist force Fm.

[0102] In the embodiment, the ECU **128** (the control apparatus) computes the first reference curve current I**1**cvref that represents the first steering assist force Fm**1** that is the steering assist force Fm that reflects the target yaw rate Ytar based on the curve radius R and the vehicle speed V and also computes the second reference curve current I**2**cvref that represents the second steering assist force Fm**2** that is the steering assist force Fm that reflects the vehicle speed V and the vehicle yaw rate Yr of the vehicle **10** (S**45** and S**48** in FIG. **8**). After the vehicle turning support based on the first reference curve current I**1**Cvref starts, the reference curve current is changed gradually or stepwise from the first reference curve current I**1**cvref to the second reference curve current I**2**cvref. After that, the vehicle turning support is performed on the basis of the second reference curve current I**2**cvref. Thus, it is possible to achieve a smooth transition from the first steering assist force Fm**1** that reflects the radius R of the curve to the second steering assist force Fm**2** that reflects the vehicle yaw rate Yr.

[0103] In this embodiment, the ECU **128** (the control apparatus) causes the steering assist force Fm (the vehicle travel support force Fda) to be generated with reference to the start point Pin of the curve **304** detected on the basis of front images If (S**33** in FIG. **7**). Thus, even if the driver does not perform steering or the amount of steering performed is small, the steering assist force Fm (the vehicle travel support force Fda) is generated so that the vehicle **10** can smoothly turn the curve **304**.

[0104] In this embodiment, the ECU **128** (the control apparatus), while performing the vehicle turning support (S**17** in FIG. **3**) for the curve **304** by using the information about the radius R of the curve **304** contained in the map information Imap, reduces the steering assist force Fm (the vehicle travel support force Fda) so that the vehicle turning support ends at the end point Pout of the curve **304** detected on the basis of front images if (**820** in FIG. **3**). Thus, the vehicle turning support for the curve **304** which uses the radius R of the curve **304** contained in the map information Imap can be ended in accordance with the end point Pout of the curve **304** detected on the basis of front images If. Therefore, it becomes possible to highly accurately end the vehicle turning support.

[0105] In the embodiment, if, when the vehicle **10** has passed the steering-requiring position set with reference to the start point Pin of the curve **304** contained in the map information Imap while the driver does not operate the steering wheel **20** (YES in S**32** in FIG. **7**), the ECU **128** determines from the front images If that the vehicle **10** has departed or is likely to depart from the lane lines **308** (YES in S**34**), then the ECU **128** (the control apparatus) causes the steering assist force Fm (the vehicle travel support force Fda) to be generated in order to avoid or recover from departure of the vehicle **10** from the lane lines **308**. Thus, in the determination regarding departure of the vehicle **10** from the lane lines **308** based on front images If, the use of the information about the start point Pin of the curve **304** contained in the map information Imap makes it possible to highly accurately determine the need for the lane departure avoidance or recovery process.

[0106] According to the embodiment, while executing the vehicle turning support for the curve **304** by using the curve radius R contained in the map information Imap, the ECU **128** reduces the steering assist force Fm so that the vehicle turning support will end at the end point Pout of the curve **304** detected on the basis of front images If (S**20** in FIG. **3**) Therefore, it becomes possible to perform a highly accurate vehicle turning support for the curve **304** based on the map information Imap and end the vehicle turning support at an appropriate timing with reference to the end point Pout of the curve **304** detected with high accuracy by using front images If.

B. Modifications

[0107] It should be apparent that the present disclosure s not limited to the foregoing embodiment but may adopt various other constructions as well on the basis of what is mentioned in this specification. For example, the following constructions can be adopted.

B1. Objects to Which to Apply the System

[0108] In the foregoing embodiment, the vehicle travel support system **14** (the vehicle travel support apparatus) is mounted on the vehicle **10** (FIG. **1**). However, the application of the vehicle travel support system of this disclosure is not limited to this embodiment, for example, from the point of view that the start point Pin of the curve **304** is detected on the basis of front images If and the radius R of the curve **304** contained in the map information Imap is used to perform the vehicle turning support for the curve **304**. For example, the

present disclosure may also be applied to a mobile object or a motion-capable apparatus equipped with the steering wheel **20** (or an operating element).

B2. EPS Apparatus **12**

B2-1. Overall Construction of EPS Apparatus **12**

[0109] The EPS apparatus **12** in the foregoing embodiment is constructed so that the EPS motor **28** transfers the steering assist force Fm to the steering shaft **42** (i.e., a so-called steering column assist type EP apparatus). However, the construction of the EPS apparatus **12** is not limited to the foregoing construction but may be any construction as long as the construction generates a steering assist force Fm. The EPS apparatus **12** may also be constructed as, for example, any one of a pinion assist type EPS apparatus, a dual pinion assist type EPS apparatus, a rack assist type EPS apparatus, and an electro-hydraulic power steering apparatus. Incidentally, in the electro-hydraulic power steering apparatus, hydraulic pressure is produced by an electric pump and then is used to generate a steering assist force Fm.

[0110] Although the foregoing embodiment adopts a construction in which the steering torque Tstr by the driver is directly transferred to the front wheels **86** (hereinafter, also referred to as "direct transfer method"), the disclosure is also applicable to steer-by-wire type electric power steering apparatuses.

B2-2. EPS Motor **28**

[0111] Although in the foregoing embodiment, the EPS motor **28** is of the three-phase alternating-current brushless type, this is not restrictive. For example, the motor **28** may also be of the three-phase alternating-current brush type, the single-phase alternating-current type, or the direct-current type.

[0112] In the foregoing embodiment, the motor **28** is supplied with electric power from the low-voltage battery **38** (FIG. **1**). In addition to or instead of this, an alternator, a fuel cell battery, or a high voltage battery may also be used to supply electric power to the motor **28**.

B2-3. EPS ECU **36**

[0113] The foregoing embodiment has been described on the assumption that the ECU **36** is mounted in the vehicle **10** (FIG. **1**). However, the ECU **36** may be constructed by providing a portion of the ECU **36** in a portable terminal and connecting the portable terminal to a network to which the vehicle **10** is connected. The same may be applied to the vehicle travel support ECU **128**.

B3. Vehicle Travel Support System **14** (Vehicle Travel Support Apparatus)

[0114] In the foregoing embodiment, a portion of the steering force (the steering torque Tstr) needed for the turning along the curve **304** is generated by the vehicle travel support system **14**. However, this is not restrictive, for example, from the point of view that the start point Pin of the curve **304** is detected on the basis of front images If and the radius R of the curve **304** contained in the map information Imap is used to perform the vehicle turning support for the curve **304**. For example, the vehicle travel support system **14** may also generate the whole steering force (steering torque Tstr) needed for the turning along the curve **304** (i.e., may perform fully automatic driving).

[0115] The foregoing embodiment has been described on the assumption that the vehicle travel support system **14** is mounted in the vehicle **10** (FIG. **1**). However, the vehicle travel support system **14** may also be constructed by providing a portion of the vehicle travel support system **14** (the vehicle travel support ECU **128** and the like) in a portable terminal and connecting the portable terminal to a network to which the vehicle **10** is connected.

[0116] In the foregoing embodiment, the EPS apparatus **12** and the vehicle travel support system **14** are separate components (FIG. **1**). However, for example, from the point of view that the vehicle turning support for the curve **304** is performed by using the radius R of the curve **304** which is contained in the map information Imap, the functions of the vehicle travel support system **14** may be included in the EPS apparatus **12**. Alternatively, the functions of the EPS apparatus **12** may be included in the vehicle travel support system **14**.

[0117] The foregoing embodiment has been described on the assumption that the GPS antenna **122** and the map information provision apparatus **124** are mounted in the vehicle **10**. However, for example, the GPS antenna **122** and the map information provision apparatus **124** may be partially or entirely provided in a portable terminal and the portable terminal may be connected to a network to which the vehicle **10** is connected.

B4. Steering Assist Control (FIG. **2**)

B4-1. Steering Assist Force Fm

[0118] In the steering assist control in the foregoing embodiment, the steering assist force Fm is a drive force (torque) in the same direction as the steering torque Tstr provided by the driver. However, this is not restrictive. For example, from the point of view of supporting the steering via the steering wheel **20**, the steering assist force Fm may be a force that acts in the opposite direction to the steering torque Tstr (e.g., may be a counterforce).

[0119] The term "supporting the steering via the steering wheel **20**" herein includes both making it easy for the driver to turn the steering wheel **20** in a direction in which the driver intends to (e.g., an operation as described in conjunction with the foregoing embodiment) and making it less easy for the driver to turn the steering wheel **20** in a direction in which the driver intends to as long as the EPS apparatus **12** is configured to directly transfer the steering torque Tstr to steering road wheels (the front wheels **86**) (i.e., as long as the EPS apparatus **12** adopts a direct transfer method).

B4-2. Leading Assist Process

[0120] In the foregoing embodiment, the leading assist process of generating the steering assist force Fm (the vehicle travel support force Fda) before the driver starts operating the steering wheel **20** is performed after the vehicle **10** reaches the start point Pin of the curve **304** (YES in S**32** followed by S**33** in FIG. **7**). However, this is not restrictive, for example, from the point of view that the vehicle turning support for the curve **304** is performed by using the radius R of the curve **304** contained in the map information Imap. For example, the ECU **128** may cause the steering assist force Fm (the vehicle travel support force Fda) to be generated before the vehicle **10**

enters the curve **304**. This makes it possible to notify the driver in advance that the vehicle turning support will be performed for the curve **304**.

[0121] In this case, the ECU **128** may determine delay of the actual timing of the driver's steering from the reference steering timing that is the steering timing set with reference to the start point Pin of the curve **304**. Furthermore, the ECU **128** may advance the timing of starting the steering assist force Fm (the vehicle travel support force Fda) prior to entry to the curve **304** according to the delay of the actual steering timing. Therefore, the timing of starting the steering assist force Fm (the vehicle travel support force Fda) prior to entry to the curve **304** can be adjusted according to the skill of the driver.

Although a specific form of embodiment has been described above and illustrated in the accompanying drawings in order to be more clearly understood, the above description is made by way of example and not as limiting the scope of the invention defined by the accompanying claims. The scope of the invention is to be determined by the accompanying claims. Various modifications apparent to one of ordinary skill in the art could be made without departing from the scope of the invention. The accompanying claims cover such modifications.

We claim:

1. A vehicle travel support system comprising:
- an image pickup apparatus that acquires a front image of a view ahead of a vehicle;
- a lane detection apparatus that detects a lane indicated on a travel path of the vehicle in the front image acquired by the image pickup apparatus;
- a position detection apparatus that detects a present position of the vehicle;
- a map information storage apparatus that stores map information;
- an actuator that generates a steering assist force; and
- a control apparatus that assists in keeping the vehicle in the lane or avoiding departure of the vehicle from the lane by causing the actuator to generate the steering assist force, wherein
- the control apparatus
- estimates subsequent travel path of the vehicle using the present position of the vehicle and the map information,
- acquires, regarding a curve included in the estimated travel path, a curve radius contained in the map information from the map information storage apparatus,
- detects a start point of the curve using the front image and performs at least one of a vehicle turning support and a deceleration support prior to entry to the curve, based on the detected start point of the curve, and
- performs the vehicle turning support for the curve by using the curve radius contained in the map information.

2. The vehicle travel support system according to claim **1**, wherein the control apparatus starts the vehicle turning support for the curve which uses the curve radius, when steering is performed by a driver of the vehicle.

3. The vehicle travel support system according to claim **2**, wherein
- the control apparatus
- computes a first steering assist force and a second steering assist force, the first steering assist force being a steering assist force that reflects at least one of a target yaw rate and a target lateral acceleration that are determined based on the curve radius and vehicle speed, and the second steering assist force being a steering assist force that reflects the vehicle speed and at least one of vehicle yaw rate and lateral acceleration, and
- starts the vehicle turning support based on the first steering assist force, subsequently changes the steering assist force gradually or stepwise from the first steering assist force to the second steering assist force, and then performs the vehicle turning support using the second steering assist force.

4. The vehicle travel support system according to claim **1**, wherein the control apparatus causes the steering assist force to be generated by using as a reference the start point of the curve which is detected based on the front image.

5. The vehicle travel support system according to claim **1**, wherein the control apparatus, while performing the vehicle turning support for the curve by using the curve radius contained in the map information, detects an end point of the curve using the front image and reduces the steering assist force so that the vehicle turning support ends at the detected end point of the curve.

6. A vehicle travel support system comprising:
- a position detection apparatus that detects a present position of a vehicle;
- a map information storage apparatus that stores map information;
- an actuator that generates a steering assist force; and
- a control apparatus that assists in keeping the vehicle in a lane or avoiding departure of the vehicle from the lane by causing the actuator to generate the steering assist force,
- the control apparatus
- estimates a travel path of the vehicle using the present position of the vehicle and the map information,
- acquires, regarding a curve included in the estimated travel path, a curve radius contained in the map information from the map information storage apparatus,
- determines an electric current that maintains at least one of a vehicle yaw rate and a lateral acceleration that currently occur on the vehicle, and performs at least one of a deceleration support and a vehicle turning support based on the determined current, and
- performs the vehicle turning support for the curve by using the curve radius contained in the map information.

7. The vehicle travel support system according to claim **1**, the control apparatus causes the steering assist force to be generated before the vehicle enters the curve.

8. The vehicle travel support system according to claim **6**, the control apparatus causes the steering assist force to be generated before the vehicle enters the curve.

9. The vehicle travel support system according claim **7**, wherein
- the control apparatus
- determines a delay of an actual steering timing at which steering is performed by a driver of the vehicle from a reference steering timing that is a steering timing set with reference to the start point of the curve, and
- advances a start timing of generating the steering assist force prior to entry to the curve, according to the delay of the actual steering timing.

10. The vehicle travel support system according to claim **2**, wherein if, the vehicle has passed a steering-requiring position set with reference to the start point of the curve contained in the map information while the driver does not operate the steering wheel, the control apparatus determines from the front image that there is departure of the vehicle from the lane or possibility of departure of the vehicle from the lane, then

the control apparatus causes the steering assist force to be generated in order to avoid or recover from departure of the vehicle from the lane.

11. A vehicle travel support method that uses a vehicle travel support system that includes

an image pickup apparatus that acquires a front image of a view ahead of a vehicle;

a lane detection apparatus that detects a lane indicated on a travel path of the vehicle in the front image acquired by the image pickup apparatus;

a position detection apparatus that detects a present position of the vehicle;

a map information storage apparatus that stores map information;

an actuator that generates a steering assist force; and

a control apparatus that assists in keeping the vehicle in the lane or avoiding departure of the vehicle from the lane by causing the actuator to generate the steering assist force, wherein

the vehicle travel support method comprising causing the control apparatus to

estimate subsequent travel path of the vehicle using the present position of the vehicle and the map information,

acquire, regarding a curve included in the estimated travel path, a curve radius contained in the map information from the map information storage apparatus,

detect a start point of the curve using the front image and perform a vehicle turning support or a deceleration support prior to entry to the curve, based on the detected start point of the curve, and

perform the vehicle turning support for the curve by using the curve radius contained in the map information, when steering is performed by a driver of the vehicle.

12. A vehicle travel support method that uses a vehicle travel support system that includes

an image pickup apparatus that acquires a front image of a view ahead of a vehicle;

a lane detection apparatus that detects a lane indicated on a travel path of the vehicle in the front image acquired by the image pickup apparatus;

a position detection apparatus that detects a present position of the vehicle;

a map information storage apparatus that stores map information;

an actuator that generates a steering assist force; and

a control apparatus that assists in keeping the vehicle in the lane or avoiding departure of the vehicle from the lane by causing the actuator to generate the steering assist force, wherein

the vehicle travel support method comprising causing the control apparatus to

estimate subsequent travel path of the vehicle using the present position of the vehicle and the map information,

acquire, regarding a curve included in the estimated travel path, a curve radius contained in the map information from the map information storage apparatus, and

while performing the vehicle turning support for the curve by using the curve radius contained in the map information, detect an end point of the curve using the front image and reduce the steering assist force so that the vehicle turning support ends at the detected end point of the curve.

13. The vehicle travel support system according to claim **6**, wherein the actuator is driven by the electric current, and the control apparatus provides the electric current to the actuator to maintain the at least one of the vehicle yaw rate and the lateral acceleration that currently occur on the vehicle.

14. The vehicle travel support system according to claim **3**, wherein the second steering assist force reflects at least one of actual vehicle yaw rate and actual lateral acceleration.

15. A vehicle comprising the vehicle travel support system according to claim **1**.

16. A portable terminal comprising the vehicle travel support system according to claim **1**.

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