## VEHICLE CONTROL DEVICE, VEHICLE CONTROL METHOD, AND STORAGE MEDIUM

## Abstract

A vehicle control device that controls traveling of a vehicle at a roundabout in which a plurality of connected roads is connected to a circular road, acquires a traveling route of the vehicle including an exit road that is a connected road to which the vehicle is to exit from the circular road, acquires speed limits of the circular road and the exit road, calculates a target vehicle speed when the vehicle exits to the exit road from the circular road based on the speed limits, calculates an acceleration necessary period or an acceleration necessary distance necessary for accelerating the vehicle to the target vehicle speed based on current vehicle speed of the vehicle traveling on the circular road and the target vehicle speed, and starts acceleration control of accelerating the vehicle at predetermined acceleration when the calculated acceleration necessary period or acceleration necessary distance satisfies a predetermined start condition.

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## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION
[0001] This application claims priority to Japanese Patent Application No. 2024-023378 filed on Feb. 20, 2024, incorporated herein by reference in its entirety.
BACKGROUND
1. Technical Field
[0002] The present disclosure relates to a vehicle control device, a vehicle control method, and a storage medium.
2. Description of Related Art
[0003] For example, Japanese Unexamined Patent Application Publication No. 2017-088161 discloses a technique of, in a vehicle including a control device capable of executing adaptive cruise control (ACC), accelerating the vehicle during exit from a roundabout (traffic circle) while keeping substantially constant speed of the vehicle between entry of the roundabout and change in direction to exit from the roundabout.
SUMMARY
[0004] With the technique of JP 2017-088161 A, it is determined whether the vehicle will exit from a roundabout based on traveling dynamics quantity (a yaw rate or a steering angle). Thus, for example, when the vehicle changes a lane during traveling in the roundabout, it may be erroneously determined that the vehicle will exit from the roundabout, which may cause unnecessary acceleration. Further, with the technique of JP 2017-088161 A, target vehicle speed set in ACC is used as target vehicle speed to which the vehicle is to be accelerated. Thus, if it is erroneously determined that the vehicle will exit from the roundabout early, the vehicle may also be accelerated exceeding a speed limit in the roundabout.
[0005] The present disclosure has been made to solve the above problem and is directed to effectively prevent unnecessary acceleration when a vehicle exits from a roundabout.
[0006] A vehicle control device of the present disclosure is a vehicle control device that controls traveling of a vehicle at a roundabout in which a plurality of connected roads is connected to a circular road, wherein the vehicle control device [0007] acquires a traveling route of the vehicle including the circular road and an exit road that is a connected road to which the vehicle is to exit from the circular road among a plurality of the connected roads, [0008] acquires speed limits of the circular road and the exit road, [0009] calculates a target vehicle speed when the vehicle exits from the circular road to the exit road based on the speed limits, [0010] calculates an acceleration necessary period or an acceleration necessary distance necessary for accelerating the vehicle to the target vehicle speed based on current vehicle speed of the vehicle that is traveling on the circular road and the target vehicle speed, and [0011] starts acceleration control of accelerating the vehicle at predetermined acceleration when the calculated acceleration necessary period or the calculated acceleration necessary distance satisfies a predetermined start condition.

## Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0012] Features, advantages, and technical and industrial significance of exemplary embodiments

of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

[0013] FIG. **1** is a schematic view illustrating a hardware configuration of a vehicle according to the present embodiment;

[0014] FIG. **2** is a schematic view illustrating a software configuration of a control device according to the present embodiment;

[0015] FIG. **3** is a schematic view for explaining acceleration control according to the present embodiment; and

[0016] FIG. **4** is a flowchart for explaining a routine of processing of the acceleration control according the present embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

[0017] A vehicle control device according to the present embodiment will be described below with reference to the drawings.

Hardware Configuration

[0018] FIG. **1** is a schematic view illustrating a hardware configuration of a vehicle VH according to the present embodiment. Hereinafter, the vehicle VH will be sometimes referred to as an own vehicle when it is necessary to distinguish the vehicle from other vehicles, and the like.

[0019] The vehicle VH includes an electronic control unit (ECU) **10**. The ECU **10** includes a central processing unit (CPU) **11**, a read only memory (ROM) **12**, a random access memory (RAM) **13**, an interface device **14**, and the like. The CPU **11** is a processor that executes various kinds of programs stored in the ROM **12**. The ROM **12**, which is a non-volatile memory (storage medium), stores data, and the like, necessary for the CPU **11** to execute various kinds of programs. The RAM **13**, which is a volatile memory, provides a work area to which various kinds of programs are loaded when the various kinds of programs are executed by the CPU **11**. The interface device **14** is a communication device for communicating with an external device.

[0020] The ECU **10** is a device that is a center of performing driver assistance such as ACC. The driver assistance is a concept including autonomous driving. To the ECU **10**, a drive device **20**, a steering device **21**, a braking device **22**, an internal sensor device **30**, an external sensor device **40**, a position information acquisition device **60**, a map database **70**, a communication device **80**, and the like, are communicably connected.

[0021] The drive device **20** generates driving force to be transmitted to a drive wheel of the vehicle VH. Examples of the drive device **20** can include an electric motor and an engine. In the present device, the vehicle VH may be any of a hybrid electric vehicle (HEV), a plug-in hybrid electric vehicle (PHEV), a fuel cell electric vehicle (FCEV), a battery electric vehicle (BEV) or an engine vehicle. The steering device **21** provides steering force to wheels of the vehicle VH. The braking device **22** provides braking force to the wheels of the vehicle VH.

[0022] The internal sensor device **30** includes sensors that acquire states of the vehicle VH. The internal sensor device **30** includes a vehicle speed sensor **31**, an accelerator sensor **32**, a brake sensor **33**, a steering angle sensor **34**, a yaw rate sensor **35**, an acceleration sensor **36**, and the like.

[0023] The vehicle speed sensor **31** detects traveling speed (vehicle speed Vs) of the vehicle VH. The accelerator sensor **32** detects an operation amount of an accelerator pedal (not illustrated) by a driver. The brake sensor **33** detects an operation amount of a brake pedal (not illustrated) by the driver. The steering angle sensor **34** detects a rotation angle (steering angle) of a steering wheel or a steering shaft (not illustrated). The yaw rate sensor **35** detects a yaw rate of the vehicle VH. The acceleration sensor **36** detects acceleration of the vehicle VH. The internal sensor device **30** transmits to the ECU **10**, states of the vehicle VH detected by the respective sensors **31** to **36** at predetermined intervals.

[0024] The external sensor device **40** includes sensors that recognize object information regarding an object around the vehicle VH. The external sensor device **40** includes a radar sensor **41**, a camera sensor **42**, and the like. Here, examples of the object information can include a peripheral

vehicle, a white line of a road, and a road sign.

[0025] The radar sensor **41** detects an object existing around the vehicle VH. The radar sensor **41** includes a millimeter-wave radar, and/or a lidar. The millimeter-wave radar radiates a radio wave in a millimeter-wave band and receives a millimeter wave reflected by an object existing within a radiation range. The millimeter-wave radar acquires a relative distance, relative speed, and the like, between the vehicle VH and the object based on a phase difference between the transmitted millimeter wave and the received reflected wave, an attenuation level of the reflected wave, a period from when the millimeter wave is transmitted until when the reflected wave is received, and the like. The lidar acquires a shape of an object detected around the vehicle VH, a relative distance, relative speed, and the like, between the vehicle VH and the object by sequentially performing scanning with pulsed laser light having a shorter wavelength than a wavelength of a millimeter wave toward a plurality of directions and receiving reflected light reflected by the object.

[0026] The camera sensor **42** captures an image of a circumference of the vehicle VH and processes the captured image data to thereby acquire object information around the vehicle VH. As the camera sensor **42**, for example, a digital camera having an imaging element such as a CMOS and a CCD can be used. The object information is information representing a type of an object detected around the vehicle VH, a relative distance, relative speed, and the like, between the vehicle VH and the object. It is only necessary to recognize the type of the object through, for example, machine learning such as pattern matching.

[0027] The external sensor device **40** repeatedly transmits the acquired object information to the ECU **10** every time a predetermined period elapses. Note that the external sensor device **40** does not necessarily have to include both the radar sensor **41** and the camera sensor **42** and may include, for example, only the radar sensor **41** or only the camera sensor **42**.

[0028] The position information acquisition device **60** acquires current position information of the vehicle VH. As the position information acquisition device **60**, for example, a global positioning system (GPS), a global navigation satellite system (GNSS), and the like, provided in a navigation system (not illustrated) can be used. The position information acquisition device **60** transmits the acquired current position information of the vehicle VH to the ECU **10** at predetermined intervals.

[0029] The map database **70**, which is a database of map information, is stored in a storage device (such as a hard disk and a flash memory) provided in the vehicle VH. The map information includes a position of an intersection on a road, and the like. Note that the map database **70** may be stored in an external server that can communicate with the vehicle VH. In this case, the vehicle VH only requires to acquire the map information from the external server through the communication device **80**.

[0030] The communication device **80** performs V2X communication. Specifically, the communication device **80** performs vehicle to infrastructure (V2I) communication between the own vehicle VH and an infrastructure. The communication device **80** can acquire information around the own vehicle VH through the V2X communication. Examples of the information around the own vehicle VH can include a position of an intersection, and the like. The communication device **80** transmits the acquired information around the own vehicle VH to the ECU **10** at predetermined intervals.

Software Configuration

[0031] FIG. **2** is a schematic view illustrating a software configuration of a control device according to the present embodiment.

[0032] As illustrated in FIG. **2**, the ECU **10** includes an ACC control unit **100**, a roundabout traveling determination unit **110**, an exit road determination unit **120**, a speed limit acquisition unit **130**, an acceleration control unit **140**, and the like, as functional components. These functional components **100** to **140** are implemented by the CPU **11** of the ECU **10** reading programs stored in the ROM **12** to the RAM **13** and executing the programs. Note that all or some of the functional components **100** to **140** may be provided in other ECUs different from the ECU **10** or an

information processing device in a facility (such as a management center) that can communicate with the vehicle VH.

[0033] The ACC control unit **100** executes ACC based on set vehicle speed or a set inter-vehicle distance. The ACC is well known, and thus will be simply described below. The ACC includes two types of control of constant-speed traveling control and following traveling control. The constant-speed traveling control is control for causing the vehicle VH to travel at constant speed in accordance with the set vehicle speed. The following traveling control is control for causing the own vehicle VH to follow a preceding vehicle that is traveling ahead of the own vehicle VH such that an inter-vehicle distance between the preceding vehicle and the own vehicle VH becomes a set inter-vehicle distance.

[0034] The ACC control unit **100** detects a preceding vehicle that becomes a following target, ahead of the own vehicle VH based on the detection result of the external sensor device **40**. The ACC control unit **100** executes constant-speed traveling control when a preceding vehicle that becomes a following target does not exist. In this case, the ACC control unit **100** controls actuation of the drive device **20** and the braking device **22** based on target acceleration obtained from deviation between vehicle speed Vs and the set vehicle speed. It is only necessary to acquire the vehicle speed Vs based on the detection result of the vehicle speed sensor **31**. On the other hand, when a preceding vehicle that becomes a following target exists ahead of the own vehicle VH, the ACC control unit **100** executes following traveling control. In this case, the ACC control unit **100** controls actuation of the drive device **20** and the braking device **22** based on target acceleration obtained from deviation between an actual inter-vehicle distance and the set inter-vehicle distance. It is only necessary to acquire the inter-vehicle distance between the own vehicle VH and the preceding vehicle based on the detection result of the external sensor device **40**.

[0035] The roundabout traveling determination unit **110** determines whether the vehicle VH is traveling at a roundabout during execution of the ACC by the ACC control unit **100**. Here, the roundabout refers to an intersection at which a plurality of roads is connected to a circular road and is also referred to as a traffic circle. Hereinafter, roads connected to the circular road will be referred to as "connected roads". The roundabout traveling determination unit **110** executes determination as to whether the vehicle VH is traveling on the circular road of the roundabout in a state where the map information in the map database **70** is available, and when a traveling route is set by the navigation system. The state where the map information is available refers to a state where at least the position information acquisition device **60** can acquire current position information of the vehicle VH (for example, a state where the vehicle VH is not traveling at a place where a GPS signal cannot be received such as inside a tunnel).

[0036] The roundabout traveling determination unit **110** determines that the vehicle VH is traveling on the circular road of the roundabout when the roundabout exists on the traveling route set by the navigation system, and when the current position information of the vehicle VH acquired by the position information acquisition device **60** substantially coincides with position information of the roundabout acquired based on the map information in the map database **70**. Note that the position information of the roundabout may be acquired based on infrastructure information received by the communication device **80** through V2I communication. Further, when the external sensor device **40** recognizes a road sign, or the like, that indicates a roundabout, it may be determined that the vehicle VH is traveling on the circular road of the roundabout based on the recognition result.

[0037] The exit road determination unit **120** determines a connected road to which the vehicle VH is to exit from the circular road among the plurality of connected roads. Specifically, the exit road determination unit **120** determines the connected road to which the vehicle VH is to exit based on the traveling route set by the navigation system. Note that the technique of the present disclosure does not exclude determination of the connected road to which the vehicle VH is to exit based on driver operation information including blinking of a direction indicator, and the like.

[0038] The speed limit acquisition unit **130** acquires a speed limit of the circular road of the

roundabout (hereinafter, referred to as a circular road speed limit V.sub.R) on which the vehicle VH travels and a speed limit of the connected road (hereinafter, referred to as an after-exit speed limit V.sub.Lim) to which the vehicle VH is to exit from the circular road. Specifically, the speed limit acquisition unit **130** acquires the circular road speed limit V.sub.R and the after-exit speed limit V.sub.Lim based on the map information in the map database **70**. Note that the circular road speed limit V.sub.R and the after-exit speed limit V.sub.Lim may be acquired based on the infrastructure information, and the like, acquired by the communication device **80** through the V2I communication. Further, when the external sensor device **40** recognizes a road sign, or the like, indicating an upper speed limit, the circular road speed limit V.sub.R and the after-exit speed limit V.sub.Lim may be acquired based on the recognition result.

[0039] In the present embodiment, the ACC control unit **100** executes deceleration control of decelerating the vehicle VH when the set vehicle speed of the ACC is higher than the circular road speed limit V.sub.R when the vehicle VH is caused to enter the circular road of the roundabout. Further, the ACC control unit **100** executes acceleration control of accelerating the vehicle VH when the after-exit speed limit V.sub.Lim is higher than the circular road speed limit V.sub.R when the vehicle VH is caused to exit to the connected road from the circular road of the roundabout. Hereinafter, the acceleration control to be executed by the acceleration control unit **140** will be described in detail.

Acceleration Control

[0040] The acceleration control unit **140** executes acceleration control of accelerating the vehicle VH before the vehicle VH exits from the circular road when a preceding vehicle that becomes a following target of the ACC does not exist ahead of the own vehicle VH and when the after-exit speed limit V.sub.Lim is higher than the circular road speed limit V.sub.R while the vehicle VH is traveling on the circular road of the roundabout. FIG. **3** is a schematic view for explaining the acceleration control according to the present embodiment. FIG. **3** illustrates a circular road R**1** on which the vehicle VH is traveling, and a connected road R**2** to which the vehicle VH is to exit. Further, FIG. **3** illustrates a connection portion X between the circular road R**1** and the connected road R**2**, that is, an exit portion.

[0041] When the vehicle VH enters the circular road R**1** (see time to in FIG. **3**), the acceleration control unit **140** calculates exit target vehicle speed V.sub.target that is target vehicle speed when the vehicle VH reaches the exit portion X. As one example, the acceleration control unit **140** calculates the exit target vehicle speed V.sub.target based on a minimum function (Min V.sub.target (V.sub.R, V.sub.Lim)) of the circular road speed limit V.sub.R and the after-exit speed limit V.sub.Lim. When the exit target vehicle speed V.sub.target is obtained, the acceleration control unit **140** calculates a period necessary for accelerating the vehicle VH to the exit target vehicle speed V.sub.target (hereinafter, an acceleration necessary period T.sub.r) when the vehicle VH is accelerated from the current vehicle speed Vs at predetermined acceleration A. The acceleration necessary period Tr can be obtained by dividing a difference between the exit target vehicle speed V.sub.target and the current vehicle speed Vs by the acceleration A (Tr=(V.sub.target−Vs)/A). Further, when the acceleration necessary period Tr is obtained, the acceleration control unit **140** calculates a distance necessary for accelerating the vehicle VH to the exit target vehicle speed V.sub.target from the current vehicle speed Vs (hereinafter, referred to as an acceleration necessary distance Dr). The acceleration necessary distance Dr can be obtained by multiplying a difference between the exit target vehicle speed V.sub.target and the current vehicle speed Vs by the acceleration necessary period Tr (Dr=(V.sub.target−Vs)×Tr).

[0042] The acceleration control unit **140** calculates a period until when the vehicle VH reaches the exit portion X (hereinafter, referred to as a predicted reaching period T) when the vehicle VH travels at the current vehicle speed Vs and a distance until when the vehicle VH reaches the exit portion X from a current position (hereinafter, referred to as a predicted reaching distance D). It is only necessary to acquire the current vehicle speed Vs of the vehicle VH based on the detection

result of the vehicle speed sensor **31** and acquire the current position of the vehicle VH based on the detection result of the position information acquisition device **60**. The position information of the exit portion X may be acquired based on the map information in the map database **70** or may be acquired based on the detection result of the external sensor device **40**.

[0043] The acceleration control unit **140** starts acceleration control of accelerating the vehicle VH at predetermined acceleration A (see time t**1** in FIG. **3**) when an acceleration start condition that satisfies the following first condition and second condition is satisfied.

[0044] First condition: when the acceleration necessary period Tr becomes equal to or longer than the predicted reaching period T (Tr≥T).

[0045] Second condition: when the acceleration necessary distance Dr becomes equal to or less than the predicted reaching distance D (Dr≤D).

[0046] The acceleration control unit **140** ends the acceleration control (see time t**2** in FIG. **3**) when the vehicle speed Vs of the vehicle VH reaches the exit target vehicle speed V.sub.target or an end condition that the driver performs override operation of depressing an accelerator pedal is satisfied after the acceleration control is started as a result of the first condition and the second condition being satisfied. When the acceleration control unit **140** ends the acceleration control, control is restored to normal ACC by the ACC control unit **100** thereafter.

[0047] FIG. **4** is a flowchart for explaining a routine of processing of the acceleration control to be executed by the CPU **11** of the ECU **10**. The present routine is started by execution of the ACC.

[0048] In step S**100**, the ECU **10** determines whether the map information in the map database **70** is available. When the map information is available (Yes), the ECU **10** causes the processing to proceed to step S**110**. On the other hand, when the map information is not available (No), the ECU **10** returns the present routine.

[0049] In step S**110**, the ECU **10** determines whether a traveling route is set by the navigation system. When the traveling route is set by the navigation system (Yes), the ECU **10** causes the processing to proceed to step S**120**. On the other hand, when the traveling route is not set by the navigation system (No), the ECU **10** returns the present routine. Note that order of the processing in step S**100** and the processing in step S**110** is random, and the processing may be performed at the same time.

[0050] In step S**120**, the ECU **10** determines whether the vehicle VH is traveling on a circular road of a roundabout. Specifically, the ECU **10** determines that the vehicle VH is traveling on the circular road of the roundabout when the roundabout exists on the traveling route set by the navigation system, and when the current position information of the vehicle VH acquired by the position information acquisition device **60** substantially coincides with position information of the roundabout acquired based on the map information in the map database **70**. When it is determined that the vehicle VH is traveling on the circular road of the roundabout (Yes), the ECU **10** causes the processing to proceed to step S**130**. On the other hand, when it is determined that the vehicle VH is not traveling on the circular road of the roundabout (No), the ECU **10** returns the present routine.

[0051] In step S**130**, the ECU **10** determines whether a preceding vehicle that becomes a following target exists ahead of the own vehicle VH based on the detection result of the external sensor device **40**. When a preceding vehicle does not exist (No), the ECU **10** causes the processing to proceed to step S**140**. On the other hand, when a preceding vehicle exists (Yes), the ECU **10** returns the present routine.

[0052] In step S**140**, the ECU **10** determines a connected road to which the vehicle VH is to exit from the circular road. Then, in step S**145**, the ECU **10** acquires the circular road speed limit V.sub.R and the after-exit speed limit V.sub.Lim.

[0053] In step S**150**, the ECU **10** calculates the exit target vehicle speed V.sub.target based on a minimum function of the circular road speed limit V.sub.R and the after-exit speed limit V.sub.Lim. Then, in step S**160**, the ECU **10** calculates the acceleration necessary period Tr necessary for accelerating the vehicle VH to the exit target vehicle speed V.sub.target when the vehicle VH is

accelerated at predetermined acceleration A from the current vehicle speed Vs. Further, in step S**165**, the ECU **10** calculates the acceleration necessary distance Dr necessary for accelerating the vehicle VH to the exit target vehicle speed V.sub.target from the current vehicle speed Vs.

[0054] In step S**170**, the ECU **10** determines whether the first condition that the acceleration necessary period Tr becomes equal to or longer than the predicted reaching period T is satisfied. When the first condition is satisfied (Yes), the ECU **10** causes the processing to proceed to step S**175**. On the other hand, when the first condition is not satisfied (No), the ECU **10** returns the processing to step S**170**.

[0055] In step S**175**, the ECU **10** determines whether the second condition that the acceleration necessary distance Dr becomes equal to or less than the predicted reaching distance D is satisfied. When the second condition is satisfied (Yes), the ECU **10** causes the processing to proceed to step S**180**. On the other hand, when the second condition is not satisfied (No), the ECU **10** returns the processing to step S**150**.

[0056] In step S**180**, the ECU **10** executes the acceleration control of accelerating the vehicle VH at predetermined acceleration A. Then, in step S**185**, the ECU **10** determines whether the end condition of the acceleration control is satisfied. When the end condition is satisfied (Yes), specifically, the vehicle speed Vs of the vehicle VH reaches the exit target vehicle speed V.sub.target or when the driver performs override operation of depressing the accelerator pedal, the ECU **10** causes the processing to proceed to step S**190**, ends the acceleration control and returns the present routine. In other words, control is restored to normal ACC. On the other hand, when the end condition is not satisfied (No), the ECU **10** returns the processing to step S**180** and continues the acceleration control.

[0057] According to the present embodiment described in detail above, the ECU **10** determines the connected road R**2** to which the vehicle VH is to exit from the circular road R**1** based on the traveling route set by the navigation system. This can prevent erroneous determination (such as, for example, lane change, or the like, being erroneously determined as exit) that is made when exit determination from the circular road R**1** is made based on a yaw rate, a steering angle, or the like, and can effectively prevent unnecessary acceleration of the vehicle VH in the circular road R**1**.

[0058] Further, the ECU **10** acquires a speed limit of the connected road R**2** (after-exit speed limit V.sub.Lim) to which the vehicle VH is to exit based on the map information in the map database **70** and sets the exit target vehicle speed V.sub.target based on the acquired after-exit speed limit V.sub.Lim. Then, the ECU **10** is configured to calculate the acceleration necessary period Tr and the acceleration necessary distance Dr necessary for the vehicle speed Vs of the vehicle VH to reach the exit target vehicle speed V.sub.target and determine an optimal start timing of the acceleration control based on the calculated acceleration necessary period Tr and acceleration necessary distance Dr. This can effectively prevent the vehicle VH from accelerating exceeding the speed limit in the circular road R**1** while implementing prompt acceleration suited for the sense of the driver when the vehicle VH exits from the circular road R**1**, and can reliably improve safety.

[0059] While the vehicle control device, the vehicle control method, and the storage medium according to the present embodiment have been described above, the present disclosure is not limited to the above embodiment and can be variously modified without deviating from the purpose of the present disclosure. For example, while the ACC has been described as one example in the above embodiment, the technique of the present disclosure can be also applied to a vehicle capable of executing only cruise control or an autonomous driving vehicle in which part or all of driving operation is autonomously performed.

## Claims

**1.** A vehicle control device that controls traveling of a vehicle at a roundabout in which a plurality of connected roads is connected to a circular road, wherein the vehicle control device: acquires a

traveling route of the vehicle including the circular road and an exit road that is a connected road to which the vehicle is to exit from the circular road among a plurality of the connected roads; acquires speed limits of the circular road and the exit road; calculates a target vehicle speed when the vehicle exits from the circular road to the exit road based on the speed limits; calculates an acceleration necessary period or an acceleration necessary distance necessary for accelerating the vehicle to the target vehicle speed based on current vehicle speed of the vehicle that is traveling on the circular road, and the target vehicle speed; and starts acceleration control of accelerating the vehicle at predetermined acceleration when the calculated acceleration necessary period or the calculated acceleration necessary distance satisfies a predetermined start condition.

**2**. The vehicle control device according to claim 1, wherein a predicted reaching period until the vehicle reaches an exit portion that is a connection portion of the circular road and the exit road and a predicted reaching distance until the vehicle reaches the exit portion are calculated, and the start condition is satisfied when the acceleration necessary period becomes equal to or longer than the predicted reaching period or the acceleration necessary distance becomes equal to or less than the predicted reaching distance.

**3**. The vehicle control device according to claim 1, wherein the target vehicle speed is calculated using a minimum function that employs a smaller value between the speed limit of the circular road and the speed limit of the exit road.

**4**. A vehicle control method of controlling traveling of a vehicle at a roundabout in which a plurality of connected roads is connected to a circular road, the vehicle control method comprising: acquiring a traveling route of the vehicle including the circular road and an exit road that is a connected road to which the vehicle is to exit from the circular road among a plurality of the connected roads; acquiring speed limits of the circular road and the exit road; calculating target vehicle speed when the vehicle exits to the exit road from the circular road based on the speed limits; calculating an acceleration necessary period or an acceleration necessary distance necessary for accelerating the vehicle to the target vehicle speed based on current vehicle speed of the vehicle that is traveling on the circular road and the target vehicle speed; and starting acceleration control of accelerating the vehicle at predetermined acceleration when the calculated acceleration necessary period or the calculated acceleration necessary distance satisfies a predetermined start condition.

**5**. A non-transitory storage medium storing a program that causes a computer of a vehicle control device that controls traveling of a vehicle at a roundabout in which a plurality of connected roads is connected to a circular road to execute processing of: acquiring a traveling route of the vehicle including the circular road and an exit road that is a connected road to which the vehicle is to exit from the circular road among a plurality of the connected roads; acquiring speed limits of the circular road and the exit road; calculating target vehicle speed when the vehicle exits to the exit road from the circular road based on the speed limits; calculating an acceleration necessary period or an acceleration necessary distance necessary for accelerating the vehicle to the target vehicle speed based on current vehicle speed of the vehicle that is traveling on the circular road and the target vehicle speed; and starting acceleration control of accelerating the vehicle at predetermined acceleration when the calculated acceleration necessary period or the calculated acceleration necessary distance satisfies a predetermined start condition.