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Oka et al.

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(54) **DRIVING ASSISTANCE DEVICE, DRIVING ASSISTANCE METHOD, AND STORAGE MEDIUM**

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(52) **U.S. Cl.**
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(58) **Field of Classification Search**
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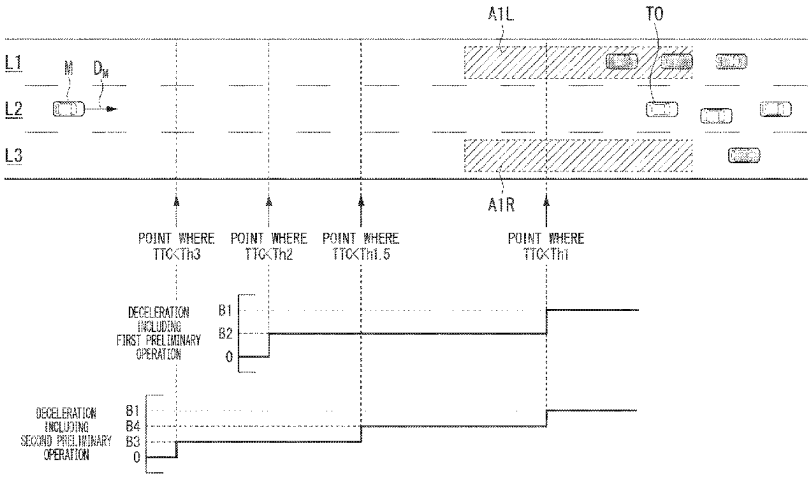
(57) **ABSTRACT**

At least one processor executes a first preliminary operation control process of notifying that an object is present when an indicator value is less than a second threshold and there is a travel path along which the vehicle is able to travel on one of left and right sides of the object and executes a second preliminary operation control process of notifying a driver when the indicator value is less than a third threshold and there is no travel path on both left and right sides of the object. The second preliminary operation or the first preliminary operation is executed when the indicator value is less than the third threshold, there is a travel path along which the vehicle is able to travel, and it is estimated that there is an interfering object in the travel path on the assumption that the vehicle has approached the object.

9 Claims, 11 Drawing Sheets



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B60W 10/20 (2006.01)
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(52) **U.S. Cl.**
CPC *B60W 2554/4041* (2020.02); *B60W 2554/804* (2020.02); *B60W 2710/18* (2013.01); *B60W 2710/20* (2013.01)

(58) **Field of Classification Search**
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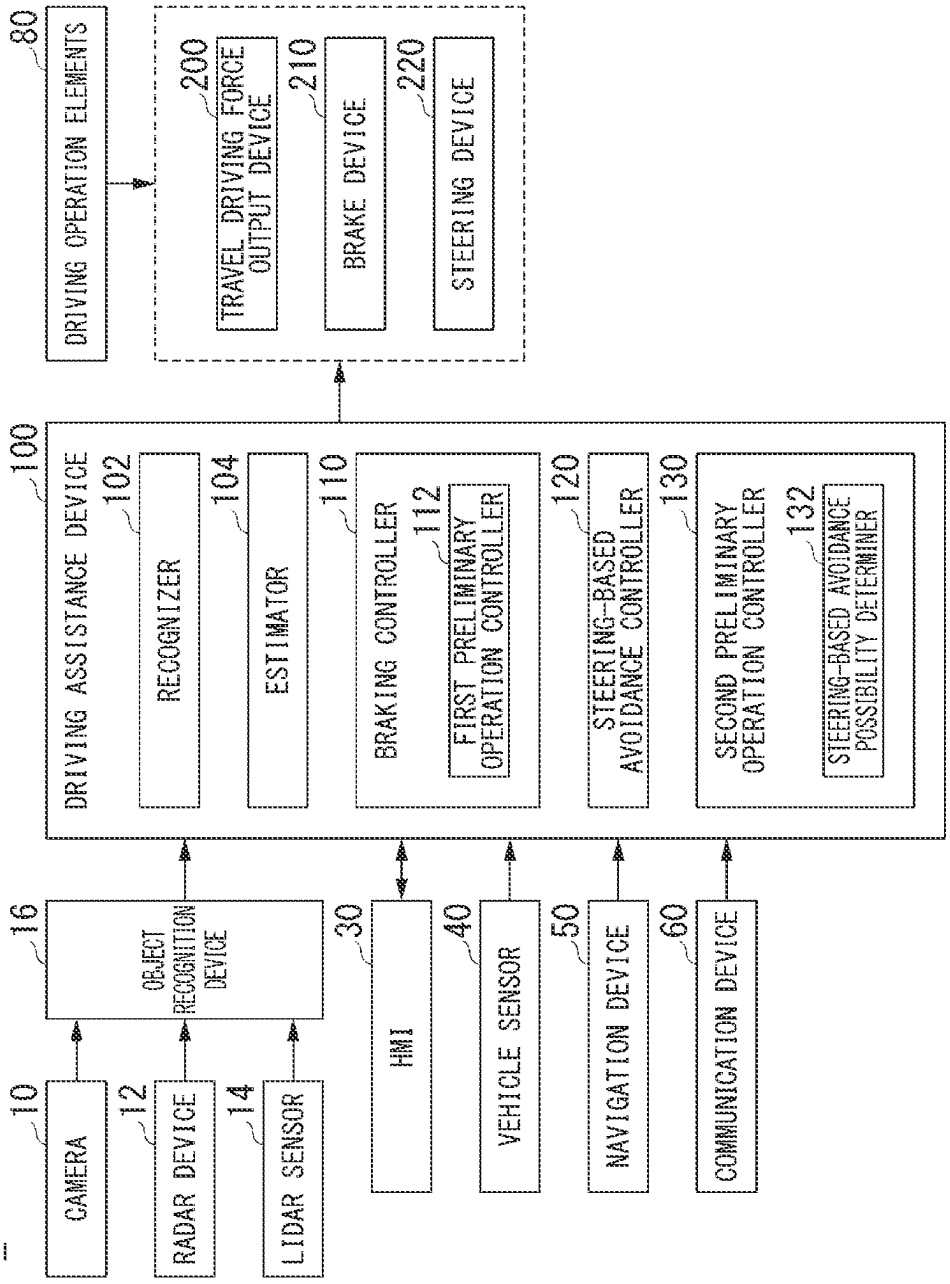
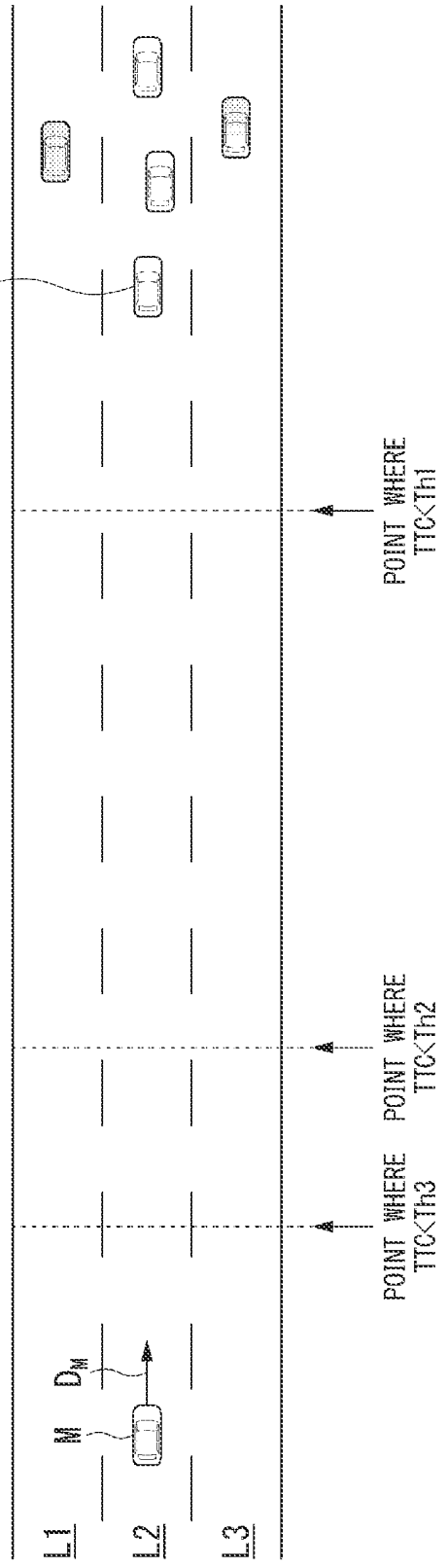

M
CAMERA
10
RADAR DEVICE
12
LIDAR SENSOR
14
OBJECT RECOGNITION DEVICE
16
HMI
30
VEHICLE SENSOR
40
NAVIGATION DEVICE
50
COMMUNICATION DEVICE
60
DRIVING ASSISTANCE DEVICE
100
RECOGNIZER
102
ESTIMATOR
104
BRAKING CONTROLLER
110
FIRST PRELIMINARY OPERATION CONTROLLER
112
STEERING-BASED AVOIDANCE CONTROLLER
120
SECOND PRELIMINARY OPERATION CONTROLLER
130
STEERING-BASED AVOIDANCE POSSIBILITY DETERMINER
132
DRIVING OPERATION ELEMENTS
80
TRAVEL DRIVING FORCE OUTPUT DEVICE
200
BRAKE DEVICE
210
STEERING DEVICE
220

FIG. 1

FIG. 2


TO
M
D_M
L1
L2
L3
POINT WHERE TTC<Th1
POINT WHERE TTC<Th2
POINT WHERE TTC<Th3

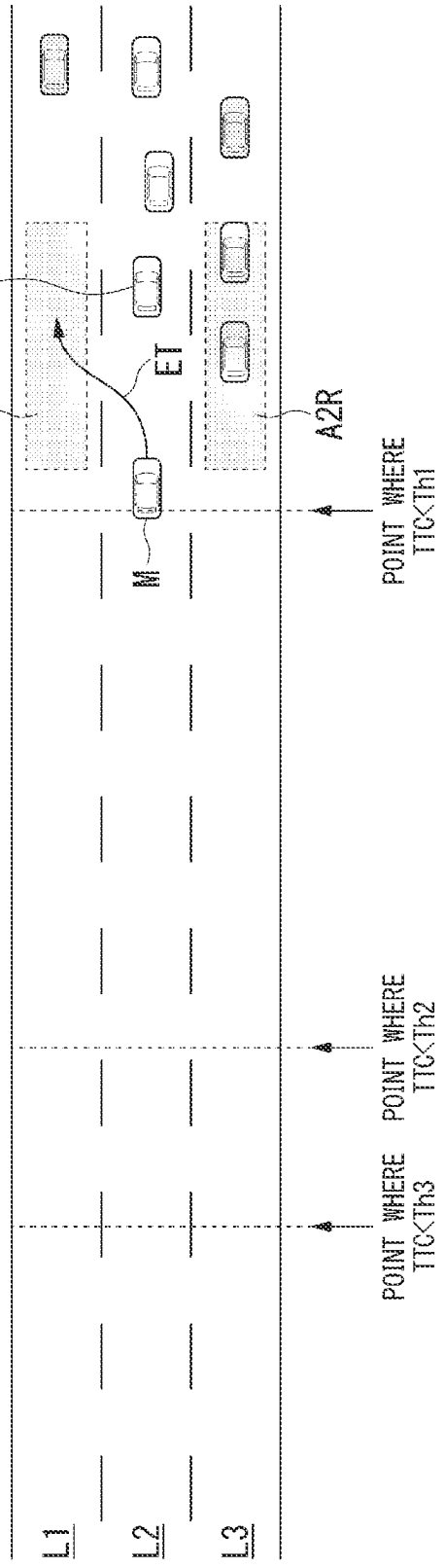

TO
ET
A2L
A2R
M
POINT WHERE TTC<Th1
POINT WHERE TTC<Th2
POINT WHERE TTC<Th3
L1
L2
L3

FIG. 3

FIG. 4

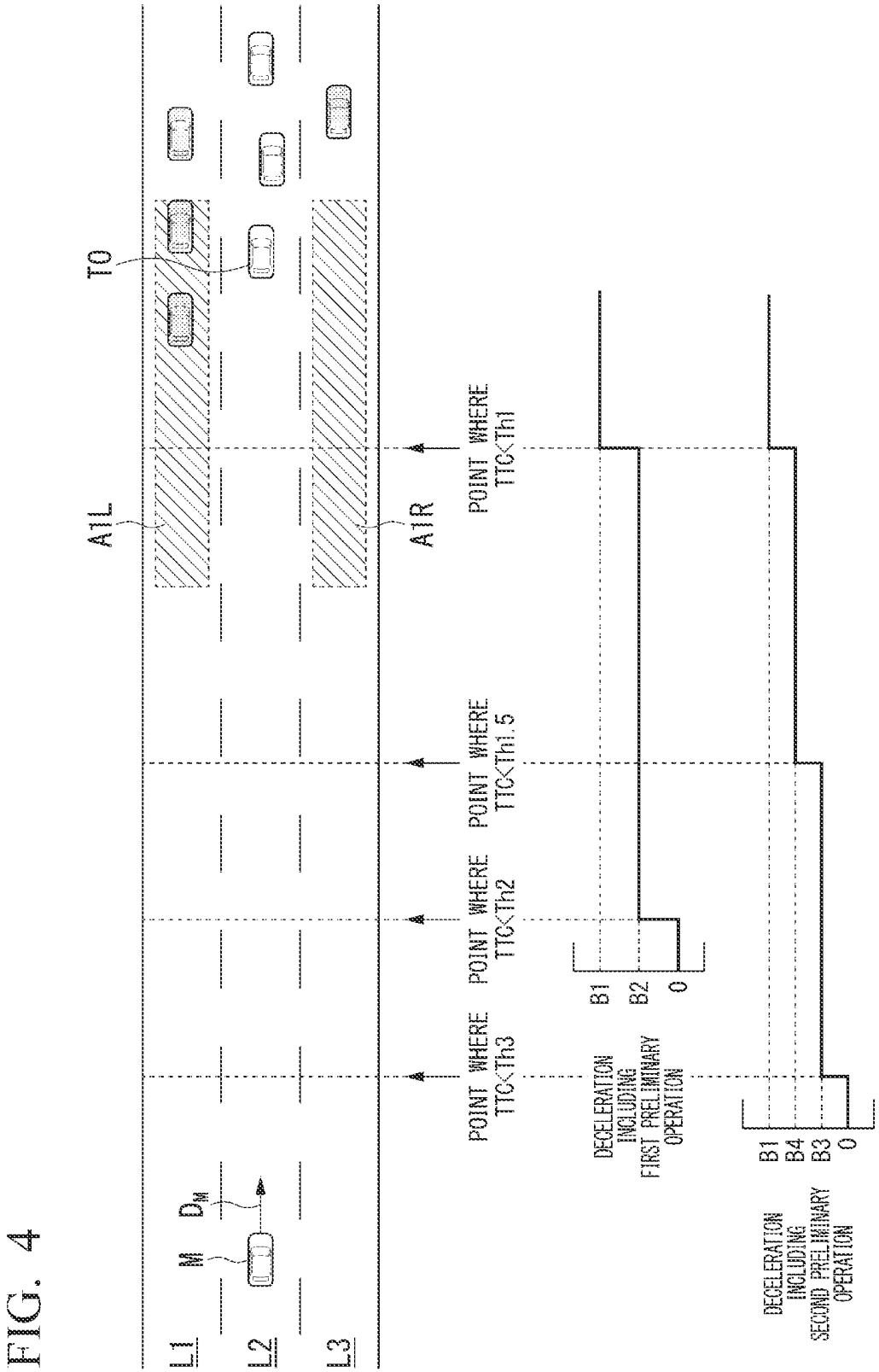

L1
L2
L3
M
D_M
T0
A1L
A1R
POINT WHERE TTC<Th3
POINT WHERE TTC<Th2
POINT WHERE TTC<Th1.5
POINT WHERE TTC<Th1
DECELERATION INCLUDING FIRST PRELIMINARY OPERATION
B1
B2
0
DECELERATION INCLUDING SECOND PRELIMINARY OPERATION
B1
B4
B3
0

FIG. 5

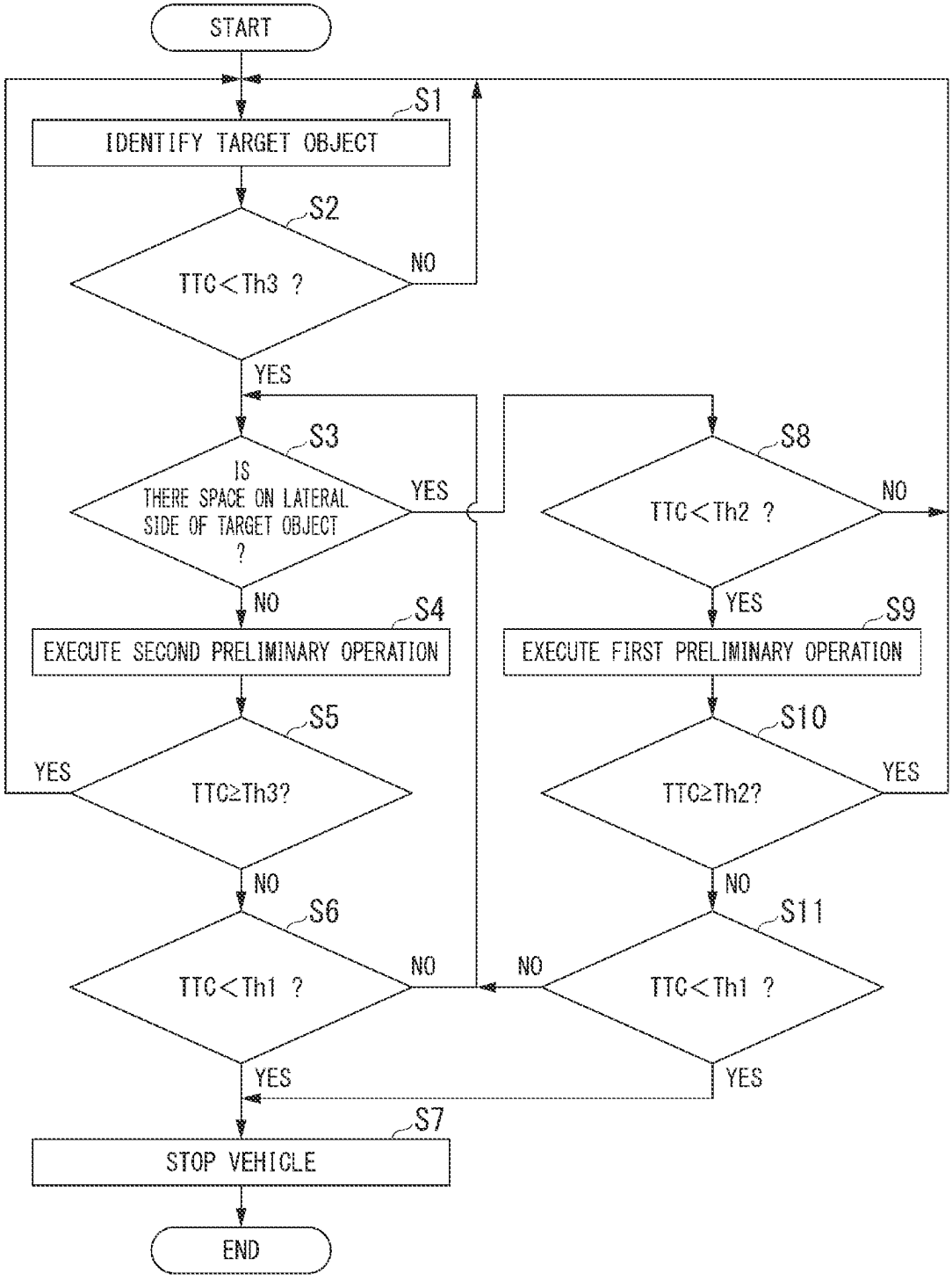

START
S1
IDENTIFY TARGET OBJECT
S2
TTC<Th3 ?
NO
YES
S3
IS THERE SPACE ON LATERAL SIDE OF TARGET OBJECT ?
YES
NO
S4
EXECUTE SECOND PRELIMINARY OPERATION
S5
TTC≥Th3?
YES
NO
S6
TTC<Th1 ?
NO
YES
S8
TTC<Th2 ?
NO
YES
S9
EXECUTE FIRST PRELIMINARY OPERATION
S10
TTC≥Th2?
YES
NO
S11
TTC<Th1 ?
NO
YES
S7
STOP VEHICLE
END

FIG. 6

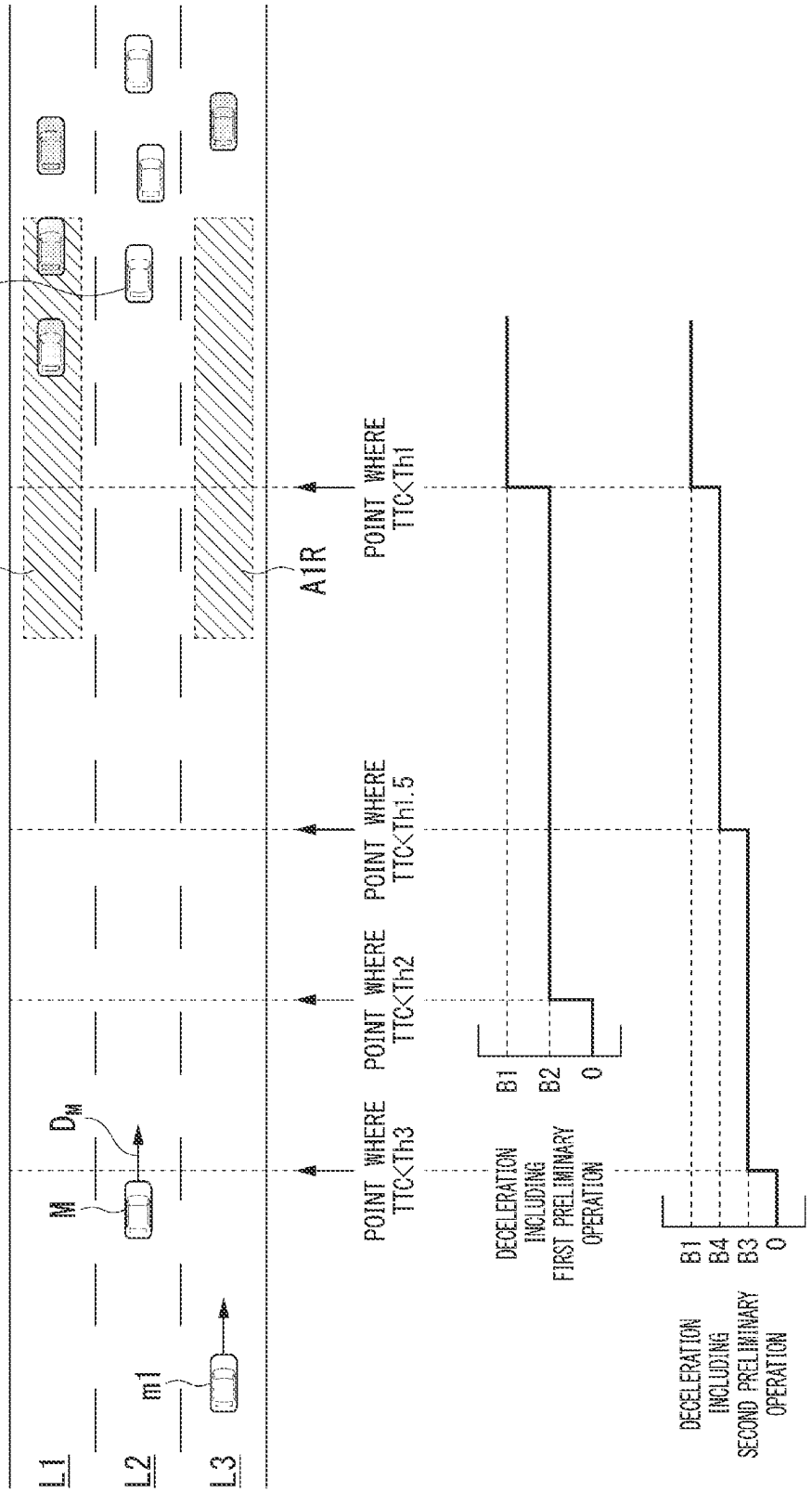

L1
L2
L3
M
m1
D_M
T0
A1L
A1R
POINT WHERE TTC<Th3
POINT WHERE TTC<Th2
POINT WHERE TTC<Th1.5
POINT WHERE TTC<Th1
DECELERATION INCLUDING FIRST PRELIMINARY OPERATION
B1
B2
0
DECELERATION INCLUDING SECOND PRELIMINARY OPERATION
B1
B4
B3
0

FIG. 7

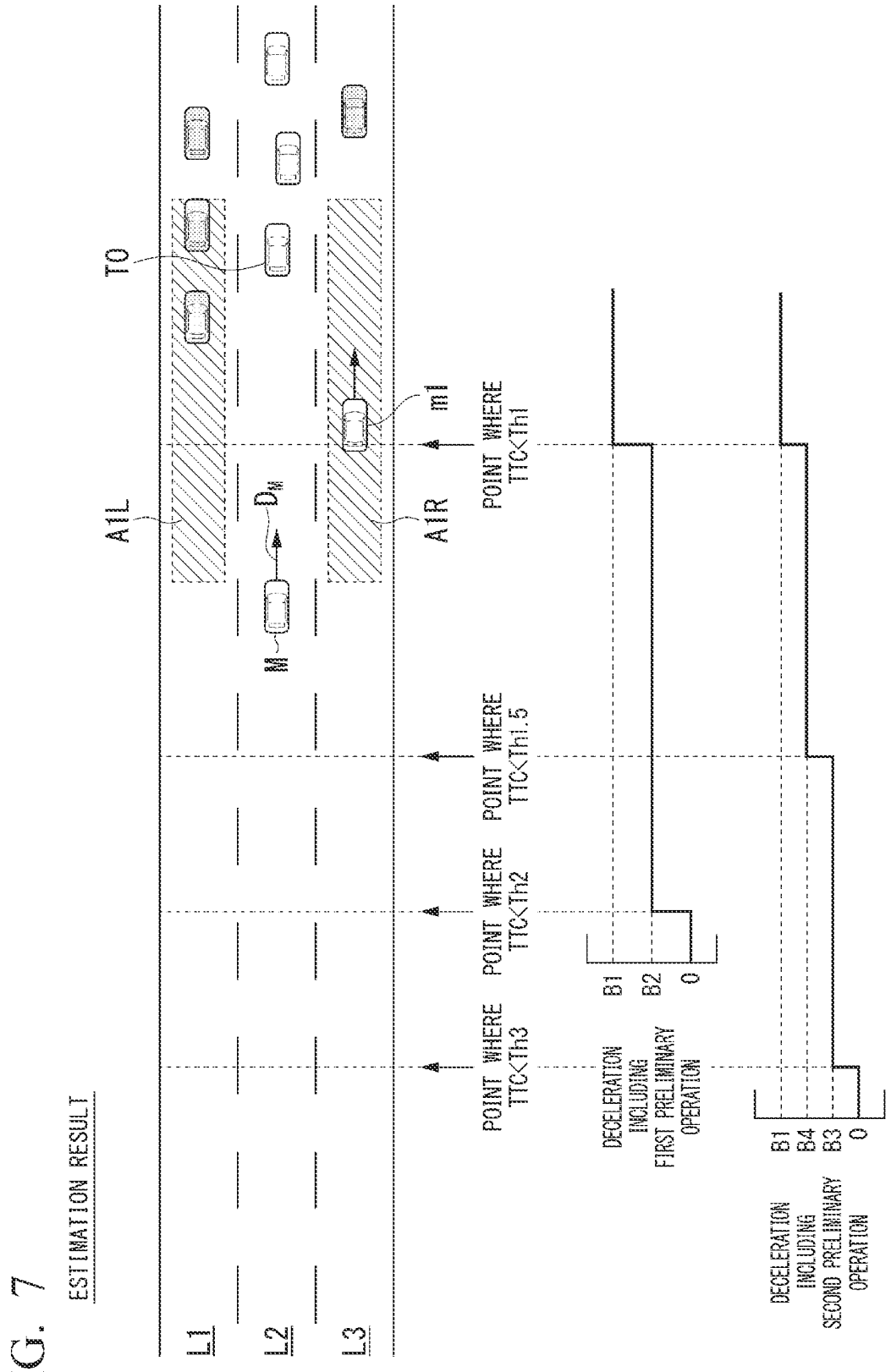

ESTIMATION RESULT
L1
L2
L3
T0
A1L
A1R
m1
M
D_M
POINT WHERE TTC<Th3
POINT WHERE TTC<Th2
POINT WHERE TTC<Th1.5
POINT WHERE TTC<Th1
DECELERATION INCLUDING FIRST PRELIMINARY OPERATION
B1
B2
0
DECELERATION INCLUDING SECOND PRELIMINARY OPERATION
B1
B4
B3
0

FIG. 8

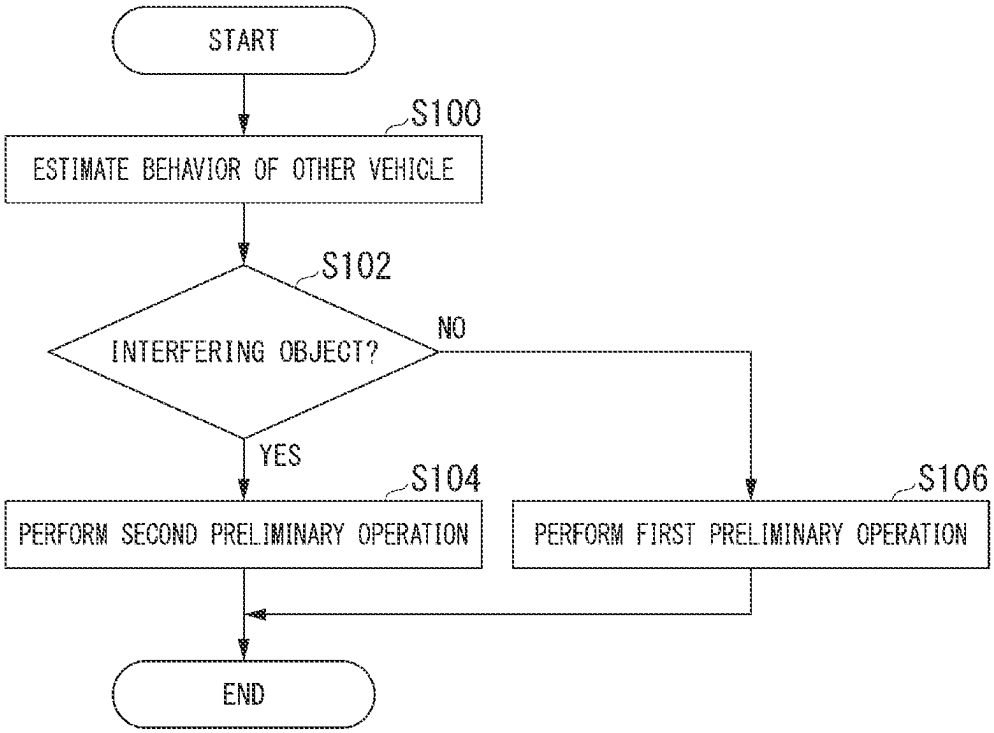

START
S100
ESTIMATE BEHAVIOR OF OTHER VEHICLE
S102
INTERFERING OBJECT?
NO
YES
S104
PERFORM SECOND PRELIMINARY OPERATION
S106
PERFORM FIRST PRELIMINARY OPERATION
END

FIG. 9

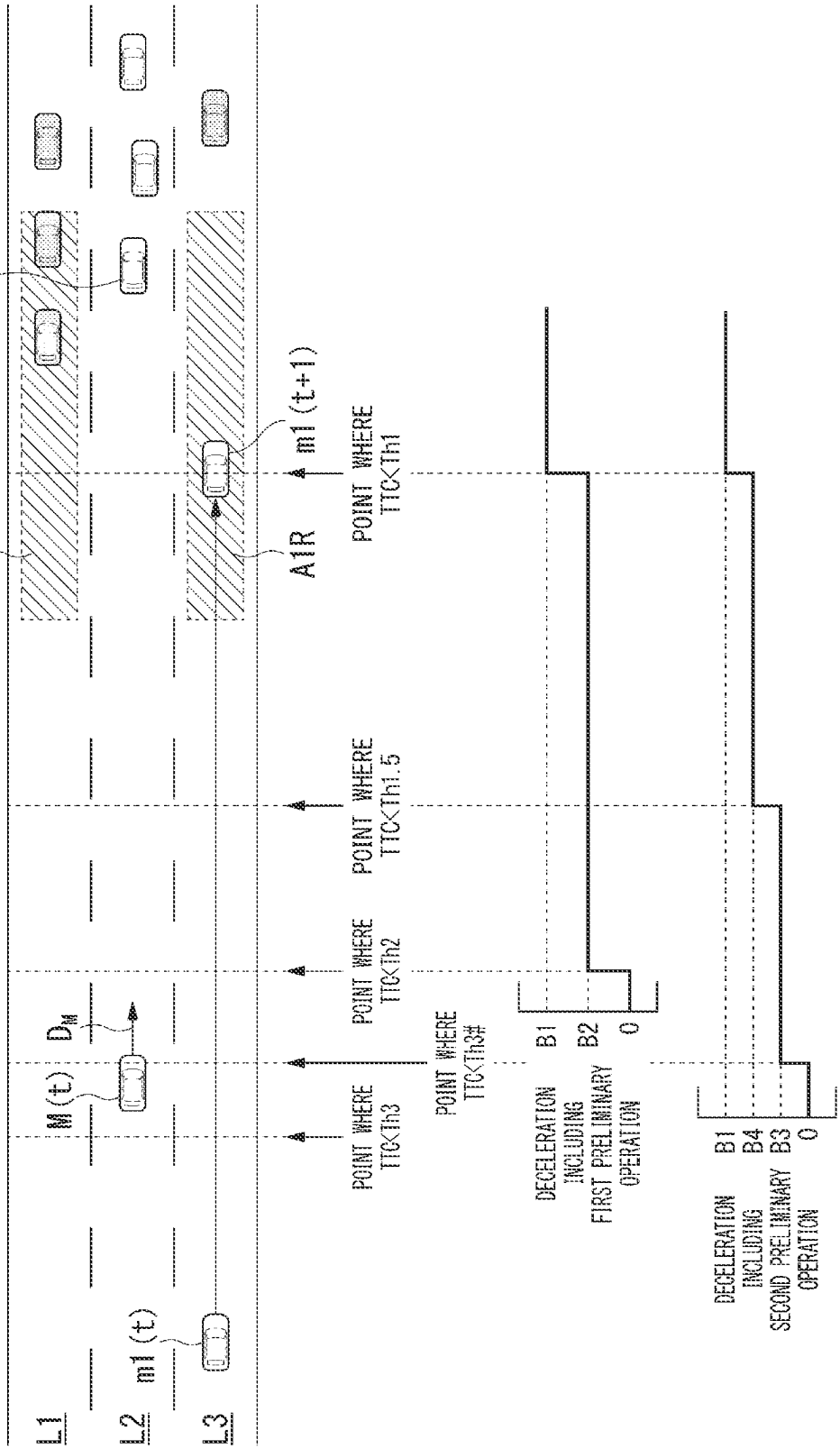

L1
L2
L3
m1 (t)
M (t)
D_M
T0
A1L
A1R
m1 (t+1)
POINT WHERE TTC<Th3
POINT WHERE TTC<Th2
POINT WHERE TTC<Th3#
POINT WHERE TTC<Th1.5
POINT WHERE TTC<Th1
DECELERATION INCLUDING FIRST PRELIMINARY OPERATION
B1
B2
0
DECELERATION INCLUDING SECOND PRELIMINARY OPERATION
B1
B4
B3
0

FIG. 10

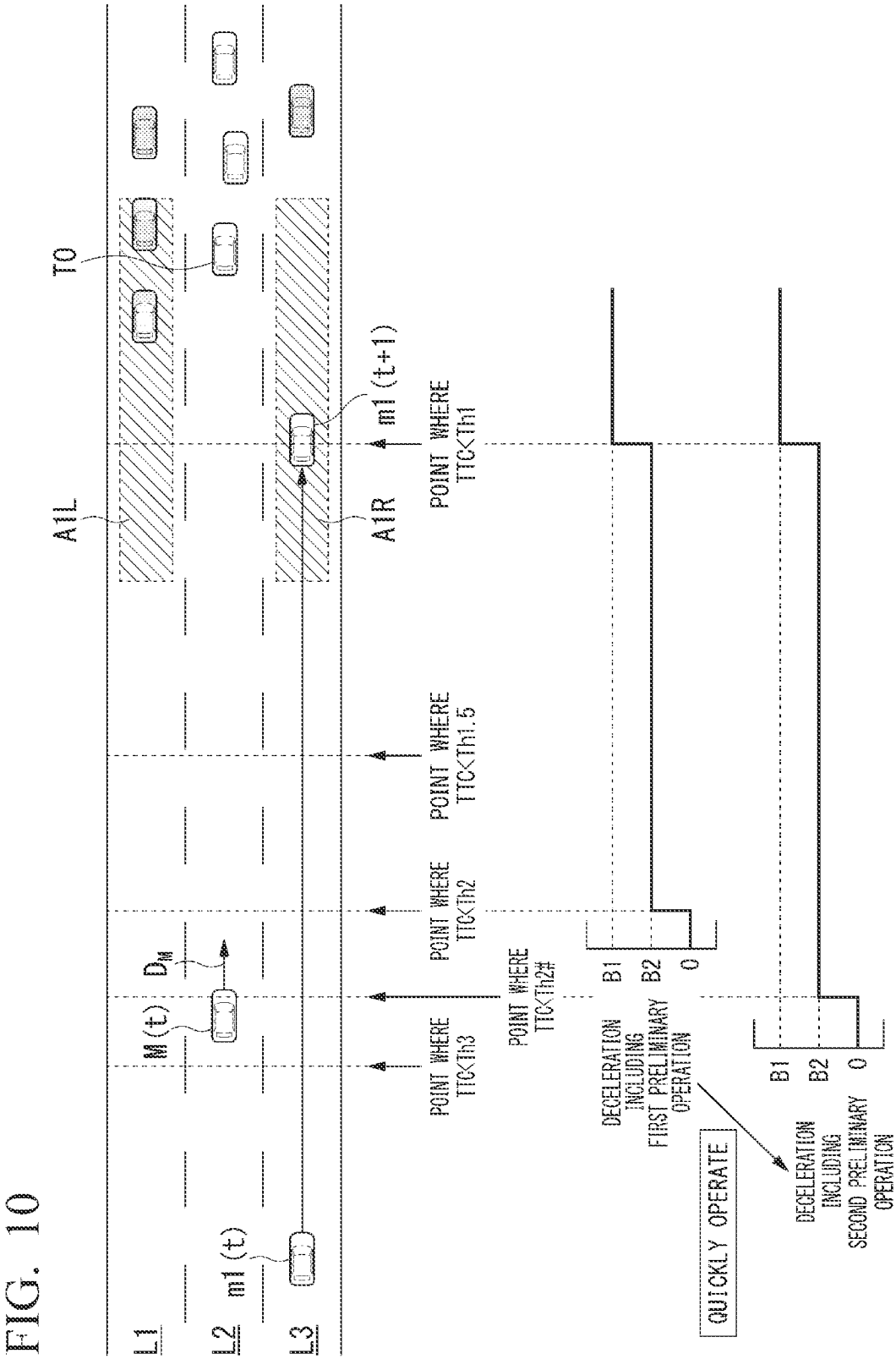
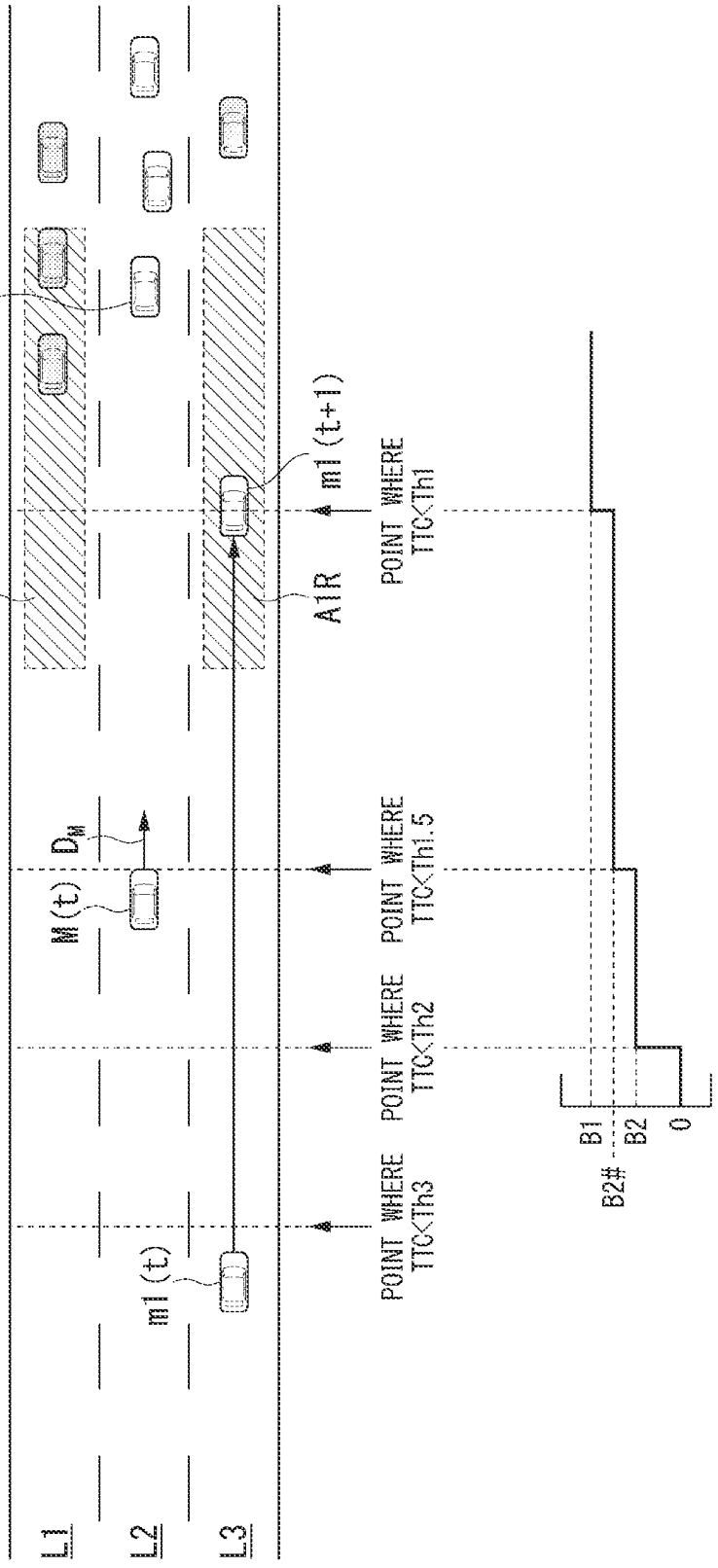

T0
A1L
A1R
m1 (t+1)
POINT WHERE TTC<Th1
POINT WHERE TTC<Th1.5
POINT WHERE TTC<Th2
POINT WHERE TTC<Th2#
POINT WHERE TTC<Th3
M (t)
D_M
m1 (t)
L1
L2
L3
B1
B2
0
DECELERATION INCLUDING FIRST PRELIMINARY OPERATION
QUICKLY OPERATE
DECELERATION INCLUDING SECOND PRELIMINARY OPERATION

FIG. 11


L1
L2
L3
TO
A1L
A1R
m1(t)
M(t)
D_M
m1(t+1)
POINT WHERE TTC<Th3
POINT WHERE TTC<Th2
POINT WHERE TTC<Th1.5
POINT WHERE TTC<Th1
B1
B2
B2#
0

DRIVING ASSISTANCE DEVICE, DRIVING ASSISTANCE METHOD, AND STORAGE MEDIUM

CROSS-REFERENCE TO RELATED APPLICATION

Priority is claimed on Japanese Patent Application No. 2022-043718, filed Mar. 18, 2022, the content of which is incorporated herein by reference.

BACKGROUND

Field of the Invention

The present invention relates to a driving assistance device, a driving assistance method, and a storage medium.

Description of Related Art

Recently, an invention of a vehicle control device for performing automated deceleration control and automated steering control has been disclosed (Japanese Unexamined Patent Application, First Publication No. 2020-50010).

SUMMARY

In a vehicle capable of performing automated steering control in addition to automated deceleration control, a probability that any sudden change in a surrounding environment of a vehicle can be coped with quickly becomes high and a degree of control margin becomes relatively high. On the other hand, because automated steering control becomes difficult if there is no avoidance space on a lateral side of a target object, a degree of control margin is no different from that of a vehicle that performs only automated deceleration control. In the conventional technology, it may be difficult to perform an operation corresponding to the above-described environment difference.

The present invention has been made in consideration of such circumstances and an objective of the present invention is to provide a driving assistance device, a driving assistance method, and a storage medium capable of performing an appropriate operation corresponding to a surrounding situation of a target object.

A driving assistance device, a driving assistance method, and a storage medium adopt the following configurations.

(1): According to an aspect of the present invention, there is provided a driving assistance device including: a storage medium storing computer-readable instructions; and at least one processor connected to the storage medium, the at least one processor executing the computer-readable instructions to: execute referring process of referring to an output of a detection device for detecting that an object is located in front of a vehicle; execute one or both of a braking control process of instructing a brake device of the vehicle to stop the vehicle when an indicator value that decreases as the vehicle approaches the object is less than a first threshold, and a steering-based avoidance control process of instructing a steering device of the vehicle to avoid a collision with the object in steering; execute a first preliminary operation control process of performing a first preliminary operation of notifying a driver of the vehicle that the object is present when the indicator value is less than a second threshold and it is determined, at or near a time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel on one of left and right sides of the object after the vehicle avoids the collision with the object in the steering; and execute a second preliminary operation control process of performing a second preliminary operation of notifying the driver of the vehicle that the object is present when the indicator value is less than a third threshold and it is determined, at a time point when the indicator value is less than the third threshold, that there is no travel path along which the vehicle is able to travel on both left and right sides of the object after the vehicle avoids the collision with the object in the steering, wherein the first threshold is less than the second threshold and the second threshold is less than the third threshold, and wherein the second preliminary operation or the first preliminary operation is executed when it is determined, at or near the time point when the indicator value is less than the third threshold, that there is a travel path along which the vehicle is able to travel and it is estimated that there is an interfering object that interferes with the travel path along which the vehicle is able to travel on the assumption that the vehicle has approached the object.

(2): In the above-described aspect (1), the at least one processor performs the first preliminary operation at the time point when the indicator value is less than the second threshold when the indicator value is less than the second threshold, it is determined, at or near the time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel, and it is estimated that there is no interfering object.

(3): In the above-described aspect (1) or (2), the interfering object is an object estimated to be located in an available travel space on the assumption that the vehicle has approached the available travel space.

(4): In any one of the above-described aspects (1) to (3), the interfering object is another vehicle located behind the vehicle and traveling at a higher speed than the vehicle in a lane corresponding to the available travel space.

(5): In any one of the above-described aspects (1) to (4), the at least one processor performs the second preliminary operation when the indicator value is less than the third threshold, the indicator value is not less than the second threshold, it is determined that there is a travel path along which the vehicle is able to travel, and it is estimated that the interfering object is located.

(6): In any one of the above-described aspects (1) to (4), the at least one processor performs the first preliminary operation when the indicator value is less than the third threshold, the indicator value is not less than the second threshold, it is determined that there is a travel path along which the vehicle is able to travel, and it is estimated that the interfering object is located.

(7): In any one of the above-described aspects (1) to (4), the at least one processor performs the first preliminary operation when the indicator value is less than the second threshold, it is determined, at or near the time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel, and it is estimated that the interfering object is not located, and, when the indicator value is less than the second threshold, it is determined, at a time point when the indicator value is not less than a first threshold, that there is a travel path along which

the vehicle is able to travel, and it is estimated that the interfering object is not present, the at least one processor makes the transition to the first preliminary operation having a higher operation level than the first preliminary operation that is performed when it is estimated that the interfering object is not located.

(8): According to an aspect of the present invention, there is provided a driving assistance method including: executing, by a driving assistance device, referring process of referring to an output of a detection device for detecting that an object is located in front of a vehicle; one or both of a braking control process of instructing a brake device of the vehicle to stop the vehicle when an indicator value that decreases as the vehicle approaches the object is less than a first threshold, and a steering-based avoidance control process of instructing a steering device of the vehicle to avoid a collision with the object in steering; executing, by the driving assistance device, a first preliminary operation control process of performing a first preliminary operation of notifying a driver of the vehicle that the object is present when the indicator value is less than a second threshold and it is determined, at or near a time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel on one of left and right sides of the object after the vehicle avoids the collision with the object in the steering; and executing, by the driving assistance device, a second preliminary operation control process of performing a second preliminary operation of notifying the driver of the vehicle that the object is present when the indicator value is less than a third threshold and it is determined, at a time point when the indicator value is less than the third threshold, that there is no travel path along which the vehicle is able to travel on both left and right sides of the object after the vehicle avoids the collision with the object in the steering, wherein the first threshold is less than the second threshold and the second threshold is less than the third threshold, and wherein the second preliminary operation or the first preliminary operation is executed when it is determined, at or near the time point when the indicator value is less than the third threshold, that there is a travel path along which the vehicle is able to travel and it is estimated that there is an interfering object that interferes with the travel path along which the vehicle is able to travel on the assumption that the vehicle has approached the object.

(9): According to an aspect of the present invention, there is provided a non-transitory computer storage medium storing a program for causing a computer to: execute referring process of referring to an output of a detection device for detecting that an object is located in front of a vehicle; execute one or both of a braking control process of instructing a brake device of the vehicle to stop the vehicle when an indicator value that decreases as the vehicle approaches the object is less than a first threshold, and a steering-based avoidance control process of instructing a steering device of the vehicle to avoid a collision with the object in steering; execute a first preliminary operation control process of performing a first preliminary operation of notifying a driver of the vehicle that the object is present when the indicator value is less than a second threshold and it is determined, at or near a time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel on one of left and right sides of the object after the vehicle avoids the collision with the object in the steering; and execute a second preliminary operation control process of performing a second preliminary operation of notifying the driver of the vehicle that the object is present when the indicator value is less than a third threshold and it is determined, at a time point when the indicator value is less than the third threshold, that there is no travel path along which the vehicle is able to travel on both left and right sides of the object after the vehicle avoids the collision with the object in the steering, wherein the first threshold is less than the second threshold and the second threshold is less than the third threshold, and wherein the second preliminary operation or the first preliminary operation is executed when it is determined, at or near the time point when the indicator value is less than the third threshold, that there is a travel path along which the vehicle is able to travel and it is estimated that there is an interfering object that interferes with the travel path along which the vehicle is able to travel on the assumption that the vehicle has approached the object.

According to the above-described aspects, it is possible to perform an appropriate operation corresponding to a surrounding situation of a target object.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a configuration diagram of a vehicle in which a driving assistance device according to an embodiment is mounted.

FIG. **2** is a diagram showing an overview of a function of the driving assistance device.

FIG. **3** is a diagram showing an example of an operation scene of a steering-based avoidance controller.

FIG. **4** is a diagram for describing a preliminary operation.

FIG. **5** is a flowchart showing an example of a flow of a process executed by the driving assistance device.

FIG. **6** is a diagram (1-1) for describing a change example of control content.

FIG. **7** is a diagram (1-2) for describing a change example of control content.

FIG. **8** is a flowchart showing another example of a flow of a process executed by the driving assistance device.

FIG. **9** is a diagram (2) for describing a change example of control content.

FIG. **10** is a diagram (3) for describing a change example of control content.

FIG. **11** is a diagram (4) for describing a change example of control content.

DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments of a driving assistance device, a driving assistance method, and a storage medium according to the present invention will be described with reference to the drawings. As used throughout this disclosure, the singular forms "a," "an," and "the" include plural reference unless the context clearly dictates otherwise.

[Overall Configuration]

FIG. **1** is a configuration diagram of a vehicle M in which a driving assistance device **100** of an embodiment is mounted. The vehicle M is, for example, a vehicle such as a two-wheeled vehicle, a three-wheeled vehicle, or a four-wheeled vehicle, and a drive source thereof is an internal combustion engine such as a diesel engine or a gasoline

engine, an electric motor, or a combination thereof. The electric motor operates using electric power generated by a power generator connected to the internal combustion engine or electric power that is supplied when a secondary battery or a fuel cell is discharged.

For example, the vehicle M includes a camera **10**, a radar device **12**, a light detection and ranging (LIDAR) sensor **14**, an object recognition device **16**, a human machine interface (HMI) **30**, a vehicle sensor **40**, a navigation device **50**, a communication device **60**, driving operation elements **80**, a driving assistance device **100**, a travel driving force output device **200**, a brake device **210**, and a steering device **220**. Such devices and equipment are connected to each other by a multiplex communication line such as a controller area network (CAN) communication line, a serial communication line, or a wireless communication network. Also, the configuration shown in FIG. **1** is merely an example and some of the components may be omitted or other components may be further added.

For example, the camera **10** is a digital camera using a solid-state imaging element such as a charge-coupled device (CCD) or a complementary metal oxide semiconductor (CMOS). The camera **10** is attached to any location on the vehicle (hereinafter, the vehicle M) in which the vehicle system **1** is mounted. When the view in front of the vehicle M is imaged, the camera **10** is attached to an upper part of a front windshield, a rear surface of a rearview mirror, or the like. When the view to the rear is imaged, the camera **10** is attached at any position such as a sideview mirror, a rear bumper, or a rear windshield. For example, the camera **10** periodically and iteratively images the surroundings of the vehicle M. The camera **10** may be a stereo camera.

The radar device **12** radiates radio waves such as millimeter waves around the vehicle M and detects at least a position (a distance to and a direction) of an object by detecting radio waves (reflected waves) reflected by the object. The radar device **12** is attached to any location on the vehicle M. The radar device **12** may detect a position and speed of the object in a frequency modulated continuous wave (FM-CW) scheme.

The LIDAR sensor **14** radiates light (or electromagnetic waves of a wavelength close to an optical wavelength) to the vicinity of the vehicle M and measures scattered light. The LIDAR sensor **14** detects a distance to an object on the basis of a time period from light emission to light reception. The radiated light is, for example, pulsed laser light. The LIDAR sensor **14** is attached to any location on the vehicle M. The radar device **12** or the LIDAR sensor **14** is attached to a front portion or a rear portion of the vehicle M, for example, so that a situation in front of and behind the vehicle M is detected.

The object recognition device **16** performs a sensor fusion process for detection results from some or all of the camera **10**, the radar device **12**, and the LIDAR sensor **14** to recognize a position, a type, a speed, and the like of an object. The object recognition device **16** outputs recognition results to the driving assistance device **100**. The object recognition device **16** may output detection results of the camera **10**, the radar device **12**, and the LIDAR sensor **14** to the driving assistance device **100** as they are. The object recognition device **16** may be omitted from the vehicle system **1**. Some or all of the camera **10**, the radar device **12**, the LIDAR sensor **14**, and the object recognition device **16** are an example of a "detection device."

The HMI **30** provides an occupant of the vehicle M with various types of information and receives an input operation from the occupant. The HMI **30** includes various types of display devices, a speaker, a buzzer, a vibration generation device (a vibrator), a touch panel, a switch, a key, and the like.

The vehicle sensor **40** includes a vehicle speed sensor configured to detect the speed of the vehicle M, an acceleration sensor configured to detect acceleration, a yaw rate sensor configured to detect an angular speed around a vertical axis, a direction sensor configured to detect a direction of the vehicle M, and the like.

The navigation device **50** has, for example, a global navigation satellite system (GNSS) receiver, a guidance controller, a storage storing map information, and the like. The GNSS receiver identifies a position of the vehicle M on the basis of signals received from GNSS satellites. A position of the vehicle M may be identified or corrected by an inertial navigation system (INS) using an output of the vehicle sensor **40**. For example, the guidance controller decides on a route from the position of the vehicle M identified by the GNSS receiver (or any input position) to a destination input by the occupant with reference to the map information and causes the HMI **30** to output guidance information so that the vehicle M travels along a path. The map information is, for example, information in which a road shape is expressed by a link indicating a road and nodes connected by the link. The map information may include curvature of a road, point of interest (POI) information, and the like. The navigation device **50** may transmit a current position and a destination of the vehicle M to a navigation server via the communication device and acquire a route from the navigation server.

The communication device **60** is a communication interface that communicates with other vehicles. The communication device **60** acquires situations such as positions, speeds, and acceleration of other vehicles from the other vehicles.

The driving operation element **80** includes, for example, an accelerator pedal, a brake pedal, a steering wheel, a shift lever, and other operation elements. A sensor for detecting an operation amount or the presence or absence of an operation is attached to the driving operation element **80** and a detection result thereof is output to some or all of the travel driving force output device **200**, the brake device **210**, and the steering device **220**.

The travel driving force output device **200** outputs a travel driving force (torque) for enabling the vehicle to travel to driving wheels. For example, the travel driving force output device **200** includes a combination of an internal combustion engine, an electric motor, a transmission, and the like, and an electronic control unit (ECU) that controls the internal combustion engine, the electric motor, the transmission, and the like. The ECU controls the above-described components in accordance with information input from the driving assistance device **100** or information input from the driving operation element **80**.

For example, the brake device **210** includes a brake caliper, a cylinder configured to transfer hydraulic pressure to the brake caliper, an electric motor configured to generate hydraulic pressure in the cylinder, and an ECU. The ECU controls the electric motor in accordance with the information input from the driving assistance device **100** or the information input from the driving operation element **80** so that brake torque according to a braking operation is output to each wheel. The brake device **210** may include a mechanism configured to transfer the hydraulic pressure generated according to an operation on the brake pedal included in the driving operation elements **80** to the cylinder via a master cylinder as a backup. Also, the brake device **210** is not

limited to the above-described configuration and may be an electronically controlled hydraulic brake device configured to control an actuator in accordance with information input from the driving assistance device **100** and transfer the hydraulic pressure of the master cylinder to the cylinder.

For example, the steering device **220** includes a steering ECU and an electric motor. For example, the electric motor changes a direction of steerable wheels by applying a force to a rack and pinion mechanism. The steering ECU drives the electric motor in accordance with the information input from the driving assistance device **100** or the information input from the driving operation element **80** to change the direction of the steerable wheels.

[Driving Assistance Device]

The driving assistance device **100** includes, for example, a recognizer **102**, an estimator **104**, a braking controller **110**, a steering-based avoidance controller **120**, and a second preliminary operation controller **130**. The braking controller **110** includes a first preliminary operation controller **112** and the second preliminary operation controller **130** includes a steering-based avoidance possibility determiner **132**. Each of these functional components is implemented, for example, by a hardware processor such as a central processing unit (CPU) executing a program (software). Also, some or all of the above components may be implemented by hardware (including a circuit; circuitry) such as a large-scale integration (LSI) circuit, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a graphics processing unit (GPU) or may be implemented by software and hardware in cooperation. The program may be pre-stored in a storage device (a storage device including a non-transitory storage medium) such as a hard disk drive (HDD) or a flash memory of the driving assistance device **100** or may be stored in a removable storage medium such as a digital video disc (DVD) or a compact disc (CD)-read-only memory (ROM) and installed in the HDD or the flash memory of the driving assistance device **100** when the storage medium (the non-transitory storage medium) is mounted in a drive device. Functional components of some or all of the braking controller **110**, the steering-based avoidance controller **120**, and the second preliminary operation controller **130** may be integrated.

Setting is performed inside of the travel driving force output device **200**, the brake device **210**, and the steering device **220** so that instructions from the driving assistance device **100** to the travel driving force output device **200**, the brake device **210**, and the steering device **220** are issued with preference over a detection result from the driving operation element **80**. Also, in relation to braking, if a braking force based on an operation amount of the brake pedal is larger than that in the instruction from the driving assistance device **100**, setting may be performed so that the braking operation is preferentially executed. Also, as a mechanism for preferentially issuing an instruction from the driving assistance device **100**, the communication priority in the in-vehicle LAN may be used.

FIG. **2** is a diagram showing an overview of a function of the driving assistance device **100**. Hereinafter, each part of the driving assistance device **100** will be described with reference to FIG. **2** and FIG. **1**. In FIG. **2**, the vehicle M is traveling on a three-lane road and is in a lane L**2** in the center thereof. DM denotes a traveling direction of the vehicle M.

The recognizer **102** recognizes an object with reference to an output of the detection device (described above) for detecting that an object is located in front of or behind the vehicle M. The recognizer **102** recognizes the position, the speed, the acceleration, and the like of the object in front of or behind the vehicle M with reference to the output of the detection device.

The estimator **104** estimates the future behavior of the object on the basis of a recognition result of the recognizer **102**. The estimator **104** estimates the position of the object after a prescribed time on the basis of an estimation result. For example, the estimator **104** estimates the behavior of another vehicle that is the object on the basis of the acceleration of the other vehicle and the situation in front of the other vehicle. For example, the estimator **104** estimates the behavior of the other vehicle by applying the acceleration and speed of the other vehicle to a profile provided in advance. Also, the estimator **104** may estimate the behavior of the other vehicle using information (position, speed, acceleration, and the like) acquired by the communication device **60** in place of (or in addition to) the recognition result of the recognizer **102**.

The braking controller **110** instructs the brake device **210** and/or the travel driving force output device **200** to decelerate and stop the vehicle M when a degree of proximity between a target object TO among objects and the vehicle M satisfies a first condition with reference to an output of the detection device (described above) that detects that an object is located in front of the vehicle M. The target object TO is an object located on the same travel path as the vehicle M and on the traveling direction side of the vehicle M and is an object with which the vehicle M should avoid a collision, rather than objects that the vehicle M can pass over such as manholes. The braking controller **110** extracts such an object and sets the extracted object as the target object TO. In the example of FIG. **2**, another vehicle at the rear end of the conventional example is set as the target object TO. The travel path is, for example, a lane, but may be a virtual lane virtually set by the vehicle M on a road surface on which there is no road marking. The same is also true for the following description.

The "degree of proximity" is represented by various types of indicator values that indicate the degree of proximity between objects. For example, the "degree of proximity" is time to collision (TTC), which is an indicator value obtained by dividing a distance by a relative speed (positive in a direction in which objects approach each other). Also, when the relative speed is negative (in a direction in which objects move away from each other), the TTC is provisionally set to infinity. The TTC is an indicator value indicating that the "degree of proximity" increases as the value decreases. The fact that the "first condition" is satisfied indicates, for example, that the TTC is less than a first threshold Th**1**. The first threshold Th**1** is, for example, a value of about 1.1 to 1.9 [sec]. Instead of the TTC, an indicator value having a similar property thereto, for example, a headway time, a distance, or another indicator value, may be used as the "degree of proximity" Also, the TTC adjusted in consideration of acceleration and jerk may be used as the "degree of proximity" In the following description, it is assumed that the "degree of proximity" is the TTC.

When the TTC is less than the first threshold Th**1**, for example, the braking controller **110** instructs the brake device **210** and/or the travel driving force output device **200** to output a braking force for decelerating the vehicle M at first deceleration B**1**. The first deceleration B**1** is, for example, a deceleration of about 0.1 to 0.9 [G] (close to 1). Thereby, the braking controller **110** causes the vehicle M to quickly decelerate and stop and avoids a collision with the target object TO. The ECU of the brake device **210** or the travel driving force output device **200** has a function of

obtaining a brake output, a regeneration control amount, an engine brake amount, or the like from instruction-specific deceleration. The ECU decides on each control amount on the basis of the instruction-specific deceleration and the speed of the vehicle M. This is well-known technology and detailed description thereof will be omitted.

The operation of the first preliminary operation controller **112** will be described below and the steering-based avoidance controller **120** will be described first.

FIG. **3** is a diagram showing an example of an operation scene of the steering-based avoidance controller **120**. The steering-based avoidance controller **120** determines whether or not there is a space where the vehicle M is able to travel in a travel path (for example, a lane L**1** or L**2**) on a lateral side of the target object TO when it is determined that it is difficult for the braking controller **110** to stop the vehicle M in front of the target object TO, generates an avoidance trajectory ET when it is determined that there is a space, and issues an instruction to the steering device **220** so that the vehicle M travels along the avoidance trajectory ET (steering-based avoidance). For example, the steering-based avoidance controller **120** determines whether or not an object is located in lateral side areas extending slightly in front of and behind the target vehicle on both lateral sides of the target vehicle TO, such as areas A**2**L and A**2**R shown in FIG. **3**, and determines that there is a space where the vehicle M is able to travel in a travel path on a lateral side of the target object TO when there is no object. The determination of whether or not it is difficult for the braking controller **110** to stop the vehicle M in front of the target object TO may be made by the braking controller **110**, or may be made by the steering-based avoidance controller **120**. The steering-based avoidance controller **120** may also recognize a boundary of a travel path by, for example, recognizing a white line or a road shoulder of a camera image, and determine that an object is located in an area when neither of the available travel areas A**2**L and A**2**R is present, for example, when neither of the lanes L**1** and L**3** is present.

Steering-based avoidance is performed in a situation in which a sudden change in the surrounding environment of the vehicle has occurred such as a situation in which a target object TO decelerates unexpectedly or an object different from a recognized target object TO intervenes between the vehicle M and the target object TO and is set as a new target vehicle TO. In this situation, there is a possibility that a countermeasure cannot be taken at deceleration calculated in advance so that the vehicle stops in front of the target vehicle TO, but it is possible to increase a probability that sudden changes in the surrounding environment of the vehicle can be coped with by providing a steering-based avoidance function.

[Preliminary Operation]

The processes of the first preliminary operation controller **112** and the second preliminary operation controller **130** will be described below. FIG. **4** is a diagram for describing a preliminary operation.

When a degree of proximity between a target object TO and the vehicle M satisfies a second condition (for example, when the TTC is less than a second threshold Th**2**), the first preliminary operation controller **112** performs a first preliminary operation for notifying a driver of the vehicle M of the presence of the target object TO. The first preliminary operation is, for example, an operation of instructing the brake device **210** and/or the travel driving force output device **200** to output a braking force for decelerating the vehicle M at second deceleration B**2** from the time when the TTC is less than the second threshold Th**2** to the time when the TTC is less than the first threshold Th**1**. The second deceleration B**2** is deceleration less than the first deceleration B**1** (or close to zero). The second threshold Th**2** is a value larger than the first threshold Th**1**. Accordingly, the first condition is a condition that is satisfied when the degree of proximity is higher than that of the second condition.

When it is determined that the degree of proximity between the target object TO and the vehicle M satisfies a third condition (for example, the TTC is less than a third threshold Th**3**) and there is no available travel space in both travel paths on lateral sides of the target object TO after the vehicle M avoids a collision with the target object TO in steering at the time point when the third condition is satisfied, the second preliminary operation controller **130** performs a second preliminary operation of notifying the driver of the vehicle M of the presence of the target object TO. A determination related to the available travel space is made by the steering-based avoidance possibility determiner **132**. The third threshold Th**3** is a value larger than the second threshold Th**2**. Accordingly, the second condition is a condition that is satisfied when the degree of proximity is higher than that of the third condition.

For example, the steering-based avoidance possibility determiner **132** determines whether or not an object is located within lateral side areas extending slightly in front of and behind the target vehicle on both lateral sides of the target vehicle TO, such as areas A**1**L and A**1**R shown in FIG. **4**, for example, at a time point when the TTC is less than the third threshold Th**3**, and determines that there is a space where the vehicle M is able to travel in a travel path on the lateral side of the target object TO when there is no object. The areas A**1**L and MR is set to be larger than the areas A**2**L and A**2**R, respectively, for example, in consideration of future uncertain factors. Like the steering-based avoidance controller **120**, the steering-based avoidance possibility determiner **132** may also recognize the boundary of the travel path by recognizing a white line and a road shoulder in a camera image and determine that an object is located in the area when neither of the available travel areas A**1**L and MR is present, for example, when neither of the lanes L**1** and L**3** is present. In the example of FIG. **4**, because there is no object in the area MR, the steering-based avoidance possibility determiner **132** determines that there is a space where the vehicle M is able to travel in a travel path on the lateral side of the target object TO.

The second preliminary operation is, for example, an operation of instructing the brake device **210** and/or the travel driving force output device **200** to output a braking force for decelerating the vehicle M at third deceleration B**3** from the time when the TTC is less than the third threshold Th**3** to the time when the TTC is less than the first threshold Th**1** and subsequently instructing the brake device **210** and/or the travel driving force output device **200** to output a braking force for decelerating the vehicle M at fourth deceleration B**4**. The third deceleration B**3** is, for example, deceleration less than the second deceleration B**2** (or close to zero), and the fourth deceleration B**4** is deceleration greater than or substantially equal to the second deceleration and less than the first deceleration B**1**. A timing when the deceleration is switched from the third deceleration B**3** to the fourth deceleration B**4** may be set arbitrarily. For example, when a degree of proximity between the target object TO and the vehicle M satisfies a 1.5th condition (for example, when the TTC is less than a threshold Th**1.5**), the deceleration is switched from the third deceleration B**3** to the fourth deceleration B**4**. The 1.5th condition is a condition

that is satisfied when a degree of proximity is higher than that of the second condition. When the second condition is satisfied, the deceleration may be switched from the third deceleration B3 to the fourth deceleration B4.

Thus, a start timing of the second preliminary operation is earlier than that of the first preliminary operation and the second preliminary operation is performed in multiple steps. As described above, in a situation in which steering-based avoidance is possible, a probability that any sudden change in the surrounding environment of the vehicle can be coped with quickly becomes high and a degree of control margin becomes relatively high. On the other hand, because it is difficult to execute a steering-based avoidance function even if the steering-based avoidance function is provided when there is no avoidance space on the lateral side of the target object, a degree of control margin is no different from that of a vehicle that performs only an automated stop operation. That is, it is preferable to warn the driver of the vehicle M more quickly and effectively in a situation in which steering-based avoidance is difficult than in a situation in which steering-based avoidance is possible. According to the present embodiment, a start timing of the second preliminary operation is earlier than that of the first preliminary operation and the second preliminary operation is performed in multiple steps, and therefore it is possible to perform an appropriate preliminary operation corresponding to the surrounding situation of the target object.

FIG. **5** is a flowchart showing an example of a flow of a process executed by the driving assistance device **100**.

First, the braking controller **110** identifies a target object TO (step S1). Subsequently, the second preliminary operation controller **130** determines whether or not TTC between the vehicle M and the target object TO is less than the third threshold Th3 (step S2). When the TTC between the vehicle M and the target object TO is greater than or equal to the third threshold Th3, the process returns to step S1.

When it is determined that the TTC between the vehicle M and the target object TO is less than the third threshold Th3, the steering-based avoidance possibility determiner **132** of the second preliminary operation controller **130** determines whether or not there is a space where the vehicle M is able to travel in a travel path on a lateral side of the target object TO (step S3).

When it is determined that there is no space where the vehicle M is able to travel in the travel path on the lateral side of the target object TO, the second preliminary operation controller **130** executes the second preliminary operation (step S4). Subsequently, the second preliminary operation controller **130** determines whether or not the TTC between the vehicle M and the target object TO has increased to a value greater than or equal to the third threshold Th3 (step S5). When it is determined that the TTC between the vehicle M and the target object TO has increased to a value greater than or equal to the third threshold Th3, the process returns to step S1.

When it is determined that the TTC between the vehicle M and the target object TO has not increased to a value greater than or equal to the third threshold Th3, the braking controller **110** determines whether or not the TTC between the vehicle M and the target object TO is less than the first threshold Th1 (step S6). When it is determined that the TTC between the vehicle M and the target object TO is greater than or equal to the first threshold Th1, the process returns to step S3. When an affirmative determination has been obtained in step S3, the second preliminary operation is stopped and the processing from step S8 is executed. When it is determined that the TTC between the vehicle M and the target object TO is less than the first threshold Th1, the braking controller **110** causes the vehicle M to decelerate and stop by causing the brake device **210** and/or the travel driving force output device **200** to output a braking force for decelerating the vehicle M at the first deceleration B1 (step S7). At this time, as described above, in place of (or in addition to) decelerating and stopping the vehicle M, steering-based avoidance may be performed.

When an affirmative determination has been obtained in step S3, i.e., when the TTC between the vehicle M and the target object TO is less than the third threshold Th3, and there is a space where the vehicle M is able to travel in the travel path on the lateral side of the target object TO, the first preliminary operation controller **112** of the braking controller **110** determines whether or not the TTC between the vehicle M and the target object TO is less than the second threshold Th2 (step S8). When it is determined that the TTC between the vehicle M and the target object TO is greater than or equal to the second threshold Th2, the process returns to step S1.

When it is determined that the TTC between the vehicle M and the target object TO is less than the second threshold Th2, the first preliminary operation controller **112** executes the first preliminary operation (step S9). Subsequently, the first preliminary operation controller **112** determines whether or not the TTC between the vehicle M and the target object TO has increased to a value greater than or equal to the second threshold Th2 (step S10). When it is determined that the TTC between the vehicle M and the target object TO has increased to a value greater than or equal to the second threshold Th2, the process returns to step S1.

When it is determined that the TTC between the vehicle M and the target object TO has not increased to a value greater than or equal to the second threshold Th2, the braking controller **110** determines whether or not the TTC between the vehicle M and the target object TO is less than the first threshold Th1 (step S11). When it is determined that the TTC between the vehicle M and the target object TO is greater than or equal to the first threshold Th1, the process returns to step S3. When a negative determination has been obtained in step S3, the first preliminary operation is stopped and the processing from step S4 is executed. When it is determined that the TTC between the vehicle M and the target object TO is less than the first threshold Th1, the braking controller **110** causes the brake device **210** and/or the travel driving force output device **200** to output the first deceleration B1 and causes the vehicle M to decelerate and stop (step S7).

According to the above-described embodiment, when the degree of proximity between the target object TO and the vehicle M satisfies the third condition and it is determined, at a time point when the third condition is satisfied, that there is no space where the vehicle M is able to travel in both travel paths on lateral sides of the target object TO after the vehicle M avoids a collision with the target object TO in steering, it is possible to perform an appropriate preliminary operation corresponding to a surrounding situation of the target object TO by performing the second preliminary operation started at an earlier timing than the first preliminary operation.

In the above-described embodiment, in either of the first preliminary operation and the second preliminary operation, a display process, a sound output process, or a vibration output process or the like as an alert may be performed instead of the output of the braking force. In this case, as an example in which the second preliminary operation is performed in multiple steps, instead of outputting the braking

force stepwise while changing the degree of deceleration as described above, a process of differentiating a degree of attention (contrast, brightness, color, or the like) between an initial display screen and second and subsequent display screens, a process of differentiating content or a volume between an initial sound output and second and subsequent sound outputs, a process of increasing second and subsequent vibration outputs as compared with the first vibration output, or the like may be provided.

In the above-described embodiment, when the branch road to the destination set in the navigation device **50** is located on the left or right side of the lane in which the vehicle M is traveling, the lane change may be forcedly made during the preliminary operation. Thus, consequently, it is possible to move the vehicle M in a direction closer to the destination and guide the vehicle M in a state in which the object serving as the target object is not near the vehicle M.

In the example described above, the interfering object is not taken into account. Hereinafter, interfering objects may be taken into account as described below. An interfering object is an object that interferes with an available travel space on the assumption that the vehicle M has approached the target object. The interfering object is, for example, an object estimated to be located in the above available travel space when the vehicle M has approached the above available travel space. The interfering object is, for example, a vehicle located behind the vehicle M and traveling at a speed that is higher than that of the vehicle M in a lane corresponding to the above-described available travel space. The interfering object is, for example, another vehicle that passes the vehicle M, travels in the above-described available travel space and interferes with the travel of the vehicle M in the above-described available travel space.

When it is determined that the above-described available travel space is present at or near a time point when the degree of proximity between the vehicle M and the target object satisfies the third condition (for example, a time point before or after the third condition is satisfied) and it is determined that there is an interfering object that interferes with the above-described available travel space in a case where the vehicle M has approached the target object, the second preliminary operation controller **130** executes the second preliminary operation or the first preliminary operation controller **112** executes the first preliminary operation.

For example, the first preliminary operation controller **112** performs the first preliminary operation at a time point when the second condition is satisfied when the degree of proximity between the vehicle M and the target object satisfies the second condition, it is determined that the above-described available travel space is present at or near a time point when the second condition is satisfied (for example, before the second condition is satisfied or at a time point when the third condition is satisfied), and it is determined that there is no interfering object. Hereinafter, these processes related to the interfering object will be specifically described.

[Process (1)]

FIG. **6** is a diagram (1-1) for describing a process related to an interfering object. Differences from FIG. **4** will be described.

When the degree of proximity between the vehicle M and the target object satisfies the third condition, the above-described degree of proximity does not satisfy the second condition, it is determined that the above-described available travel space is present, and it is determined that there is an interfering object, the second preliminary operation controller **130** executes the second preliminary operation.

For example, the recognizer **102** recognizes that another vehicle ml is located in the lane L**3** at (or near) the time point when the vehicle M satisfies the third condition. The estimator **104** estimates the future behavior of the other vehicle ml. For example, the estimator **104** estimates a position of the other vehicle ml when the vehicle M is located near an area A**1**L or A**1**R.

FIG. **7** is a diagram (1-2) for describing a process related to an interfering object. FIG. **7** is a diagram showing an example of an estimation result of the estimator **104**. For example, when the vehicle M will be located near the area A**1**L or MR in the future, it is estimated that the other vehicle ml will be located in the area MR. That is, the estimator **104** estimates that the other vehicle ml is an interfering object.

In this case, in the situation of FIG. **6** described above, because there is no object in the area MR, the second preliminary operation is not originally performed, but the second preliminary operation controller **130** executes the second preliminary operation when it is determined that there is an interfering object.

For example, even if there is an available travel space according to steering, the second preliminary operation is executed in consideration of a possibility that another vehicle will enter this space in the future and the vehicle M will not be able to enter the space. Thereby, an appropriate operation corresponding to the surrounding situation of the target object can be performed.

[Flowchart]

FIG. **8** is a flowchart showing another example of a flow of a process executed by the driving assistance device **100**. The present process is a process that is executed when the third condition is satisfied and another vehicle is located. The other vehicle is, for example, a vehicle located behind the vehicle M in a lane adjacent to a lane in which the vehicle M is traveling and traveling at a speed higher than that of the vehicle M.

First, the estimator **104** estimates the behavior of the other vehicle (step S**100**). The driving assistance device **100** determines whether or not the other vehicle is an interfering object on the basis of an estimation result of the estimator **104** (step S**102**). When the other vehicle is an interfering object, the second preliminary operation controller **130** executes the second preliminary operation (step S**104**). When the other vehicle is not an interfering object, for example, the first preliminary operation controller **112** executes the first preliminary operation (step S**106**). For example, the first preliminary operation is executed at a time point when the second condition is satisfied. Thereby, the process of one routine of the present flowchart ends.

[Process (2)]

FIG. **9** is a diagram (2) for describing a process related to an interfering object. Differences from FIG. **4** and the like will be described.

When the degree of proximity between the vehicle M and the target object satisfies the third condition, the above-described degree of proximity does not satisfy the second condition, it is determined that the above-described available travel space is present, and it is determined that there is an interfering object, the second preliminary operation controller **130** executes the second preliminary operation.

A case where it is determined that there is no object in the area MR and there is no interfering object at a time point when the degree of proximity between the vehicle M and the target object satisfies the third condition is assumed. Subsequently, it is determined, before the second condition is

satisfied (at a time point when the degree of proximity satisfies a threshold value Th**3** #), that the above-described available travel space is present and it is estimated that there is an interfering object, the second preliminary operation controller **130** executes the second preliminary operation. That is, the second preliminary operation is performed at a timing before the first preliminary operation is performed. The threshold Th**3** # is a threshold having a magnitude between the threshold Th**3** and the threshold Th**2**.

In the example of FIG. **9**, there is another vehicle m behind the vehicle M at the time t and the other vehicle ml estimates that there is an object in the area MR at time t+1. Time t+1 is a time when it is estimated that the vehicle M is located near the area A**1**R. For example, the driving assistance device **100** may estimate the position of the vehicle M at time t+1 on the assumption that the vehicle M travels in the first preliminary operation or may estimate the position of the vehicle M at time t+1 on the assumption that the vehicle M travels on the basis of a prescribed standard different from that of the first preliminary operation.

As described above, when it is determined that there is an interfering object after the third condition is satisfied, the driving assistance device **100** can perform a preliminary operation at an early stage by performing the second preliminary operation. Thereby, an appropriate operation corresponding to the surrounding situation of the target object can be performed.

[Process (3)]

FIG. **10** is a diagram (3) for describing a process related to an interfering object. Differences from FIG. **9** and the like will be described.

When the degree of proximity between the vehicle M and the target object satisfies the third condition, the above-described degree of proximity does not satisfy the second condition, it is determined that the above-described available travel space is present, and it is estimated that there is an interfering object, the first preliminary operation controller **112** executes the first preliminary operation.

A case where it is determined that there is no object in the area MR and there is no interfering object at a time point when the degree of proximity between the vehicle M and the target object satisfies the third condition is assumed. Subsequently, before the second condition is satisfied (at a time point when the degree of proximity satisfies a threshold value Th**2** #), the first preliminary operation controller **112** executes the first preliminary operation when it is determined that the above-described available travel space is present and there is an interfering object. That is, a timing at which the first preliminary operation is performed is advanced. The threshold Th**2** # is a threshold having a magnitude between the threshold Th**3** and the threshold Th**2**.

As described above, when it is determined that an interfering object is located after the third condition is satisfied, the driving assistance device **100** can perform a preliminary operation at an early stage by performing the first preliminary operation. Thereby, an appropriate operation corresponding to the surrounding situation of the target object can be performed.

[Process (4)]

FIG. **11** is a diagram (4) for describing a process related to an interfering object. Differences from FIG. **4** and the like will be described.

For example, the first preliminary operation controller **112** performs the first preliminary operation when the degree of proximity between the vehicle M and the target object satisfies the second condition, it is determined that the above-described available travel space is present at or near a time point when the second condition is satisfied (before the second condition is satisfied or at a time point when the third condition is satisfied), and it is determined that there is no interfering object. When the degree of proximity between the vehicle M and the target object satisfies the second condition, it is determined, at a time point when the degree of proximity does not satisfy the first condition, that the above-described available travel space is present, and it is determined that the interfering object is not present, the first preliminary operation controller **112** makes the transition to the first preliminary operation having a higher operation level than the first preliminary operation that is performed when it is determined that the interfering object is not located.

A case where it is determined that there is no object in the area A**1**R and there is no interfering object at a time point when the degree of proximity between the vehicle M and the target object satisfies the second condition is assumed. Subsequently, before the first condition is satisfied (at a time point when the degree of proximity satisfies the threshold Th**1.5**), the first preliminary operation controller **112** changes content of the first preliminary operation when it is determined that the above-described available travel space is present and it is estimated that there is an interfering object. For example, the first preliminary operation controller **112** controls the vehicle M by increasing the deceleration from the deceleration B**2** to deceleration B**2**#. Also, the first preliminary operation controller **112** may increase the degree of alarm. A threshold Th**1.5**# is a threshold having a magnitude between the threshold Th**2** and the threshold Th**1**.

As described above, when it is determined that there is an interfering object after the second condition is satisfied, the driving assistance device **100** can perform an appropriate preliminary operation by changing the content of the first preliminary operation. Thereby, an appropriate operation corresponding to the surrounding situation of the target object can be performed.

All the above-described processes may be performed or some processes may be performed selectively. Also, in the above-described example, when the vehicle M has approached the target object, another vehicle located in the above-described available travel space is determined to be an interfering object. Alternatively (or additionally), the interfering object may be another vehicle located within a prescribed distance (several tens of meters, 100 meters, or several hundreds of meters) in front of and behind the vehicle M.

The embodiment described above can be represented as follows.

A driving assistance device including:

a storage medium storing computer-readable instructions; and

a processor connected to the storage medium, the processor executing the computer-readable instructions to:

refer to an output of a detection device for detecting that an object is located in front of a vehicle and instruct a brake device of the vehicle to stop the vehicle when a degree of proximity between a target object among objects and the vehicle satisfies a first condition;

instruct a steering device of the vehicle to avoid a collision with the target object in steering;

perform a first preliminary operation when the degree of proximity between the target object and the vehicle satisfies a second condition and it is determined, at or near a time point when the second condition is satisfied, that there is an available travel space in one of travel

paths on lateral sides of the target object after the vehicle avoids the collision with the object in the steering; and

perform a second preliminary operation when the degree of proximity between the target object and the vehicle satisfies a third condition and it is determined, at or near a time point when the third condition is satisfied, that there is no available travel space in both travel paths on lateral sides of the target object after the vehicle avoids the collision with the object in the steering,

wherein the first condition is a condition that is satisfied when the degree of proximity is higher than that of the second condition,

wherein the second condition is a condition that is satisfied when the degree of proximity is higher than that of the third condition, and

wherein, when it is determined, at or near a time point when the degree of proximity satisfies the third condition, that the available travel space is present and it is estimated that there is an interfering object that interferes with the available travel space on the assumption that the vehicle has approached the target object, a second preliminary operation controller performs the second preliminary operation or a first preliminary operation controller performs the first preliminary operation.

Although modes for carrying out the present invention have been described above using embodiments, the present invention is not limited to the embodiments and various modifications and substitutions can also be made without departing from the scope and spirit of the present invention.

What is claimed is:

1. A driving assistance device comprising:

a storage medium storing computer-readable instructions; and

at least one processor connected to the storage medium, the at least one processor executing the computer-readable instructions to:

execute referring process of referring to an output of a detection device for detecting that an object is located in front of a vehicle;

execute one or both of a braking control process of instructing a brake device of the vehicle to stop the vehicle when an indicator value that decreases as the vehicle approaches the object is less than a first threshold, and a steering-based avoidance control process of instructing a steering device of the vehicle to avoid a collision with the object in steering;

execute a first preliminary operation control process of performing a first preliminary operation of notifying a driver of the vehicle that the object is present when the indicator value is less than a second threshold and it is determined, at or near a time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel on one of left and right sides of the object after the vehicle avoids the collision with the object in the steering; and

execute a second preliminary operation control process of performing a second preliminary operation of notifying the driver of the vehicle that the object is present when the indicator value is less than a third threshold and it is determined, at a time point when the indicator value is less than the third threshold, that there is no travel path along which the vehicle is able to travel on both left and right sides of the object after the vehicle avoids the collision with the object in the steering,

wherein the first threshold is less than the second threshold and the second threshold is less than the third threshold,

wherein the second preliminary operation or the first preliminary operation is executed when it is determined, at the time point when the indicator value is less than the third threshold, that there is a travel path along which the vehicle is able to travel and it is estimated that there is an interfering object that interferes with the travel path along which the vehicle is able to travel on the assumption that the vehicle has approached the object,

the first preliminary operation includes some or all of outputting braking force, displaying, outputting sound, and outputting vibration, and

the second preliminary operation includes some or all of outputting braking force, displaying, outputting sound, and outputting vibration.

2. The driving assistance device according to claim **1**, wherein the at least one processor performs the first preliminary operation at the time point when the indicator value is less than the second threshold, it is determined, at the time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel, and it is estimated that there is no interfering object.

3. The driving assistance device according to claim **1**, wherein the interfering object is an object estimated to be located in an available travel space on the assumption that the vehicle has approached the available travel space.

4. The driving assistance device according to claim **1**, wherein the interfering object is another vehicle located behind the vehicle and traveling at a higher speed than the vehicle in a lane corresponding to an available travel space.

5. The driving assistance device according to claim **1**, wherein the at least one processor performs the second preliminary operation when the indicator value is less than the third threshold, the indicator value is not less than the second threshold, it is determined that there is a travel path along which the vehicle is able to travel, and it is estimated that the interfering object is present.

6. The driving assistance device according to claim **1**, wherein the at least one processor performs the first preliminary operation when the indicator value is less than the third threshold, the indicator value is not less than the second threshold, it is determined that there is a travel path along which the vehicle is able to travel, and it is estimated that the interfering object is present.

7. The driving assistance device according to claim **1**,

wherein the at least one processor performs the first preliminary operation when the indicator value is less than the second threshold, it is determined, at the time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel, and it is estimated that the interfering object is not present, and

wherein, when the indicator value is less than the second threshold, it is determined, at a time point when the indicator value is not less than a first threshold, that there is a travel path along which the vehicle is able to travel, and it is estimated that the interfering object is present, the at least one processor makes a transition to the first preliminary operation having a higher operation level than the first preliminary operation that is performed when it is estimated that the interfering object is not present.

8. A driving assistance method comprising:

executing, by a driving assistance, referring process of referring to an output of a detection device for detecting that an object is located in front of a vehicle;

executing, by a driving assistance device, one or both of a braking control process of instructing a brake device of the vehicle to stop the vehicle when an indicator value that decreases as the vehicle approaches the object is less than a first threshold, and a steering-based avoidance control process of instructing a steering device of the vehicle to avoid a collision with the object in steering;

executing, by the driving assistance device, a first preliminary operation control process of performing a first preliminary operation of notifying a driver of the vehicle that the object is present when the indicator value is less than a second threshold and it is determined, at a time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel on one of left and right sides of the object after the vehicle avoids the collision with the object in the steering; and

executing, by the driving assistance device, a second preliminary operation control process of performing a second preliminary operation of notifying the driver of the vehicle that the object is present when the indicator value is less than a third threshold and it is determined, at a time point when the indicator value is less than the third threshold, that there is no travel path along which the vehicle is able to travel on both left and right sides of the object after the vehicle avoids the collision with the object in the steering,

wherein the first threshold is less than the second threshold and the second threshold is less than the third threshold,

wherein the second preliminary operation or the first preliminary operation is executed when it is determined, at the time point when the indicator value is less than the third threshold, that there is a travel path along which the vehicle is able to travel and it is estimated that there is an interfering object that interferes with the travel path along which the vehicle is able to travel on the assumption that the vehicle has approached the object,

the first preliminary operation includes some or all of outputting braking force, displaying, outputting sound, and outputting vibration, and

the second preliminary operation includes some or all of outputting braking force, displaying, outputting sound, and outputting vibration.

9. A non-transitory computer storage medium storing a program for causing a computer to:

execute referring process of referring to an output of a detection device for detecting that an object is located in front of a vehicle;

execute one or both of a braking control process of instructing a brake device of the vehicle to stop the vehicle when an indicator value that decreases as the vehicle approaches the object is less than a first threshold, and a steering-based avoidance control process of instructing a steering device of the vehicle to avoid a collision with the object in steering;

execute a first preliminary operation control process of performing a first preliminary operation of notifying a driver of the vehicle that the object is present when the indicator value is less than a second threshold and it is determined, at a time point when the indicator value is less than the second threshold, that there is a travel path along which the vehicle is able to travel on one of left and right sides of the object after the vehicle avoids the collision with the object in the steering; and

execute a second preliminary operation control process of performing a second preliminary operation of notifying the driver of the vehicle that the object is present when the indicator value is less than a third threshold and it is determined, at a time point when the indicator value is less than the third threshold, that there is no travel path along which the vehicle is able to travel on both left and right sides of the object after the vehicle avoids the collision with the object in the steering,

wherein the first threshold is less than the second threshold and the second threshold is less than the third threshold,

wherein the second preliminary operation or the first preliminary operation is executed when it is determined, at the time point when the indicator value is less than the third threshold, that there is a travel path along which the vehicle is able to travel and it is estimated that there is an interfering object that interferes with the travel path along which the vehicle is able to travel on the assumption that the vehicle has approached the object,

the first preliminary operation includes some or all of outputting braking force, displaying, outputting sound, and outputting vibration, and

the second preliminary operation includes some or all of outputting braking force, displaying, outputting sound, and outputting vibration.

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