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Yoshino et al.

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(54) **ROUTE PLANNING DEVICE AND ROUTE PLANNING METHOD**

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(51) **Int. Cl.**

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A01D 101/00	(2006.01)
G05D 1/644	(2024.01)
G05D 105/15	(2024.01)
G05D 107/20	(2024.01)

(52) **U.S. Cl.**

CPC ***A01D 34/008*** (2013.01); ***G05D 1/644*** (2024.01); *A01D 2101/00* (2013.01); *G05D 2105/15* (2024.01); *G05D 2107/23* (2024.01)

(58) **Field of Classification Search**

CPC .. A01D 34/008; A01D 2101/00; G05D 1/644; G05D 2105/15; G05D 2107/23; G05D 2109/10

See application file for complete search history.

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(57) **ABSTRACT**

A route planning device according to the present disclosure acquires target work start position information, target work start posture information, current position information, and current posture information, and generates a movement route for causing a work machine to reach a target work start position in a target work start posture, by combining a forward route along which the work machine moves forward and a backward route along which the work machine moves backward, based on the target work start position information, the target work start posture information, the current position information, and the current posture information.

13 Claims, 9 Drawing Sheets

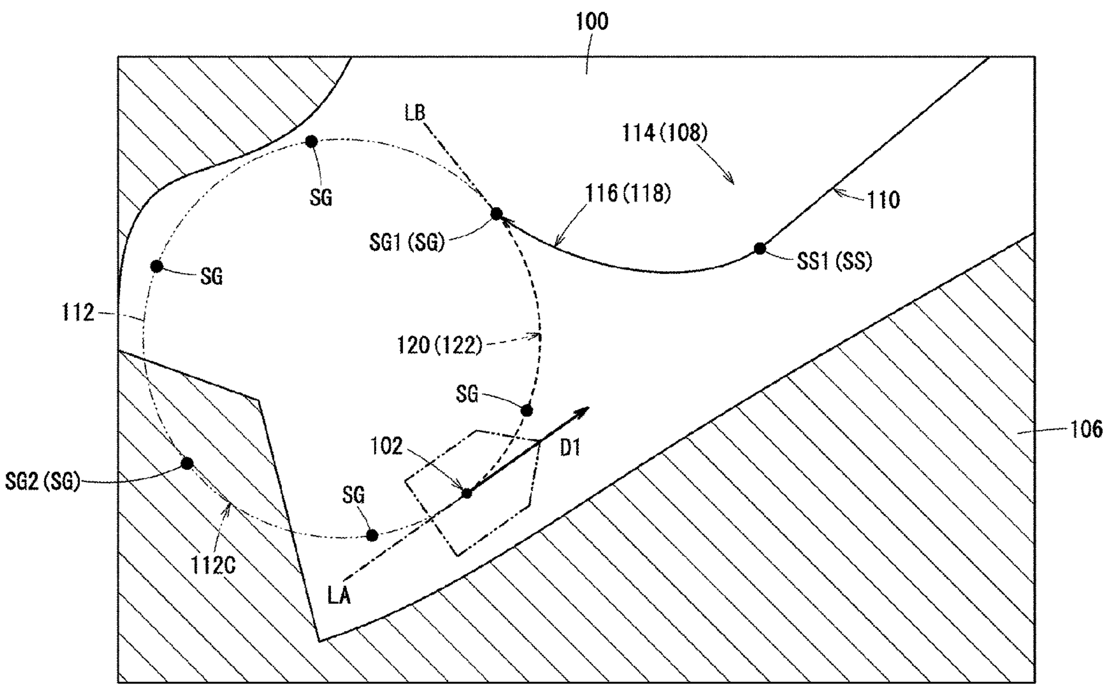
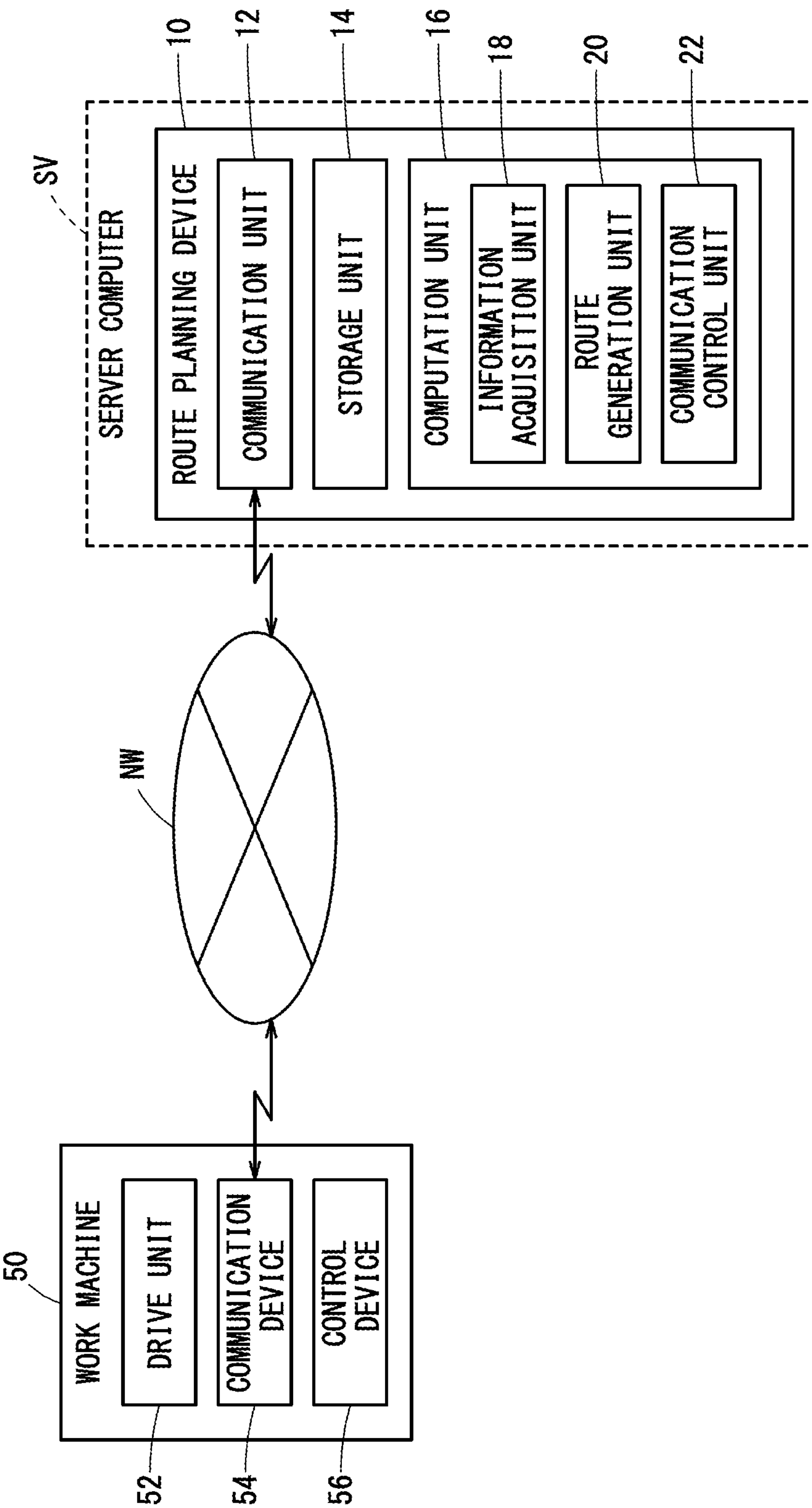


FIG. 1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10
ROUTE PLANNING DEVICE
12
COMMUNICATION UNIT
14
STORAGE UNIT
16
COMPUTATION UNIT
18
INFORMATION ACQUISITION UNIT
20
ROUTE GENERATION UNIT
22
COMMUNICATION CONTROL UNIT
NW
50
WORK MACHINE
52
DRIVE UNIT
54
COMMUNICATION DEVICE
56
CONTROL DEVICE

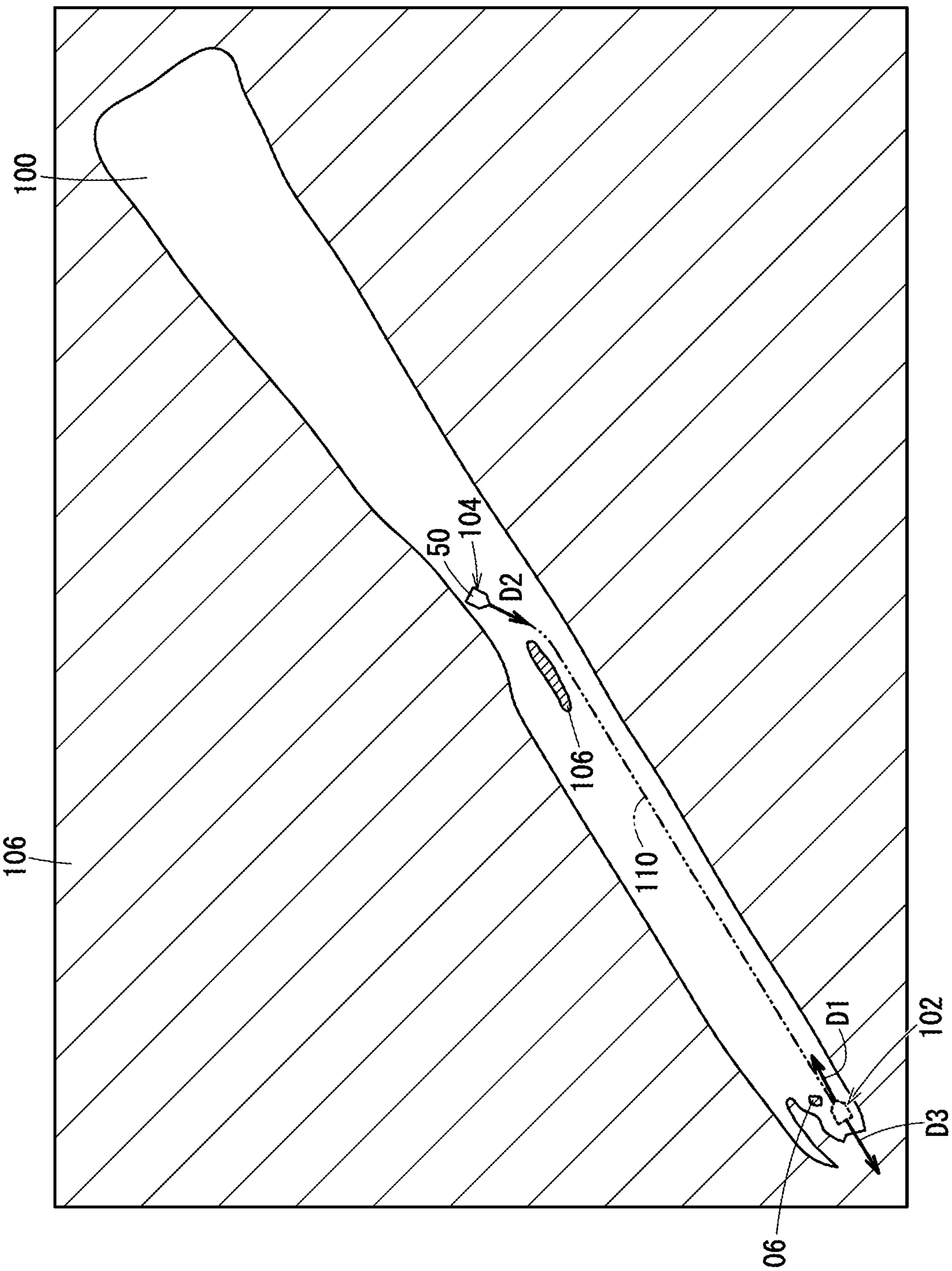
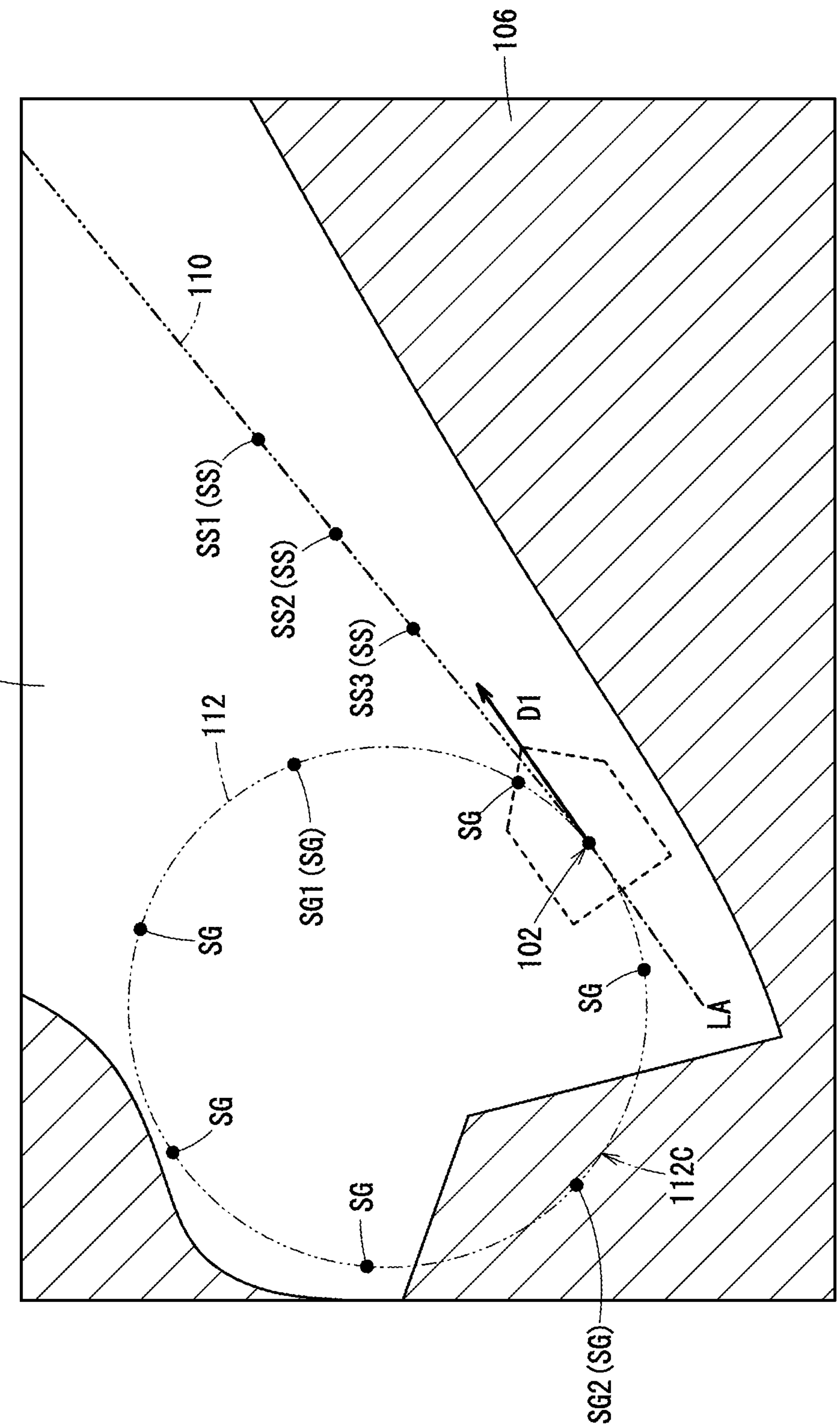


FIG. 2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SS2 (SS)
SS3 (SS)
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112
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SG1 (SG)
102
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SG
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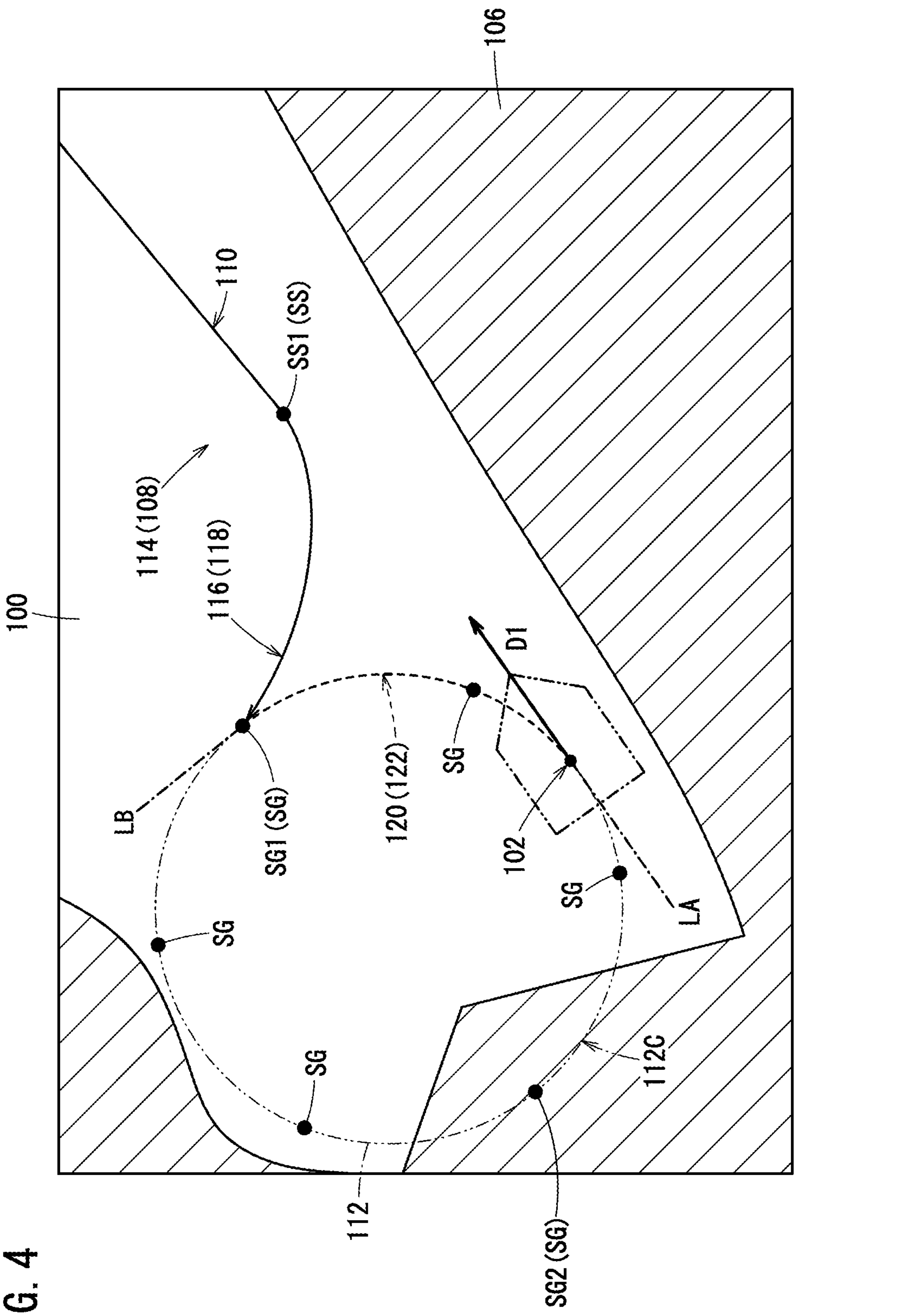
112C
SG2 (SG)

FIG. 3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110
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SG
112C
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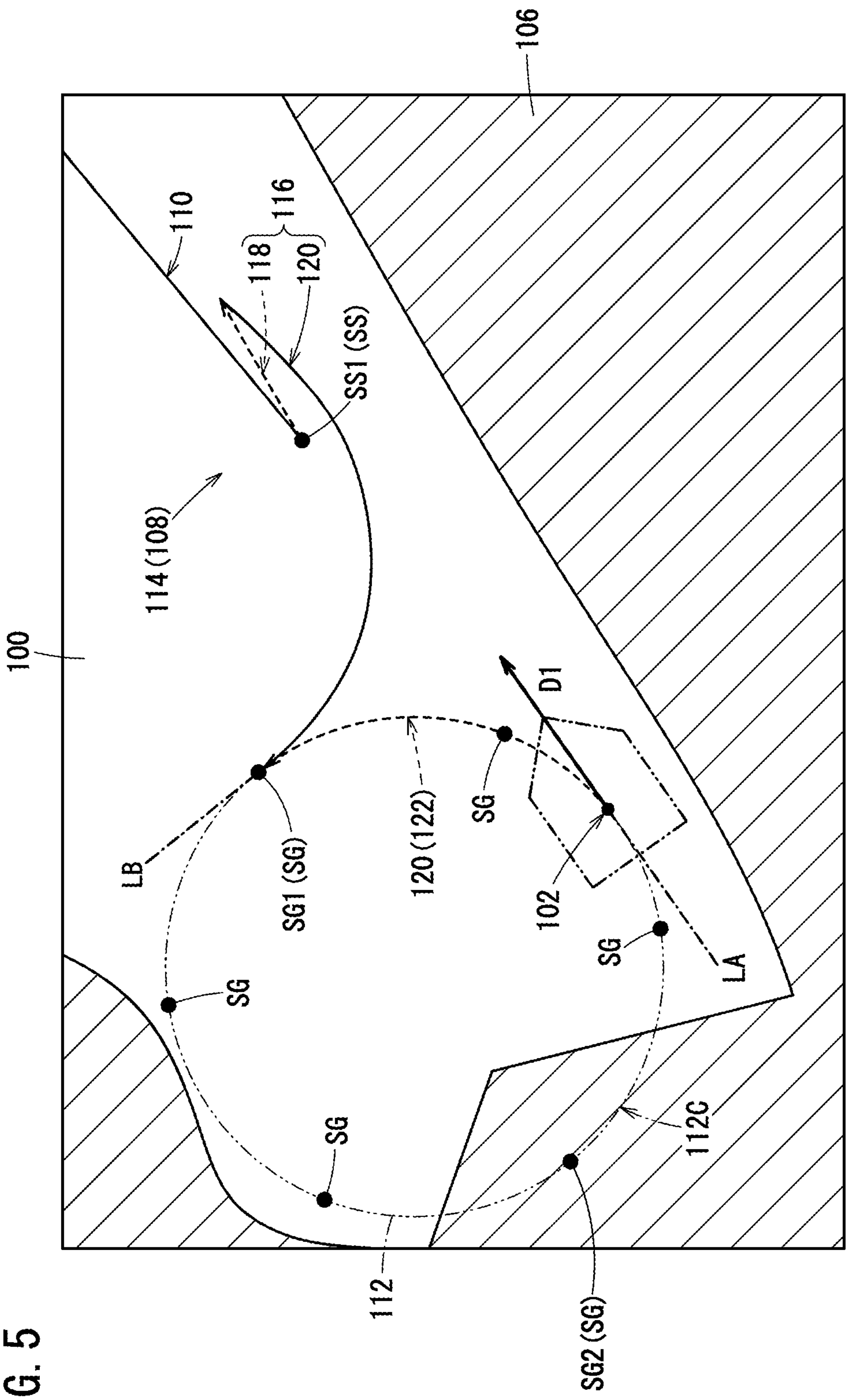
SG2 (SG)

FIG. 4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D1
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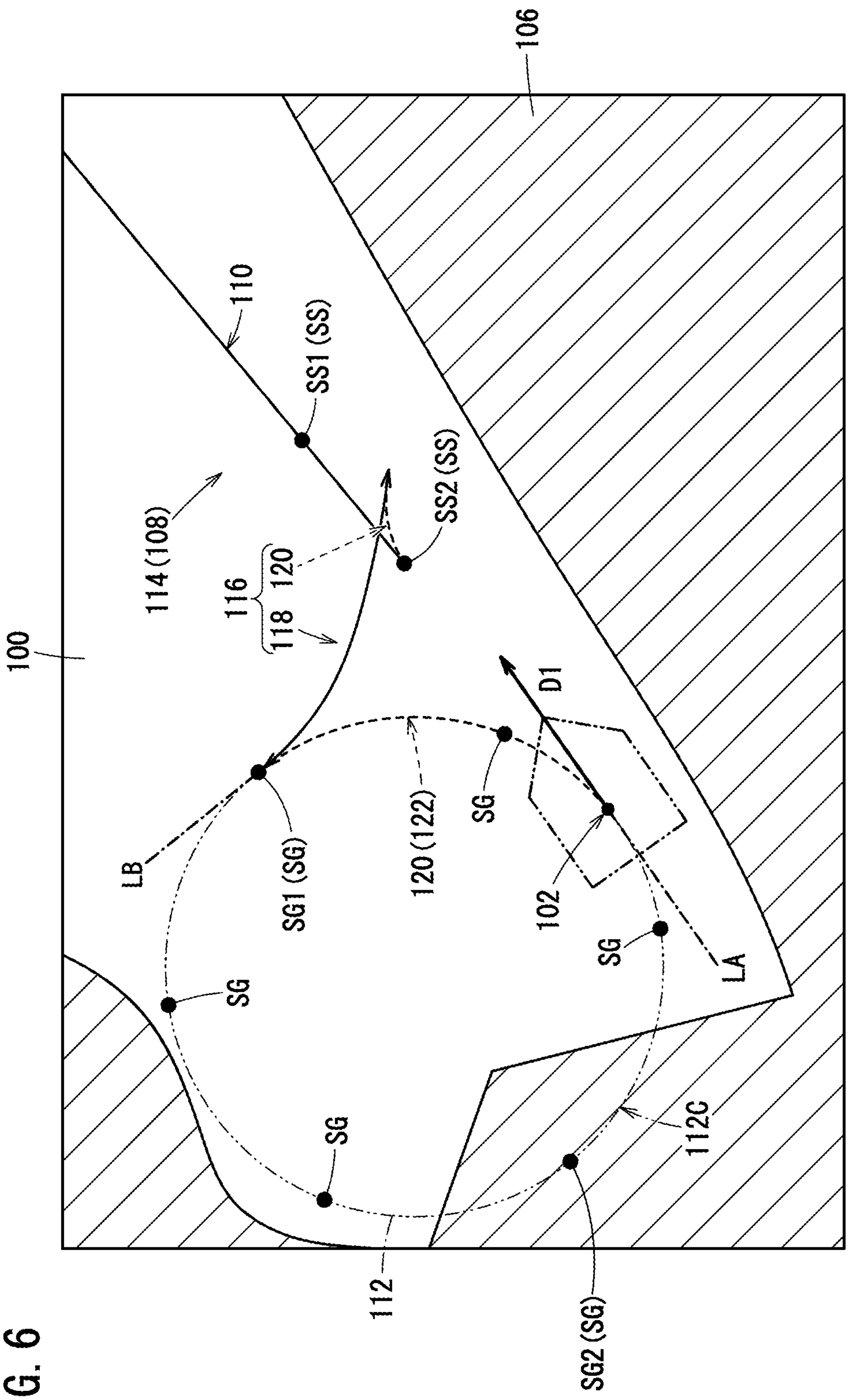
112C
112
SG2 (SG)

FIG. 5

FIG. 6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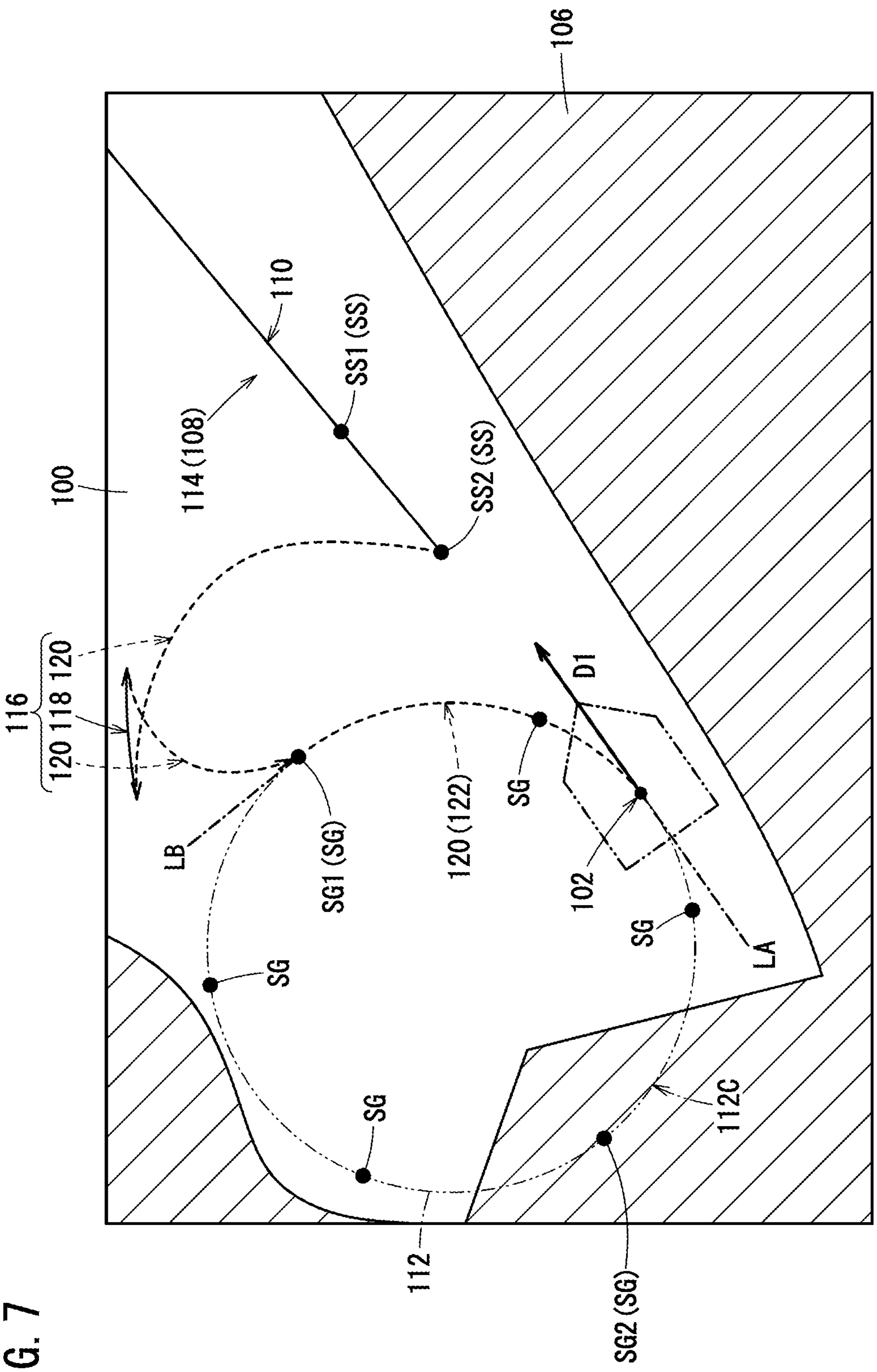
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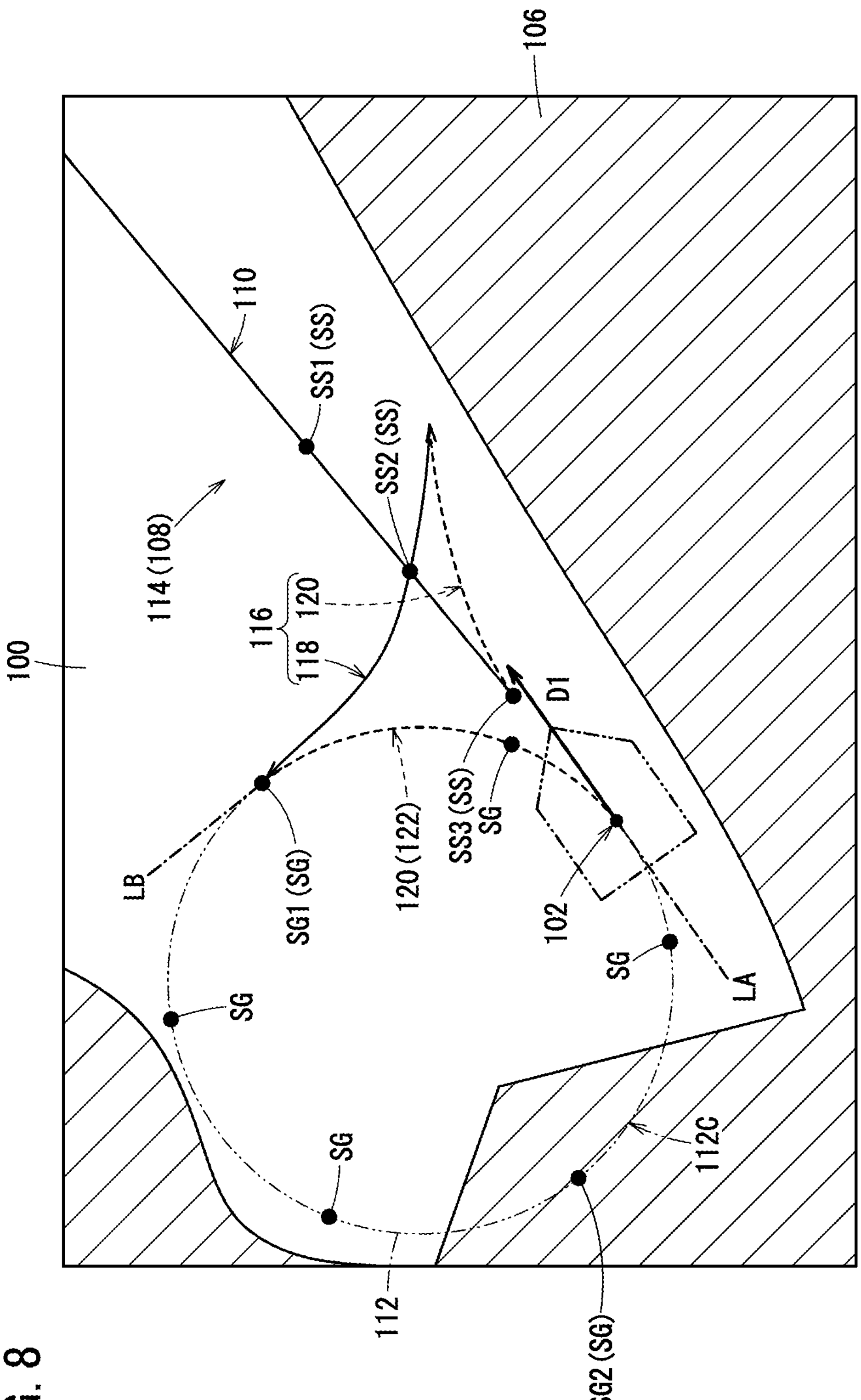
SG
112C
112
SG2 (SG)

FIG. 7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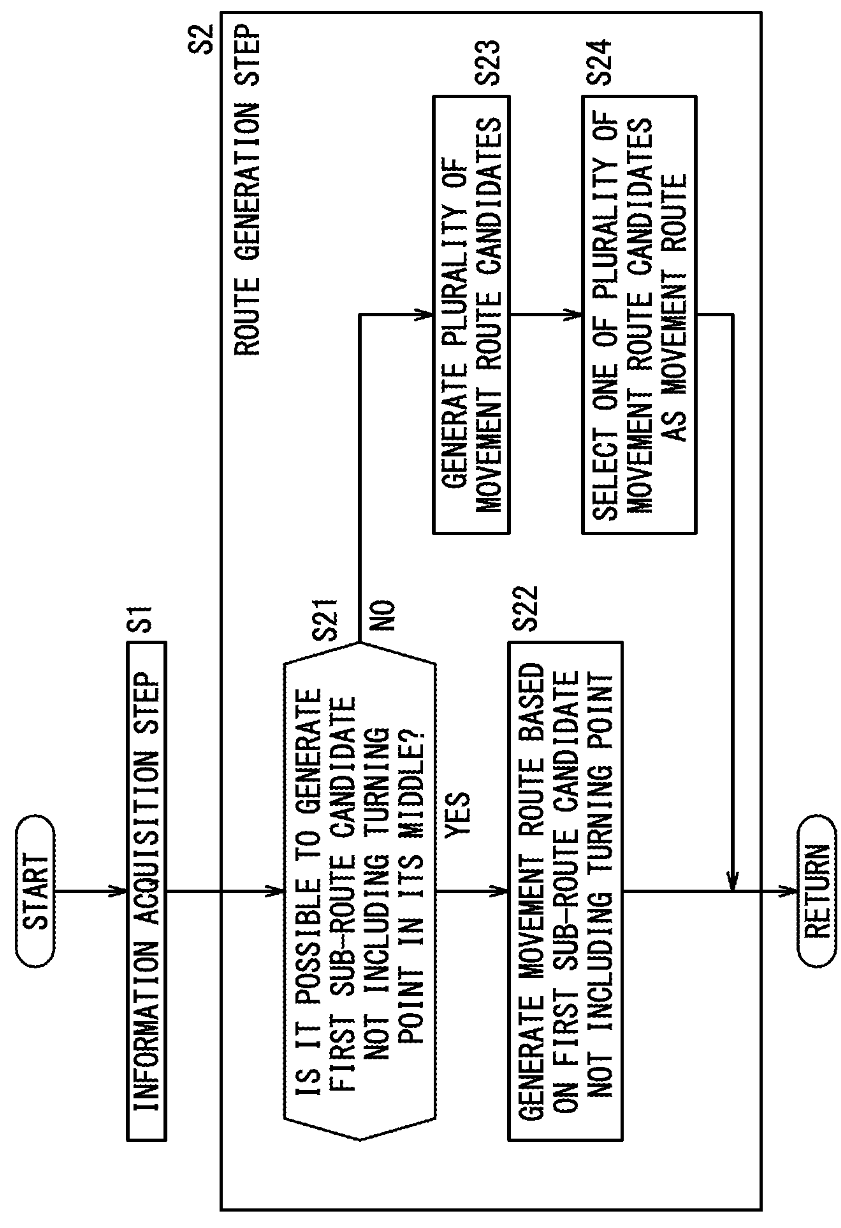
SG1 (SG)
LB
102
SG
LA
SG
SG
112C
112
SG2 (SG)

FIG. 8

FIG. 9


START
S1
INFORMATION ACQUISITION STEP
S2
ROUTE GENERATION STEP
S21
IS IT POSSIBLE TO GENERATE FIRST SUB-ROUTE CANDIDATE NOT INCLUDING TURNING POINT IN ITS MIDDLE?
YES
NO
S22
GENERATE MOVEMENT ROUTE BASED ON FIRST SUB-ROUTE CANDIDATE NOT INCLUDING TURNING POINT
S23
GENERATE PLURALITY OF MOVEMENT ROUTE CANDIDATES
S24
SELECT ONE OF PLURALITY OF MOVEMENT ROUTE CANDIDATES AS MOVEMENT ROUTE
RETURN

ROUTE PLANNING DEVICE AND ROUTE PLANNING METHOD

BACKGROUND OF THE INVENTION

Field of the Invention

The present disclosure relates to a route planning device and a route planning method.

Description of the Related Art

JP 2001-344017 A discloses an automatic traveling machine capable of executing lawn mowing while automatically moving based on information indicating a work area to be mowed.

SUMMARY OF THE INVENTION

In order to cause a work machine such as a lawn mower to perform work, the work machine must be moved to a work start position before the work is started. In this regard, there is a long-awaited need for appropriate technology.

The present invention has the object of solving the aforementioned problem.

According to a first aspect of the present invention, there is provided a route planning device comprising one or more processors that execute computer-executable instructions stored in a memory, wherein the one or more processors execute the computer-executable instructions to cause the route planning device to: acquire target work start position information indicating a target work start position that is a target position at which a work machine is caused to start work, target work start posture information indicating a target work start posture that is a target posture of the work machine at the target work start position, current position information indicating a current position of the work machine, and current posture information indicating a posture of the work machine at the current position; and generate a movement route for causing the work machine to reach the target work start position in the target work start posture, by combining a forward route along which the work machine moves forward and a backward route along which the work machine moves backward, based on the target work start position information, the target work start posture information, the current position information, and the current posture information.

According to a second aspect of the present invention, there is provided a route planning method comprising: acquiring target work start position information indicating a target work start position that is a target position at which a work machine is caused to start work, target work start posture information indicating a target work start posture that is a target posture of the work machine at the target work start position, current position information indicating a current position of the work machine, and current posture information indicating a posture of the work machine at the current position; and generating a movement route for causing the work machine to reach the target work start position in the target work start posture, by combining a forward route along which the work machine moves forward and a backward route along which the work machine moves backward, based on the target work start position information, the target work start posture information, the current position information, and the current posture information.

According to the present invention, it is possible to cause the work machine to reach the target work start position in the target work start posture.

The above and other objects, features, and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings, in which a preferred embodiment of the present invention is shown by way of illustrative example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing a work machine and a route planning device according to an embodiment;

FIG. **2** is a plan view schematically showing a work area;

FIG. **3** is a plan view for explaining a method for generating a movement route;

FIG. **4** is a plan view for explaining the method for generating the movement route;

FIG. **5** is a plan view for explaining the method for generating the movement route;

FIG. **6** is a plan view for explaining the method for generating the movement route;

FIG. **7** is a plan view for explaining the method for generating the movement route;

FIG. **8** is a plan view for explaining the method for generating the movement route; and

FIG. **9** is a flowchart showing a route planning method according to an embodiment.

DETAILED DESCRIPTION OF THE INVENTION

It is possible to derive a global route connecting any two points, based on a route generation algorithm such as rapidly exploring random tree (RRT). When a work machine is located at a place different from a target work start position that is a target position at which the work machine is caused to start work, it is conceivable to derive a route along which the work machine is to be moved from the current position of the work machine to the target work start position, based on a route generation algorithm.

However, route generation algorithms such as RRT do not take into account the posture of the work machine. Therefore, when the work machine is simply moved along the route generated using the route generation algorithm such as the RRT, the posture of the work machine that has reached the target work start position may not be a posture suitable for starting the work. For example, the orientation of the work machine that has reached the target work start position may be opposite to the orientation of the work machine suitable for starting the work. As a result, the work machine cannot start the work smoothly.

As a method for adjusting the posture (orientation) of the work machine, it is conceivable to cause the work machine to make a pivot turn. However, when the pivot turn is made, for example, wheels or the like (not shown) provided in the work machine relatively strongly rub the traveling surface (lawn grass). When the traveling surface (lawn grass) is strongly rubbed by wheels or the like, the traveling surface is damaged. Therefore, it is not preferable to make the pivot turn.

In view of the above-described problems, an embodiment will be described below.

Embodiment

FIG. **1** is a block diagram showing a work machine **50** and a route planning device **10** according to an embodiment.

The work machine **50** is a machine capable of performing work while autonomously traveling. The work is, for example, lawn mowing. The work machine **50** is, for example, a lawn mower, but is not limited thereto.

The work machine **50** includes a drive unit **52** for performing work. The drive unit **52** includes, for example, a motor (not shown) for driving wheels (not shown) and the like provided in the work machine **50**, a rotary cutter (not shown) for mowing, and a motor (not shown) for rotating the rotary cutter, but the present invention is not limited thereto.

The work machine **50** further includes a communication device **54** and a control device **56**. The communication device **54** is a device for communicating via a network NW. The network NW is, for example, the Internet, but may be a local area network (LAN). The control device **56** is, for example, an electronic control unit (ECU). The control device **56** includes, for example, a processor, a memory, and the like (not shown). The control device **56** can cause the work machine **50** to autonomously traveling by causing the processor to execute a program stored in the memory, for example. The control device **56** may control the drive unit **52** and the communication device **54** based on a program.

The route planning device **10** is a computer that generates a movement route **108** (described later) for the work machine **50**. The route planning device **10** is provided in a server computer SV installed in a data center or the like, for example, but may be provided in the work machine **50** (the control device **56**). In the present embodiment, a case where the route planning device **10** is provided in the server computer SV will be described as an example.

The route planning device **10** includes a communication unit **12**, a storage unit **14**, and a computation unit **16**.

The communication unit **12** includes a communication module (not shown). The communication unit **12** is communicably connected to the communication device **54** of the work machine **50** via the network NW.

The storage unit **14** includes, for example, one or more memories. More specifically, the storage unit **14** includes, for example, a nonvolatile memory such as a random access memory (RAM), and a volatile memory such as a read only memory (ROM) and a flash memory. The nonvolatile memory stores, for example, map information, a computer-executable program, and the like. The volatile memory stores, for example, data or the like that is temporarily necessary when a processor (the computation unit **16**) described below performs computation based on a program.

The computation unit **16** includes predetermined processing circuitry. The processing circuitry includes one or more processors such as a central processing unit (CPU) and a graphics processing unit (GPU). At least a part of the processing circuitry may be realized by a predetermined integrated circuit such as an application specific integrated circuit (ASIC) or a field-programmable gate array (FPGA).

The computation unit **16** includes an information acquisition unit **18**, a route generation unit **20**, and a communication control unit **22**. The information acquisition unit **18**, the route generation unit **20**, and the communication control unit **22** are realized by the processor of the computation unit **16** executing a program stored in the memory of the storage unit **14**. At least a part of the information acquisition unit **18**, the route generation unit **20**, and the communication control unit **22** may be realized by the above-described integrated circuit or the like.

The information acquisition unit **18** acquires work area information, target work start position information, target work start posture information, current position information (initial position information), and current posture information (initial posture information).

The work area information is information indicating a work area **100** (see also FIG. **2**). The work area **100** is an area in which work is performed by the work machine **50**. In a case where the work machine **50** is a lawn mower, the work area **100** is an area where lawn mowing is performed.

FIG. **2** is a plan view schematically showing the work area **100**.

The work area **100** is specified based on, for example, teaching data created in advance for playback control of the work machine **50**. Therefore, the information acquisition unit **18** can acquire the work area information by acquiring information indicating the teaching data.

FIG. **2** further shows a travel restriction area **106**. The travel restriction area **106** is an area in which travel of the work machine **50** is restricted. The travel restriction area **106** can be specified as an area other than the work area **100**, based on the work area information. The travel restriction area **106** may also include an area in which an obstacle (rock, fence, or the like) that inhibits travel of the work machine **50** is located.

The target work start position information is information indicating a target work start position **102**. The target work start position **102** is a position at which the work machine **50** is planned to start the work. Similarly to the work area **100**, the target work start position information is specified based on, for example, teaching data of the work machine **50**. The information acquisition unit **18** can acquire the target work start position information by acquiring information indicating the teaching data of the work machine **50**.

The target work start posture information is information indicating a target work start posture. The target work start posture is a target posture of the work machine **50** at the target work start position **102**. The target work start posture information indicates, as the target work start posture, the orientation (an arrow D**1** in FIG. **2**) of the work machine **50** at the target work start position **102**, for example, but the target work start posture information is not limited thereto.

The target work start posture information is supplied from a user of the work machine **50** to the information acquisition unit **18**, for example, but the present invention is not limited thereto. For example, the information acquisition unit **18** may acquire, based on the teaching data described above, information indicating a planned traveling direction of the work machine **50** immediately after the start of the work. The information indicating the planned traveling direction of the work machine **50** immediately after the start of the work indicates the orientation (the arrow D**1**) of the work machine **50** at the target work start position **102**. Therefore, the information indicating the planned traveling direction of the work machine **50** immediately after the start of the work is acquired as the target work start posture information.

The current position information is an initial position of the work machine **50** before starting to move toward the target work start position **102**. That is, the current position information is information indicating a current position **104** of the work machine **50**. For example, the current position information is supplied from a positioning sensor (not shown) provided in the work machine **50** to the information acquisition unit **18** via the network NW, but the present invention is not limited thereto.

The current posture information is information indicating a current posture (initial posture) which is the posture of the work machine **50** at the current position **104**. The current posture information indicates, for example, the orientation (an arrow D**2** in FIG. **2**) of the work machine **50** at the current position **104**, but the current posture information is not limited thereto. The current posture information is supplied to the information acquisition unit **18** via the network NW from, for example, an attitude sensor, a direction sensor, or the like (not shown) provided in the work machine **50**, but the present invention is not limited thereto.

The route generation unit **20** generates (creates) the movement route **108** described later, based on the work area information, the target work start position information, the target work start posture information, the current position information, and the current posture information. The movement route **108** is a route for causing the work machine **50** to reach the target work start position **102** in the target work start posture. More specifically, the route generation unit **20** generates the movement route **108**, for example, in the manner described below.

The route generation unit **20** generates a global route **110** connecting the current position **104** and the target work start position **102**, based on the work area information, the target work start position information, the current position information, and a predetermined route generation algorithm. An example of the global route **110** is shown in FIG. **2**.

The predetermined route generation algorithm is, for example, the above-described RRT, but is not limited thereto. The RRT is preferable in that it is an algorithm capable of generating the global route **110** at a relatively high speed.

Based on the work area information, the route generation unit **20** can generate the global route **110** that falls within the range of the work area **100**. As a result, it is possible to prevent the work machine **50** from moving within the travel restriction area **106**.

However, when the work machine **50** is simply moved along the global route **110**, the posture of the work machine **50** at the target work start position **102** may not coincide with the target work start posture. More specifically, as shown in FIG. **2**, for example, the orientation (an arrow D**3**) of the work machine **50** that has reached the target work start position **102** may not coincide with the orientation (the arrow D**1**) of the work machine **50** for starting the work.

Therefore, in order to cause the work machine **50** to reach the target work start position **102** in the target work start posture, the route generation unit **20** generates the movement route **108** in the manner described below.

FIG. **3** is a plan view for explaining a method for generating the movement route **108**.

The route generation unit **20** generates the movement route **108** by changing a part of the global route **110**. The route generation unit **20** sets an imaginary circle **112** as shown in FIG. **3**, based on the target work start position information and the target work start posture information. The imaginary circle **112** is an imaginary circle in contact with an imaginary straight line LA. The imaginary straight line LA is an imaginary straight line that extends along the planned traveling direction (the arrow D**1**) of the work machine **50** indicated by the target work start posture, and that passes through the target work start position **102**. A contact point between the imaginary circle **112** and the imaginary straight line LA coincides with the target work start position **102**, but the present invention is not limited thereto. The radius of the imaginary circle **112** is equal to, for example, the minimum turning radius of the work machine **50**, but is not limited thereto.

In addition, the route generation unit **20** sets a plurality of sub-start position candidates SS (SS**1** to SS**3**) on the global route **110**, and sets a plurality of sub-goal position candidates SG (SG**1**) on a circumference **112**C of the imaginary circle **112**.

The sub-start position candidate SS is a candidate for a sub-start position set on the movement route **108**. The sub-start position is a position at which the work machine **50** starts moving out of the global route **110**. The plurality of sub-start position candidates SS are arranged at regular intervals on the global route **110** based on, for example, intervals determined in advance. Note that the sub-start position candidates SS may be set within a range of a predetermined distance from the target work start position **102**. As a result, the number of the sub-start position candidates SS can be suppressed, and thus the processing load of the route generation unit **20** when generating a movement route candidate **114** described later can be reduced.

The sub-goal position candidate SG is a candidate for a sub-goal position set on the movement route **108**. The sub-goal position is a target position of the work machine **50** at the time when the work machine **50** moves from the global route **110** to the imaginary circle **112**. Further, the sub-goal position is a turning point at which the work machine **50** that has reached the imaginary circle **112** turns toward the target work start position **102**. The plurality of sub-goal position candidates SG are arranged at regular intervals on the circumference **112**C of the imaginary circle **112** based on, for example, intervals determined in advance.

Note that the sub-goal position candidates SG may be set within a range of a predetermined distance from the target work start position **102**. As a result, the number of the sub-goal position candidates SG can be suppressed, and thus the processing load of the route generation unit **20** when generating the movement route candidate **114** described later can be reduced.

Further, the route generation unit **20** does not set the sub-goal position candidates SG in the travel restriction area **106**. Alternatively, the route generation unit **20** does not use the sub-goal position candidates SG included within the travel restriction area **106** to generate the movement route **108**.

Each of FIGS. **4** to **8** is a plan view for explaining the method for generating the movement route **108**.

Based on the work area information, the current posture information, the sub-start position candidate SS, and the sub-goal position candidate SG, the route generation unit **20** generates the movement route candidate **114**, which is a candidate for the movement route **108**. Specifically, based on the work area information, the route generation unit **20** generates the movement route candidate **114** such that the movement route candidate **114** is included in the work area **100**.

The movement route candidate **114** includes a first sub-route candidate **116**. The first sub-route candidate **116** is a candidate for a route along which the work machine **50** is to be moved from the sub-start position candidate SS to the sub-goal position candidate SG. For example, the first sub-route candidate **116** is generated such that the orientation of the work machine **50** that has reached the sub-goal position candidate SG is along an imaginary straight line LB. The imaginary straight line LB is an imaginary straight line in contact with the imaginary circle **112** at the sub-goal position candidate SG. The orientation of the work machine **50** at the time of reaching the sub-goal position candidate SG can be predicted based on the current posture information.

The first sub-route candidate **116** includes, for example, a forward route **118** along which the work machine **50** is moved forward, but the present invention is not limited thereto. The first sub-route candidate **116** may include a backward route **120** along which the work machine **50** is moved backward. The forward route **118** is, for example, a route along which the work machine **50** turns forward, but is not limited thereto. The backward route **120** is, for example, a route along which the work machine **50** turns backward, but is not limited thereto.

As shown in FIGS. **4** to **8**, the route generation unit **20** can generate the first sub-route candidate **116** in accordance with a combination of the sub-start position candidate SS and the sub-goal position candidate SG.

FIG. **4** shows an example of a case where the radius of an imaginary arc from the sub-start position candidate SS**1** to the sub-goal position candidate SG**1** is larger than the minimum turning radius of the work machine **50**. In such a case, as shown in FIG. **4**, the route generation unit **20** can form a route from the sub-start position candidate SS**1** to the sub-goal position candidate SG**1** by only one forward route **118**. That is, in such a case, the simple first sub-route candidate **116** as shown in FIG. **4** can be generated. The first sub-route candidate **116** as shown in FIG. **4** does not require the work machine **50** to make a turn during moving from the sub-start position candidate SS**1** to the sub-goal position candidate SG**1**.

FIG. **5** shows an example of a case where the radius of the imaginary arc from the sub-start position candidate SS**1** to the sub-goal position candidate SG**1** is smaller than the minimum turning radius of the work machine **50**. In such a case, as shown in FIG. **5**, the route generation unit **20** generates the first sub-route candidate **116** by combining the forward route **118** and the backward route **120**. The first sub-route candidate **116** formed by combining the forward route **118** and the backward route **120** requires the work machine **50** to make a turn during moving from the sub-start position candidate SS**1** to the sub-goal position candidate SG**1**.

Each of FIGS. **6** and **7** shows an example of the first sub-route candidate **116** along which the work machine **50** is to be moved from a sub-start position candidate SS**2** different from the sub-start position candidate SS**1** to the sub-goal position candidate SG**1**. FIG. **8** shows an example of the first sub-route candidate **116** along which the work machine **50** is to be moved from a sub-start position candidate SS**3** to the sub-goal position candidate SG**1**.

The first sub-route candidate **116** shown in each of FIGS. **4** to **8** includes the sub-goal position candidate SG**1** as an end point, but the present invention is not limited thereto. The route generation unit **20** may generate the first sub-route candidate **116** along which the work machine **50** is to be moved from any one of the plurality of sub-start position candidates SS to a sub-goal position candidate SG other than the sub-goal position candidate SG**1**.

A sub-goal position candidate SG**2** shown in FIGS. **4** to **8**, which is one of the plurality of sub-goal position candidates SG, is included in the travel restriction area **106**. As described above, the route generation unit **20** does not use the sub-goal position candidates SG included in the travel restriction area **106** to generate the movement route **108**. Therefore, the route generation unit **20** does not generate the first sub-route candidate **116** that is based on the sub-goal position candidate SG**2**.

The movement route candidate **114** further includes a second sub-route candidate **122**. The second sub-route candidate **122** is a candidate for a route along which the work machine **50** is to be moved from the sub-goal position candidate SG, which is the end point of the first sub-route candidate **116**, to the target work start position **102**. The second sub-route candidate **122** is generated along the imaginary circle **112**. When the radius of the imaginary circle **112** is equal to the minimum turning radius of the work machine **50**, the length of the second sub-route candidate **122** is reduced.

The second sub-route candidate **122** is, for example, the backward route **120** along which the work machine **50** is turned backward along the imaginary circle **112**, but may be the forward route **118** along which the work machine **50** is turned forward along the imaginary circle **112**. When the second sub-route candidate **122** is formed by the backward route **120**, the movement route candidate **114** for causing the work machine **50** to reach the target work start position **102** while moving backward (turning backward) is generated.

When the contact point between the imaginary circle **112** and the imaginary straight line LA does not coincide with the target work start position **102**, the route generation unit **20** may include, in the second sub-route candidate **122**, a route extending along the imaginary straight line LA from the contact point to the target work start position **102**. As a result, even when the contact point between the imaginary circle **112** and the imaginary straight line LA does not coincide with the target work start position **102**, the movement route candidate **114** that allows the work machine **50** to reach the target work start position **102** is generated.

According to the above-described first sub-route candidate **116**, the orientation of the work machine **50** reaching the sub-goal position candidate SG is along the tangential direction of the imaginary circle **112**. In addition, according to the above-described second sub-route candidate **122**, since the work machine **50** moves along the imaginary circle **112**, the orientation of the work machine **50** is maintained in the tangential direction of the imaginary circle **112**. Therefore, by moving the work machine **50** along the movement route candidate **114** including the first sub-route candidate **116** and the second sub-route candidate **122**, the orientation of the work machine **50** at the target work start position **102** is along the imaginary straight line LA. That is, according to the movement route candidate **114** generated by the route generation unit **20**, the orientation of the work machine **50** at the target work start position **102** can be made to coincide with the planned traveling direction of the work machine **50** indicated by the target work start posture information.

Note that, as described above, the route generation unit **20** can generate a plurality of movement route candidates **114** by combining an arbitrary sub-start position candidate SS and an arbitrary sub-goal position candidate SG. The route generation unit **20** selects one of the plurality of movement route candidates **114** as the movement route **108**. For example, the route generation unit **20** selects, as the movement route **108**, the movement route candidate **114** along which the moving distance of the work machine **50** is minimized. As a result, it is possible to shorten the time required for the work machine **50** to move along the movement route **108**. In addition, it is possible to suppress the amount of energy consumed for the work machine **50** to move along the movement route **108**. For example, when the route generation unit **20** generates four movement route candidates **114** shown in FIGS. **5** to **8**, the shortest movement route candidate **114** among the four movement route candidates **114** is assumed to be the movement route candidate **114** shown in FIG. **5**. In this case, the route generation unit **20** selects the movement route candidate **114** shown in FIG. **5** as the movement route **108**.

In this way, the route generation unit **20** generates the movement route **108** by appropriately combining the forward route **118** and the backward route **120** based on the work area information, the target work start position information, the target work start posture information, the current position information, and the current posture information.

By combining the forward route **118** and the backward route **120**, the movement route **108** for causing the work machine **50** to make a turn can be generated. If the work machine **50** is caused to make a turn, it is possible to cause the work machine **50** to perform direction change without causing the work machine **50** to make a pivot turn. That is, if the work machine **50** is caused to make a turn, it is possible to cause the work machine **50** to change its posture while suppressing damage to the traveling surface of the work machine **50** (damage to the lawn grass).

The communication control unit **22** controls the communication unit **12** to transmit information (a route plan) indicating the movement route **108** generated by the route generation unit **20**, to the communication device **54** provided in the work machine **50**. As a result, it is possible for the control device **56** provided in the work machine **50** to acquire the route plan. The control device **56** can cause the work machine **50** to reach the target work start position **102** while placing the work machine **50** in the target work start posture, by causing the work machine **50** to travel based on the acquired route plan. The work machine **50** that has reached the target work start position **102** in the target work start posture can start the work smoothly.

FIG. **9** is a flowchart showing a route planning method according to an embodiment.

The route planning method includes an information acquisition step S**1** and a route generation step S**2**. This route planning method is executed by the above-described route planning device **10**.

In the information acquisition step S**1**, the information acquisition unit **18** acquires the target work start position information, the target work start posture information, the current position information, and the current posture information.

In the route generation step S**2**, the route generation unit **20** generates the movement route **108** for causing the work machine **50** to reach the target work start position **102** in the target work start posture. The route generation unit **20** generates the movement route **108** based on the target work start position information, the target work start posture information, the current position information, and the current posture information that are acquired in the information acquisition step S**1**. By appropriately combining the forward route **118** and the backward route **120**, the route generation unit **20** can generate the movement route **108** for causing the work machine **50** to reach the target work start position **102** while the posture thereof is placed in the target work start posture. That is, the route generation unit **20** can generate the movement route **108** that allows the work machine **50** to reach the target work start position **102** in the target work start posture without causing the work machine **50** to make a pivot turn. In this manner, the route planning method of FIG. **9** ends.

Although not limited, in the route generation step S**2**, the route generation unit **20** may determine whether or not it is possible to generate the first sub-route candidate **116** that does not include, in the middle thereof, the turning point of the work machine **50** (S**21**). When it is possible to generate the first sub-route candidate **116** that does not include, in the middle thereof, the turning point of the work machine **50** (S**21**: YES), the route generation unit **20** may generate the movement route **108** that is based on this first sub-route candidate **116** (S**22**) and end the route generation step S**2**. In this case, a simple movement route **108** in which only the sub-goal position (the sub-goal position candidate SG) is set as the turning point of the work machine **50** is generated. When it is difficult to generate the first sub-route candidate **116** that does not include, in the middle thereof, the turning point of the work machine **50** (S**21**: NO), the route generation unit **20** may generate the movement route candidate **114** that includes the turning point in the middle of the first sub-route candidate **116**. A plurality of such movement route candidates **114** may be generated (S**23**). When a plurality of the movement route candidates **114** are generated, one of the plurality of movement route candidates **114** is selected as the movement route **108** (S**24**).

The following notes (appendices) are further disclosed in relation to the above-described embodiment.

APPENDIX 1

The route planning device (**10**) according to the present disclosure includes one or more processors that execute computer-executable instructions stored in a memory, wherein the one or more processors execute the computer-executable instructions to cause the route planning device to: acquire the target work start position information indicating the target work start position (**102**) that is a target position at which the work machine (**50**) is caused to start work, the target work start posture information indicating the target work start posture that is a target posture of the work machine at the target work start position, the current position information indicating the current position (**104**) of the work machine, and the current posture information indicating the posture of the work machine at the current position; and generate the movement route (**108**) for causing the work machine to reach the target work start position in the target work start posture, by combining the forward route (**118**) along which the work machine moves forward and the backward route (**120**) along which the work machine moves backward, based on the target work start position information, the target work start posture information, the current position information, and the current posture information. According to this feature, it is possible to cause the work machine to reach the target work start position in the target work start posture.

APPENDIX 2

In the route planning device according to Appendix 1, the one or more processors may cause the route planning device to generate the movement route in a manner so that the work machine reaches the target work start position while moving backward.

APPENDIX 3

In the route planning device according to Appendix 1 or 2, the movement route may be formed by alternately arranging the forward route and the backward route. According to this feature, the work machine can be caused to make a turn, and is therefore not required to make a pivot turn.

APPENDIX 4

In the route planning device according to any one of Appendices 1 to 3, the forward route may be a route along which the work machine turns forward, the backward route may be a route along which the work machine turns backward, and the one or more processors may cause the route planning device to generate the movement route in a manner so that the work machine reaches the target work start position while turning backward.

APPENDIX 5

In the route planning device according to Appendix 4, the one or more processors may cause the route planning device to set the sub-goal position on the imaginary circle (**112**) passing through the target work start position, and to generate the movement route in a manner so that the work machine reaches the target work start position while turning backward along the imaginary circle from the sub-goal position.

APPENDIX 6

In the route planning device according to Appendix 5, the radius of the imaginary circle may be equivalent to the minimum turning radius of the work machine. According to this feature, since the moving distance of the work machine along the imaginary circle is minimized, the moving distance of the work machine is reduced.

APPENDIX 7

In the route planning device according to Appendix 5 or 6, the one or more processors may cause the route planning device to set the plurality of sub-goal position candidates (SG) on the imaginary circle, the plurality of sub-goal position candidates being candidates for the sub-goal position, and to select, as the movement route, one of the plurality of movement route candidates (**114**) each including one of the plurality of sub-goal position candidates as a turning point.

APPENDIX 8

In the route planning device according to Appendix 7, the one or more processors may cause the route planning device to select, as the movement route, the movement route candidate along which the moving distance of the work machine is minimized. According to this feature, the energy consumption of the work machine is suppressed.

APPENDIX 9

In the route planning device according to any one of Appendices 1 to 8, the one or more processors may cause the route planning device to further acquire the information indicating the work area (**100**) in which the work is performed by the work machine, and to generate the movement route in a manner so that the movement route is included in the work area. According to this feature, the movement route can be generated within a range in which the work machine is allowed to travel.

APPENDIX 10

In the route planning device according to Appendix 9, the work machine may be a lawn mower, and the work area may be an area in which lawn mowing is performed by the work machine.

APPENDIX 11

In the route planning device according to any one of Appendices 1 to 10, the route planning device may be provided in the work machine.

APPENDIX 12

In the route planning device according to any one of Appendices 1 to 11, the information indicating the movement route generated by the route planning device may be supplied to the work machine via the communication device (**54**) provided in the work machine.

APPENDIX 13

The route planning method according to the present disclosure includes: the step (S**1**) of acquiring the target work start position information indicating the target work start position (**102**) that is a target position at which the work machine (**50**) is caused to start work, the target work start posture information indicating the target work start posture that is a target posture of the work machine at the target work start position, the current position information indicating the current position (**104**) of the work machine, and the current posture information indicating the posture of the work machine at the current position; and the step (S**2**) of generating the movement route (**108**) for causing the work machine to reach the target work start position in the target work start posture, by combining the forward route (**118**) along which the work machine moves forward and the backward route (**120**) along which the work machine moves backward, based on the target work start position information, the target work start posture information, the current position information, and the current posture information. According to this feature, it is possible to cause the work machine to reach the target work start position in the target work start posture.

It should be noted that the present invention is not limited to the disclosure described above, and various configurations can be adopted therein without departing from the essence and gist of the present invention.

The invention claimed is:

1. A route planning device comprising one or more processors that execute computer-executable instructions stored in a memory,

wherein the one or more processors execute the computer-executable instructions to cause the route planning device to:

acquire target work start position information indicating a target work start position that is a target position at which a work machine is caused to start work,

target work start posture information indicating a target work start posture that is a target posture of the work machine at the target work start position,

current position information indicating a current position of the work machine, and current posture information indicating a posture of the work machine at the current position; and

generate a movement route for causing the work machine to reach the target work start position in the target work start posture, by combining a forward route along which the work machine moves forward target work start posture and a backward route along which the work machine moves backward, based on the target work start position information, the target work start posture information, the current position information, and the current posture information,

wherein the work machine is autonomously controlled to follow the generated movement route.

2. The route planning device according to claim **1**, wherein

the one or more processors cause the route planning device to generate the movement route in a manner so that the work machine reaches the target work start position while moving backward.

3. The route planning device according to claim **1**, wherein the movement route is formed by alternately arranging the forward route and the backward route.

4. The route planning device according to claim **1**, wherein

the forward route is a route along which the work machine turns forward,

the backward route is a route along which the work machine turns backward, and

the one or more processors cause the route planning device to generate the movement route in a manner so that the work machine reaches the target work start position while turning backward.

5. The route planning device according to claim **4**, wherein

the one or more processors cause the route planning device to:

set a sub-goal position on an imaginary circle passing through the target work start position; and

generate the movement route in a manner so that the work machine reaches the target work start position while turning backward along the imaginary circle from the sub-goal position.

6. The route planning device according to claim **5**, wherein

a radius of the imaginary circle is equivalent to a minimum turning radius of the work machine.

7. The route planning device according to claim **5**, wherein

the one or more processors cause the route planning device to:

set a plurality of sub-goal position candidates on the imaginary circle, the plurality of sub-goal position candidates being candidates for the sub-goal position; and

select, as the movement route, one of a plurality of movement route candidates each including one of the plurality of sub-goal position candidates as a turning point.

8. The route planning device according to claim **7**, wherein

the one or more processors cause the route planning device to select, as the movement route, a movement route candidate along which a moving distance of the work machine is minimized, among the plurality of movement route candidates.

9. The route planning device according to claim **1**, wherein

the one or more processors cause the route planning device to:

further acquire information indicating a work area in which the work is performed by the work machine; and

generate the movement route in a manner so that the movement route is included in the work area.

10. The route planning device according to claim **9**, wherein

the work machine is a lawn mower, and

the work area is an area in which lawn mowing is performed by the work machine.

11. The route planning device according to claim **1**, wherein

the route planning device is provided in the work machine.

12. The route planning device according to claim **1**, wherein

information indicating the movement route generated by the route planning device is supplied to the work machine via a communication device provided in the work machine.

13. A route planning method comprising:

acquiring target work start position information indicating a target work start position that is a target position at which a work machine is caused to start work, target work start posture information indicating a target work start posture that is a target posture of the work machine at the target work start position, current position information indicating a current position of the work machine, and current posture information indicating a posture of the work machine at the current position; and

generating a movement route for causing the work machine to reach the target work start position in the target work start posture, by combining a forward route along which the work machine moves forward and a backward route along which the work machine moves backward, based on the target work start position information, the target work start posture information, the current position information, and the current posture information,

wherein the work machine is autonomously controlled to follow the generated movement route.

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