United States Patent	12392110
Kind Code	B2
Date of Patent	August 19, 2025
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Work machine and method for controlling work machine

Abstract

A work machine including a vehicle body, a traveling wheel, first and second steering members, an actuator, first and second operation sensors that output operation signals indicative of operation of the first and second steering members, and a controller. The controller acquires the first and second operation signals. The controller determines whether or not the first steering member is being operated, and whether the first steering member was operated last. The controller performs an automatic control of the actuator to set the steering angle to a target angle upon determining that the first steering member is not being operated and the first steering member was operated last. The controller does not perform the automatic control upon determining that the second steering member was operated last even if the first steering member is not being operated.

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Appl. No.:	**18/558284**
Filed (or PCT Filed):	**May 18, 2022**
PCT No.:	**PCT/JP2022/020619**
PCT Pub. No.:	**WO2023/286442**
PCT Pub. Date:	January 19, 2023

Prior Publication Data

Document Identifier	**Publication Date**

Foreign Application Priority Data

JP	2021-117774	Jul. 16, 2021

Publication Classification

Int. Cl.: **E02F9/20** (20060101); **E02F3/76** (20060101)

U.S. Cl.:

CPC **E02F9/2087** (20130101); **E02F3/76** (20130101);

Field of Classification Search

CPC: E02F (9/2087); E02F (3/76); E02F (9/225); B62D (7/09); B62D (6/00); B62D (1/12); B62D (1/00)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS
(1) This application is a U.S. National stage application of International Application No. PCT/JP2022/020619, filed on May 18, 2022. This U.S. National stage application claims priority under 35 U.S.C. § 119(a) to Japanese Patent Application No. 2021-117774, filed in Japan on Jul. 16, 2021, the entire contents of which are hereby incorporated herein by reference.
BACKGROUND
Field of the Invention
(2) The present invention relates to a work machine and a method for controlling the work machine.
Background Information
(3) There is a work machine that includes a plurality of steering members for steering traveling wheels to the left or right. For example, the work machine in Japanese Patent Laid-open No. 2021-054269 includes a steering lever and a steering wheel. The operator of the work machine operates the steering members whereby the work machine changes the steering angle of the traveling wheels to the left or right. Consequently, the work machine turns to the left or right.
(4) A work machine may easily deviate from a target route due to a load caused by earth and sand during traveling or due to an uneven road surface. As a result, the operator is required to operate the steering member for maintaining the route while operating the work implement such as a blade at the same time. Such type of operation is difficult and the operating load on the operator is large.
(5) Accordingly, Japanese Patent Laid-open No. 2021-054269 discloses a steering automatic control for automatically controlling the steering angle so that the work machine maintains the traveling direction. In this steering automatic control, the orientation of the work machine when the operating of the steering lever is stopped is determined as the traveling direction. The steering angle is automatically controlled so that the work machine travels straight in the traveling direction.
SUMMARY
(6) In the abovementioned work machine, automatic control of the steering angle is performed when the operator stops the operation of the steering wheel (handle bar) or the steering lever. As a result, the automatic control may be performed due to the operator removing his hand from the steering wheel after having operated the steering wheel. In this case, after the operation of the steering wheel, the steering angle is automatically changed even though the steering wheel is not operated which increases the feeling of unease in the driving feeling for the operator. An object of the present invention is to lighten the operating load on the operator due to the automatic control of the steering angle and suppress the feeling of unease of the operator due to the automatic control in the work machine.
(7) A work machine according to a first aspect of the present invention includes a vehicle body, a traveling wheel, a first steering member, a second steering member, an actuator, a first operation sensor, a second operation sensor, and a controller. The traveling wheel is supported by the vehicle body. The first steering operating member is operable by an operator. The second steering operating member is operable by the operator. The second steering member is separate from the first steering member. The actuator changes the steering angle of the traveling wheel in response to an operation

of the first steering member. The actuator changes the steering angle in response to an operation of the second steering member. The first operation sensor outputs a first operation signal that indicates the operation of the first steering member. The second operation sensor outputs a second operation signal that indicates the operation of the second steering member. The controller acquires the first operation signal and the second operation signal.
(8) The controller determines whether or not the first steering member has been operated. The controller determines whether the first steering member has been operated last among the first steering member and the second steering member. The controller performs automatic control for controlling the actuator so as to set the steering angle to a predetermined target angle upon determining that the first steering member is not being operated and has been operated last among the first steering member and the second steering member. The controller does not perform the automatic control upon determining that the second steering member has been operated last among the first steering member and the second steering member even if the first steering member is not being operated.
(9) A method according to another aspect of the present invention is a method for controlling a work machine. The work machine includes a vehicle body, a traveling wheel, and an actuator. The traveling wheel is supported by the vehicle body. The actuator changes the steering angle of the traveling wheel. The method according to the present aspect comprises: acquiring a first operation signal that indicates an operation of a first steering member that is operable to change the steering angle; acquiring a second operation signal that indicates an operation of a second steering member separate from the first steering member and that is operable to change the steering angle; determining whether or not the first steering member is being operated; determining whether the first steering member was operated last among the first steering member and the second steering member; performing an automatic control for controlling the actuator so as to set the steering angle to a predetermined target angle upon determining that the first steering member is not being operated and the first steering member was operated last among the first steering member and the second steering member; and not performing the automatic control upon determining that the second steering member was operated last among the first steering member and the second steering member even if the first steering member is not being operated.
(10) According to the present invention, the automatic control is performed when the first steering member is not being operated and the first steering member was operated last. As a result, the operating load on the operator is lightened due to the automatic control. The automatic control is not performed upon determining that the second steering member has been operated last even if the first steering member is not being operated. As a result, the operator is able to cause the work machine to travel without interference by the automatic control. Consequently, the feeling of unease of the operator due to the automatic control is suppressed.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a perspective view of a work machine according to an embodiment.
(2) FIG. **2** is a side view of the work machine.
(3) FIG. **3** is a schematic view of a configuration of the work machine.
(4) FIG. **4** is a top view of a front part of the work machine.
(5) FIG. **5** illustrates an example of steering speed data.
(6) FIG. **6** illustrates an example of travel of the work machine due to an operation of a first steering member.
(7) FIG. **7** is a flow chart illustrating a process for determining the start of automatic control.
DETAILED DESCRIPTION OF EMBODIMENT(S)

(8) An embodiment of the present invention will be described below with reference to the drawings. FIG. **1** is a perspective view of a work machine **1** according to the embodiment. FIG. **2** is a side view of the work machine **1**. As illustrated in FIG. **1**, the work machine **1** includes a vehicle body **2**, front wheels **3**A and **3**B, rear wheels **4**A to **4**D, and a work implement **5**. The vehicle body **2** includes a front frame **11**, a rear frame, **12**, a cab **13**, and a power chamber **14**.
(9) The rear frame **12** is connected to the front frame **11**. The front frame **11** is able to articulate to the left and right with respect to the rear frame **12**. In the following explanation, the front, rear, left, and right directions signify the front, rear, left, and right directions of the vehicle body **2** while the articulate angle is zero, that is, while the front frame **11** and the rear frame **12** are straight.
(10) The cab **13** and the power chamber **14** are disposed on the rear frame **12**. An unillustrated operator's seat is disposed in the cab **13**. The power chamber **14** is disposed behind the cab **13**. The front frame **11** extends forward from the rear frame **12**. The front wheels **3**A and **3**B are attached to the front frame **11**. The rear wheels **4**A to **4**D are attached to the rear frame **12**.
(11) The work implement **5** is movably connected to the vehicle body **2**. The work implement **5** includes a supporting member **15** and a blade **16**. The supporting member **15** is movably connected to the vehicle body **2**. The supporting member **15** supports the blade **16**. The supporting member **15** includes a drawbar **17** and a circle **18**. The drawbar **17** is disposed below the front frame **11**.
(12) The drawbar **17** is connected to a front part **19** of the front frame **11**. The drawbar **17** extends rearward from the front part **19** of the front frame **11**. The drawbar **17** is swingably supported at least in the up-down direction and the left-right direction of the vehicle body **2** with respect to the front frame **11**. For example, the front part **19** includes a ball joint. The drawbar **17** is rotatably connected to the front frame **11** via the ball joint.
(13) The circle **18** is connected to a rear part of the drawbar **17**. The circle **18** is rotatably supported with respect to the drawbar **17**. The blade **16** is connected to the circle **18**. The blade **16** is supported by the drawbar **17** via the circle **18**. As illustrated in FIG. **2**, the blade **16** is supported by the circle **18** so as to be rotatable about a tilt shaft **21**. The tilt shaft **21** extends in the left-right direction.
(14) The work machine **1** includes a plurality of actuators **22** to **26** for changing the orientation of the work implement **5**. The plurality of actuators **22** to **26** include a plurality of hydraulic cylinders **22** to **25**. The plurality of hydraulic cylinders **22** to **25** are connected to the work implement **5**. The plurality of hydraulic cylinders **22** to **25** extend and contract due to hydraulic pressure. The plurality of hydraulic cylinders **22** to **25** change the orientation of the work implement **5** with respect to the vehicle body **2** by extending and contracting. In the following explanation, the extension and contraction of the hydraulic cylinders is referred to as a "stroke motion."
(15) Specifically, the plurality of hydraulic cylinders **22** to **25** include a left lift cylinder **22**, a right lift cylinder **23**, a drawbar shift cylinder **24**, and a blade tilt cylinder **25**. The left lift cylinder **22** and the right lift cylinder **23** are disposed away from each other in the left-right direction. The left lift cylinder **22** and the right lift cylinder **23** are connected to the drawbar **17**. The left lift cylinder **22** and the right lift cylinder **23** are connected to the front frame **11** via a lifter bracket **29**. The drawbar **17** swings up and down due to the stroke motions of the left lift cylinder **22** and the right lift cylinder **23**. As a result, the blade **16** moves up and down.
(16) The drawbar shift cylinder **24** is connected to the drawbar **17** and the front frame **11**. The drawbar shift cylinder **24** is connected to the front frame **11** via the lifter bracket **29**. The drawbar shift cylinder **24** extends diagonally downward from the front frame **11** toward the drawbar **17**. The drawbar **17** swings left and right due to the stroke motions of the drawbar shift cylinder **24**. The blade tilt cylinder **25** is connected to the circle **18** and the blade **16**. The blade **16** rotates about the tilt shaft **21** due to the stroke motions of the blade tilt cylinder **25**.
(17) The plurality of actuators **22** to **26** include a rotation actuator **26**. The rotation actuator **26** is connected to the drawbar **17** and the circle **18**. The rotation actuator **26** causes the circle **18** to rotate with respect to the drawbar **17**. Consequently, the blade **16** rotates about a rotating axis that

extends in the up-down direction.
(18) FIG. **3** is a schematic view illustrating a configuration of the work machine **1**. As illustrated in FIG. **3**, the work machine **1** includes a driving source **31**, a first hydraulic pump **32**, a power transmission device **33**, and a work implement valve **34**. The driving source **31** is, for example, an internal combustion engine. Alternatively, the driving source **31** may be an electric motor or a hybrid of an internal combustion engine and an electric motor. The first hydraulic pump **32** is driven by the driving source **31** thereby discharging hydraulic fluid.
(19) The control valve **34** is connected to the first hydraulic pump **32** and the plurality of hydraulic cylinders **22** to **25** via a hydraulic circuit. The control valve **34** includes a plurality of valves connected to each of the plurality of hydraulic cylinders **22** to **25**. The control valve **34** controls the flow rate of the hydraulic fluid supplied from the first hydraulic pump **32** to the plurality of hydraulic cylinders **22** to **25**. The work implement valve **34** is, for example, an electromagnetic proportional control valve. Alternatively, the work implement valve **34** may be a hydraulic pilot-type proportional control valve.
(20) In the present embodiment, the rotation actuator **26** is a hydraulic motor. The work implement valve **34** is connected to the first hydraulic pump **32** and the rotation actuator **26** via the hydraulic circuit. The work implement control valve **34** controls the flow rate of hydraulic fluid supplied from the first hydraulic pump **32** to the rotation actuator **26**. The rotation actuator **26** may be an electric motor.
(21) The power transmission device **33** transmits the driving power from the driving source **31** to the rear wheels **4**A to **4**D. The power transmission device **33** may include a torque converter and/or a plurality of speed change gears. Alternatively, the power transmission device **33** may be a transmission of another type such as a hydraulic static transmission (HST) or a hydraulic mechanical transmission (HMT).
(22) The work machine **1** includes a work implement operating member **35**, a shift member **53**, an accelerator operating member **36**, and a controller **37**. The work implement operating member **35** is operable by an operator in order to change the orientation of the work implement **5**. The work implement operating member **35** includes, for example, a plurality of operating levers. Alternatively, the work implement operating member **35** may be another member such as a switch or a touch screen. The work implement operating member **35** outputs signals indicating the operations of the work implement operating member **35** by the operator.
(23) The shift member **53** is operable by the operator for switching between forward travel and reverse travel of the work machine **1**. The shift member **53** includes, for example, a shift lever. Alternatively, the shift member **53** may be another member such as a switch or a touch screen. The shift member **53** outputs signals indicating the operations of the shift member **53** by the operator. The accelerator operating member **36** is operable by an operator for causing the work machine **1** to travel. The accelerator operating member **36** includes, for example, an accelerator pedal. Alternatively, the accelerator operating member **36** may be another member such as a switch or a touch screen. The accelerator operating member **36** outputs signals indicating the operations of the accelerator operating member **36** by the operator.
(24) The controller **37** switches between forward travel and reverse travel of the work machine **1** by controlling the power transmission device **33** in response to the operation of the shift member **53**. Alternatively, the shift member **53** may be mechanically connected to the power transmission device **33**. The action of the shift member **53** is mechanically transmitted to the power transmission device **33** whereby the gears for forward travel and reverse travel of the power transmission device **33** may be switched.
(25) The controller **37** causes the work machine **1** to travel by controlling the driving source **31** and the power transmission device **33** in response to an operation on the accelerator operating member **36**. The controller **37** also actuates the work implement **5** by controlling the first hydraulic pump **32** and the work implement valve **34** in response to an operation on the work implement operating

member **35**.
(26) The controller **37** includes a storage device **38** and a processor **39**. The processor **39** is, for example, a CPU and executes a program for controlling the work machine **1**. The storage device **38** includes a memory such as a RAM or a ROM, and an auxiliary storage device such as an SSD or an HDD. The storage device **38** stores programs and data for controlling the work machine **1**.
(27) The work machine **1** includes a direction sensor **52**. The direction sensor **52** detects the traveling direction of the vehicle body **2**. The direction sensor **52** outputs direction signals indicating the traveling direction of the vehicle body **2**. The controller **37** acquires the traveling direction of the vehicle body **2** from the direction signals from the direction sensor **52**. The traveling direction of the vehicle body **2** is represented, for example, by the yaw angle of the vehicle body **2**. The direction sensor **52** is, for example, an inertial measurement device (IMU). The controller **37** calculates the traveling direction of the vehicle body **2** based on the acceleration and the angular speed of the vehicle body **2**. Alternatively, the direction sensor **52** may be a global navigation satellite system (GNSS) receiver such as a global positioning system (GPS) device. The controller **37** may acquire the traveling direction of the vehicle body **2** from a change in the position of the work machine **1** detected by the direction sensor **52**.
(28) As illustrated in FIG. **3**, the work machine **1** includes a steering angle sensor **40**, a steering actuator **41**, and a steering valve **42**. The steering actuator **41** is a hydraulic cylinder. The steering actuator **41** extends and contracts with hydraulic fluid from the first hydraulic pump **32**. The steering actuator **41** steers the front wheels **3**A and **3**B by extending and contracting.
(29) FIG. **4** is a top view of a front part of the work machine **1**. As illustrated in FIG. **4**, the front wheels **3**A and **3**B include a first front wheel **3**A and a second front wheel **3**B. The first front wheel **3** and the second front wheel **3**B are disposed away from each other in the left-right direction. The first front wheel **3**A is supported by the front frame **11** so as to be rotatable about a first steering shaft **43**. The second front wheel **3**B is supported by the front frame **11** so as to be rotatable about a second steering shaft **44**. The first steering shaft **43** and the second steering shaft **44** extend in the up-down direction.
(30) The steering actuator **41** is connected to the front wheels **3**A and **3**B and the front frame **11**. The steering actuator **41** changes a steering angle θ**1** of the front wheels **3**A and **3**B from a predetermined neutral angle to the left or right. As illustrated in FIG. **4**, the steering angle θ**1** is the angle that the front wheels **3**A and **3**B face with respect to the front-back direction of the work machine **1**. The front-back direction of the work machine **1** signifies the front-back direction of the front frame **11**. However, the front-back direction of the work machine **1** may signify the front-back direction of the rear frame **12**.
(31) The neutral angle is a steering angle θ**1** of zero degrees. Therefore, when the steering angle θ**1** is the neutral angle, the front wheels **3**A and **3**B are facing straight forward of the work machine **1**. In FIG. **4**, **3**A′ represents the first front wheel **3** that has been steered from the neutral angle to the left by the steering angle θ**1**. **3**B′ represents the second front wheel **3**B that has been steered from the neutral angle to the left by the steering angle θ**1**.
(32) The steering valve **42** is connected through the hydraulic circuit to the first hydraulic pump **32** and the steering actuator **41**. The steering valve **42** controls the flow rate of hydraulic fluid supplied from the first hydraulic pump **32** to the steering actuator **41**. The steering valve **42** is, for example, a hydraulic pilot type of control valve.
(33) The steering angle sensor **40** detects the steering angle θ**1**. The steering angle sensor **40** outputs an angle signal indicating the steering angle θ**1**. The controller **37** acquires the current steering angle θ**1** from the angle signal from the steering angle sensor **40**. The steering angle sensor **40** detects, for example, the stroke amount of the steering actuator **41**. The steering angle θ**1** is calculated from the stroke amount of the steering actuator **41**. Alternatively, the steering angle sensor **40** may detect the steering angle θ**1** directly.
(34) The work machine **1** includes a first steering member **45** and a second steering member **46**.

The first steering member **45** and the second steering member **46** is operable by the operator for changing the steering angle θ**1** of the front wheels **3**A and **3**B to the left or right. The first steering member **45** is a lever such as a joy stick. Alternatively, the first steering member **45** may be a member other than a lever. The first steering member **45** can be tilted to the left and right from a neutral position N**1**. The first steering member **45** is connected to a first operation sensor **51**. The first operation sensor **51** outputs a first operation signal that indicates an operation on the first steering member **45** by the operator. The controller **37** acquires the operating amount of the first steering member **45** from the first operation signal from the first operation sensor **51**.
(35) The second steering member **46** is a steering wheel. Alternatively, the second steering member **46** may be a member other than a steering wheel. The second steering member **46** is rotatable about a rotation axis Ax**1**. A second operation sensor **47** is attached to the second steering member **46**. The second operation sensor **47** outputs a second operation signal that indicates an operation on the second steering member **46** by the operator. For example, the second operation sensor **47** detects the angular displacement about the rotation axis Ax**1** of the second steering member **46**. The controller **37** acquires the operating amount of the second steering member **46** from the second operation signal from the second operation sensor **47**. The second steering member **46** is held in the last operated position when not operated by the operator.
(36) The work machine **1** includes a second hydraulic pump **48**, a first pilot valve **49**, and a second pilot valve **50**. The second hydraulic pump **48** is driven by the driving source **31** thereby discharging hydraulic fluid. The first pilot valve **49** is connected through the hydraulic circuit to the second hydraulic pump **48** and the steering valve **42**. The first pilot valve **49** controls the pressure of the hydraulic fluid supplied from the second hydraulic pump **48** to the pilot port of the steering valve **42**. The first pilot valve **49** is an electromagnetic proportional control valve.
(37) The first pilot valve **49** is controlled by signals from the controller **37**. The controller **37** controls the first pilot valve **49** in response to the first operation signals from the first operation sensor **51**, thereby extending and contracting the steering actuator **41**. Consequently, the controller **37** controls the steering actuator **41** so as to change the steering angle θ**1** of the front wheels **3**A and **3**B in response to the operation of the first steering member **45**. The control of the steering angle θ**1** by means of the first steering member **45** is discussed in detail below.
(38) The second pilot valve **50** is connected through the hydraulic circuit to the second hydraulic pump **48** and the steering valve **42**. The second pilot valve **50** is connected to the second steering member **46**. The second pilot valve **50** controls the pressure of the hydraulic fluid supplied from the second hydraulic pump **48** to the pilot port of the steering valve **42** in response to the operation of the second steering member **46**. Consequently, the steering actuator **41** changes the steering angle θ**1** of the front wheels **3**A and **3**B so that the steering angle θ**1** of the front wheels **3**A and **3**B becomes the angle corresponding to the operating amount of the second steering member **46**.
(39) When the operating amount of the second steering member **46** is held in a constant manner, the steering actuator **41** holds the steering angle θ**1** of the front wheels **3**A and **3**B at the angle corresponding to the operating amount of the second steering member **46**. The second pilot valve **50** may also be an electromagnetic proportional control valve, similar to the first pilot valve **49**. In this case, the controller **37** may control the second pilot valve **50** in accordance with the operation of the second steering member **46**.
(40) Next, the control of the steering angle θ**1** by means of the first steering member **45** is discussed. The controller **37** refers to steering speed data and determines a target steering speed from the operating amount of the first steering member **45**. The controller **37** controls the steering actuator **41** so that the steering angle θ**1** changes at the target steering speed. The steering speed data prescribes the target steering speed with respect to the operating amount of the first steering member **45**.
(41) FIG. **5** illustrates an example of the steering speed data. As illustrated in FIG. **5**, the first steering member **45** is operable within a neutral range, a left steering range, and a right steering

range. The neutral range is a range that includes the position of the first steering member **45** at the operating amount 0, that is, the range includes the neutral position N**1**. The neutral range is positioned between the left steering range and the right steering range. The left steering range is positioned to the left of the neutral range. The right steering range is positioned to the right of the neutral range.

(42) The steering speed data prescribes the target steering speed to the left that increases from 0 to the maximum speed VL to the left in response to an increase in the operating amount to the left of the first steering member **45** within the left steering range. Therefore, the controller **37** controls the steering actuator **41** so as to change the steering angle θ**1** of the front wheels **3**A and **3**B to the left at a speed that corresponds to the operating amount of the first steering member **45** when the first steering member **45** is positioned in the left steering range.

(43) For example, when the first steering member **45** is operated by an operating amount A**1** to the left, the controller **37** determines a steering speed V**1** corresponding to the operating amount A**1** as the target steering speed. The controller **37** then controls the steering actuator **41** so as to change the steering angle θ**1** of the front wheels **3**A and **3**B to the left at the steering speed V**1**. Additionally, the steering angle θ**1** of the front wheels **3**A and **3**B continues to change to the left at the steering speed V**1** until reaching the maximum steering angle to the left while the first steering member **45** is held at the operating amount A**1** to the left.

(44) The steering speed data prescribes the target steering speed to the right that increases from 0 to the maximum speed VR to the right in response to an increase in the operating amount to the right of the first steering member **45** within the right steering range. Therefore, the controller **37** controls the steering actuator **41** so as to change the steering angle θ**1** of the front wheels **3**A and **3**B to the right at a speed that corresponds to the operating amount of the first steering member **45** when the first steering member **45** is positioned in the right steering range.

(45) For example, when the first steering member **45** is operated by an operating amount A**2** to the right, the controller **37** determines a steering speed V**2** corresponding to the operating amount A**2** as the target steering speed. The controller **37** then controls the steering actuator **41** so as to change the steering angle θ**1** of the front wheels **3**A and **3**B to the right at the steering speed V**2**. Additionally, the steering angle θ**1** of the front wheels **3**A and **3**B continues to change to the right at the steering speed V**2** until reaching the maximum steering angle to the right while the first steering member **45** is held at the operating amount A**2** to the right.

(46) The controller **37** controls the steering actuator **41** so that when the first steering member **45** is positioned in the neutral range, the steering angle θ**1** is held at the neutral angle. For example, when the first steering member **45** is positioned in the neutral range while the steering angle θ**1** is the neutral angle, the steering angle θ**1** is not changed and is held at the neutral angle.

(47) When the first steering member **45** and the second steering member **46** are operated at the same time, the controller **37** prioritizes the operation of the second steering member **46**. Therefore, when the first steering member **45** and the second steering member **46** are operated at the same time, the controller **37** does not perform the abovementioned control of the steering angle θ**1** through the first steering member **45**. As a result, the steering angle θ**1** changes in response to the operation of the second steering member **46**.

(48) The automatic control of the steering angle θ**1** is explained next. The controller **37** performs automatic control for controlling the steering actuator **41** so that the steering angle θ**1** becomes a predetermined target angle. The automatic control includes a center return mode and a steering stabilizer mode.

(49) In the center return mode, the controller **37** controls the steering actuator **41** so that the steering angle θ**1** automatically returns to the neutral angle when the first steering member **45** is returned from the left steering range or the right steering range to the neutral range.

(50) For example, when the steering angle θ**1** is a predetermined angle to the left, the controller **37** controls the steering actuator **41** so that the steering angle θ**1** returns from the predetermined angle

to the left to the neutral angle when the first steering member **45** is returned to the neutral range. When the steering angle θ**1** is a predetermined angle to the right, the controller **37** controls the steering actuator **41** so that the steering angle θ**1** returns from the predetermined angle to the right to the neutral angle when the first steering member **45** is returned to the neutral range.
(51) FIG. **6** illustrates an example of travel of the work machine **1** due to an operation on the first steering member **45**. As illustrated in FIG. **6**, the first steering member **45** is positioned at the neutral position N**1** while the work machine **1** is at the point P**1**. The steering angle θ**1** is the neutral angle and the work machine **1** travels straight forward. At the point P**2**, the steering angle θ**1** of the front wheels **3**A and **3**B begins to change from the neutral angle to the left when the operator operates the first steering member **45** by the operating amount A**1** within the left steering range. Consequently, the work machine **1** turns to the left.
(52) When the operator holds the first steering member **45** at the operating amount A**1** between the point P**2** and the point P**3**, the steering angle θ**1** of the front wheels **3**A and **3**B continues to increase up to the maximum steering angle θmax to the left. Consequently, the work machine **1** continues to turn to the left.
(53) When the operator returns the first steering member **45** to the neutral range at the point P**3**, the steering angle θ**1** of the front wheels **3**A and **3**B decreases from the maximum steering angle θmax toward the neutral angle due to the center return mode. At the point P**5**, the steering angle θ**1** of the front wheels **3**A and **3**B then returns to the neutral angle.
(54) In the steering stabilizer mode, the controller **37** controls the steering angle θ**1** so that the traveling direction of the vehicle body **2** is held in the target direction. As illustrated in FIG. **6**, after the operator has returned the first steering member **45** to the neutral range at the point P**3**, the controller **37** determines whether the steering angle θ**1** has returned to the neutral angle. The controller **37** determines that the steering angle θ**1** has returned to the neutral angle at the point P**5**. The controller **37** determines the traveling direction H**1** of the vehicle body **2** when the steering angle θ**1** has been determined as having returned to the neutral angle, as the target direction. Thereafter, the controller **37** controls the steering actuator **41** so that the traveling direction of the vehicle body **2** is held at the target direction (H**1**). Consequently, the work machine **1** travels straight in the target direction (H**1**).
(55) Specifically, the controller **37** determines the target angle of the steering angle θ**1** based on the difference between the current traveling direction of the vehicle body **2** and the target direction. The controller **37** controls the steering actuator **41** so that the steering angle θ**1** becomes the target angle. For example, the controller **37** determines the target angle of the steering angle θ**1** by multiplying the difference between the current traveling direction of the vehicle body **2** and the target direction by a predetermined gain. The controller **37** decreases the gain as the vehicle speed increases. Consequently, the target angle is decreased as the vehicle speed increases. The controller **37** controls the steering actuator **41** so that the steering angle θ**1** is held at the target angle by means of feedback control.
(56) The controller **37** may also calculate the vehicle speed from a change in the position of the work machine **1** detected by the abovementioned GNSS receiver. Alternatively, the work machine **1** may be provided with a rotation sensor that detects the output rotation speed of the power transmission device **33**. The controller **37** may calculate the vehicle speed from the output rotation speed of the power transmission device **33**.
(57) FIG. **7** is a flow chart illustrating a process for determining the start of automatic control. As illustrated in FIG. **7**, in step S**101**, the controller **37** determines whether a steering operation has been performed. The controller **37** determines that a steering operation has been performed when at least one of the first steering member **45** and the second steering member **46** has been operated.
(58) The controller **37** determines from the first operation signal that the first steering member **45** has been operated when the first steering member **45** is positioned in the left steering range or the right steering range. The controller **37** determines from the first operation signal that the first

steering member **45** has not been operated when the first steering member **45** is positioned in the neutral range.

(59) The controller **37** acquires the operating speed of the second steering member **46** from the second operation signal. The controller **37** determines that the second steering member **46** has been operated when the operating speed is greater than a threshold. The controller **37** determines that the second steering member **46** has not been operated when the operating speed is equal to or less than the threshold. For example, the controller **37** calculates the angular speed of the second steering member **46**. The controller **37** determines that the second steering member **46** has not been operated when the angular speed of the second steering member **46** is equal to or less than the threshold.

(60) When the controller **37** has determined that a steering operation has been performed in step S**101**, the process advances to step S**106**. In step S**106**, the steering actuator **41** is controlled in a manual mode. That is, the controller **37** does not perform the automatic control and the steering actuator **41** is controlled in response to the operation of the first steering member **45** or the second steering member **46** by the operator as described above.

(61) When the controller **37** has determined that a steering operation has not been performed in step S**101**, the process advances to step S**102**. In step S**102**, the controller **37** determines whether the first steering member **45** has been operated last among the first steering member **45** and the second steering member **46**. When the controller **37** determines that the first steering member **45** has not been operated last among the first steering member **45** and the second steering member **46** in step S**102**, the process advances to step S**106**. That is, when the second steering member **46** was operated last, the controller **37** does not perform the automatic control and the steering actuator **41** is controlled in the manual mode.

(62) When the controller **37** determines that the first steering member **45** has been operated last in step S**102**, the process advances to step S**103**. In step S**103**, the controller **37** determines whether the steering angle θ**1** has been returned to the neutral angle even once after the transition from the manual mode to the automatic control. When the controller **37** has determined that the steering angle θ**1** has not been returned to the neutral angle even once after the transition from the manual mode to the automatic control, the process advances to step S**104**.

(63) In step S**104**, the controller **37** controls the steering actuator in the center return mode. That is, the controller **37** controls the steering actuator **41** so that the steering angle θ**1** returns to the neutral angle as indicated in the actions from point P**3** to point P**5** in FIG. **6**.

(64) When the controller **37** has determined that the steering angle θ**1** has been returned to the neutral angle even once after the transition from the manual mode to the automatic control in step S**103**, the process advances to step S**105**. In step S**105**, the controller **37** controls the steering actuator in the steering stabilizer mode. In the steering stabilizer mode, the controller **37** controls the steering angle θ**1** so that the traveling direction of the vehicle body **2** is held in the target direction (H**1**) as indicated at point P**5** in FIG. **6**.

(65) In the work machine **1** according to the present embodiment discussed above, the controller performs automatic control upon determining that the first steering member is not being operated and has been operated last among the first steering member and the second steering member. The controller **37** does not perform the automatic control upon determining that the second steering member has been operated last among the first steering member and the second steering member even if the first steering member is not being operated.

(66) As a result, during the operation of the second steering member **46**, the operator is able to cause the work machine **1** to travel with a natural driving feeling without interference by the automatic control. Consequently, the feeling of unease of the operator is reduced by preventing unintended interference by the automatic control. Moreover, when the operator is operating the first steering member **45**, the automatic control can be started smoothly without the operation of a separate switch, etc., by stopping the operation of the first steering member **45**. Consequently, the

operating load of the operator can be further lightened by the automatic control.
(67) Although an embodiment of the present invention has been described so far, the present invention is not limited to the above embodiment and various modifications may be made within the scope of the invention.
(68) The work machine **1** is not limited to a motor grader and may be another work machine such as a wheel loader, a dump truck, or a forklift. The number of the steering actuator **41** is not limited to one and may be two or more. The steering actuator **41** is not limited to a hydraulic cylinder and may be a hydraulic motor or an electric motor.
(69) The steering speed data is not limited to the above embodiment and may be changed. Alternatively, the center return mode may be omitted. The controller **37** in the above embodiment controls the steering actuator **41** so as to change the steering angle θ**1** at a speed that corresponds to the operating amount of the first steering member **45**. However, the controller **37** may control the steering actuator **41** so that the steering angle θ**1** becomes an angle that corresponds to the operating amount of the first steering member **45**. That is, the control of the steering angle θ**1** by the first steering member **45** is not limited to a speed-based control and may also be a position-based control.
(70) The process performed by the controller **37** in the steering stabilizer mode is not limited to that of the above embodiment and may be changed. For example, the controller **37** may determine, as the target direction, the traveling direction H**2** of the vehicle body **2** when the operator has returned the first steering member **45** to the neutral range as indicated by point P**3** in FIG. **6**.
(71) The automatic control is not limited to the abovementioned center return mode and the steering stabilizer mode and may be changed. For example, the automatic control may also include an automatic steering mode for causing the work machine **1** to travel according to a predetermined target route. In the automatic steering mode, the controller **37** may determine the target angle of the steering angle θ**1** so that the work machine **1** moves along the target route. The target route may be input by the operator into the controller **37**. The target route may be input from an external computer into the controller **37**. Alternatively, the controller **37** may automatically generate the target route.
(72) According to the present invention, the operating load on the operator can be lightened due to the automatic control of the steering angle and the feeling of unease of the operator due to the automatic control can be suppressed in the work machine.

Claims

1. A work machine comprising: a vehicle body; a traveling wheel supported by the vehicle body; a first steering member that is operable by an operator of the work machine; a second steering member that is separate from the first steering member and that is operable by the operator; an actuator configured to: change a steering angle of the traveling wheel in response to an operation of the first steering member, and change the steering angle of the traveling wheel in response to an operation of the second steering member; a first operation sensor configured to output a first operation signal that indicates the operation of the first steering member; a second operation sensor configured to output a second operation signal that indicates the operation of the second steering member; and a controller configured to: acquire the first operation signal and the second operation signal, determine whether or not the first steering member is being operated, determine whether the first steering member was operated last among the first steering member and the second steering member, perform an automatic control to control the actuator so as to change the steering angle of the traveling wheel to a target steering angle upon determining that the first steering member is not being operated and the first steering member was operated last among the first steering member and the second steering member, and not perform the automatic control upon determining that the second steering member was operated last among the first steering member and the second steering

member, even if the first steering member is not being operated.
2. The work machine according to claim 1, wherein the first steering member is a lever.
3. The work machine according to claim 1, wherein the second steering member is a steering wheel.
4. The work machine according to claim 1, wherein when the automatic control is performed, the controller is configured to: determine a target direction and a traveling direction of the vehicle body, and determine the target steering angle so as to hold the traveling direction of the vehicle body in the target direction.
5. The work machine according to claim 1, wherein the first steering member is operable between a left steering range, a right steering range, and a neutral range between the left steering range and the right steering range; and the controller is configured to determine that the first steering member is not being operated when an operating position of the first steering member is in the neutral range.
6. The work machine according to claim 1, wherein the controller is configured to: determine whether the second steering member is being operated, and not perform the automatic control upon determining that the second steering member is being operated.
7. The work machine according to claim 6, wherein the controller is configured to: detect an operating speed of the second steering member, and determine that the second steering member is not being operated when the operating speed is equal to or less than a threshold.
8. A method for controlling a work machine including a vehicle body, a traveling wheel supported by the vehicle body, and an actuator configured to change a steering angle of the traveling wheel, the method comprising: acquiring a first operation signal that indicates an operation of a first steering member that is operable to change the steering angle of the traveling wheel, acquiring a second operation signal that indicates an operation of a second steering member that is separate from the first steering member and that is operable to change the steering angle of the traveling wheel, determining whether the first steering member is being operated, determining whether the first steering member was operated last among the first steering member and the second steering member, performing an automatic control to control the actuator so as to change the steering angle of the traveling wheel to a target steering angle upon determining that the first steering member is not being operated and the first steering member was operated last among the first steering member and the second steering member, and not performing the automatic control upon determining that the second steering member was operated last among the first steering member and the second steering member, even if the first steering member is not being operated.
9. The method according to claim 8, wherein the first steering member is a lever.
10. The method according to claim 8, wherein the second steering member is a steering wheel.
11. The method according to claim 8, further comprising: when the automatic control is performed, determining a target direction and a traveling direction of the vehicle body and determining the target steering angle so as to hold the traveling direction of the vehicle body in the target direction.
12. The method according to claim 8, wherein the first steering member is operable between a left steering range, a right steering range, and a neutral range between the left steering range and the right steering range; and the method further comprises determining that the first steering member is not being operated when an operating position of the first steering member is in the neutral range.
13. The method according to claim 8, further comprising: determining whether the second steering member is being operated; and not performing the automatic control upon determining that the second steering member is being operated.
14. The method according to claim 13, further comprising: detecting an operating speed of the second steering member; and determining that the second steering member is not being operated when the operating speed is equal to or less than a threshold.