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CONTROL SYSTEM AND CONTROL METHOD FOR LOADING MACHINE

Abstract

An operation signal input unit receives an input of a manual operation signal for a swing body and work equipment on the basis of an operation of an operation device. A movement control unit generates an automatic operation signal for driving the swing body and the work equipment. An output determination unit determines to output the manual operation signal for any of the swing body and the work equipment for which there has been an input of the manual operation signal and determines to output the automatic operation signal for any thereof for which there has been no input of the manual operation signal on the basis of the input manual operation signal. An operation signal output unit outputs the manual operation signal or the automatic operation signal for each of the swing body and the work equipment on the basis of a result of the determination.

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Background/Summary

TECHNICAL FIELD
[0001] The present disclosure relates to a control system and a control method for a loading machine.
[0002] Priority is claimed on Japanese Patent Application No. 2021-084780 filed on May 19, 2021, the content of which is incorporated herein by reference.
BACKGROUND ART
[0003] Patent Document 1 discloses a technology related to semi-automatic control of a loading machine. The semi-automatic control according to Patent Document 1 is a control performing automatic excavation by a control device receiving an excavation instruction from an operator after completion of loading with respect to a loading target such as a dump truck and controlling swinging of the loading machine and driving of work equipment.
CITATION LIST
Patent Document
Patent Document 1
[0004] Japanese Unexamined Patent Application, First Publication No. 2020-041352
SUMMARY OF INVENTION
Technical Problem
[0005] Incidentally, a position of a bucket after the control by the semi-automatic control and a position of the bucket intended by the operator do not always match.
[0006] An object of the present disclosure is to provide a control system and a control method for a loading machine in which the loading machine is controlled according to an operation by an operator during an automatic control of the loading machine.
Solution to Problem
[0007] According to one aspect of the present disclosure, a control system for a loading machine is a control device for a loading machine including a swing body swinging around a swing center, a support part supporting the swing body, and work equipment having a bucket and attached to the swing body, and the control system for a loading machine includes an operation signal input unit configured to receive an input of a manual operation signal for the swing body and the work equipment on the basis of an operation of the operation device, a movement control unit configured to generate an automatic operation signal for driving the swing body and the work equipment, an output determination unit configured to determine to output the manual operation signal for any of the swing body and the work equipment for which there has been an input of the manual operation signal and determine to output the automatic operation signal for any thereof for which there has been no input of the manual operation signal, on the basis of the input manual operation signal, and an operation signal output unit configured to output the manual operation signal or the automatic operation signal for each of the swing body and the work equipment on the basis of a result of the determination.
Advantageous Effects of Invention
[0008] According to the aspect described above, the control system for a loading machine can control the loading machine according to an operation by an operator during an automatic control of the loading machine.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0009] FIG. **1** is a schematic view illustrating a configuration of a loading machine according to a first embodiment.

[0010] FIG. **2** is a view illustrating a configuration inside a cab according to the first embodiment.

[0011] FIG, **3** is a schematic block diagram showing a configuration of a control device according to the first embodiment.

[0012] FIG. **4** is a view illustrating an example of a target posture of work equipment at the start of excavation according to the first embodiment.

[0013] FIG. **5** is a view illustrating an example of movement of the loading machine from the start of automatic loading control to the start of dumping according to the first embodiment.

[0014] FIG. **6** is a view illustrating an example of movement of the loading machine from the start of dumping to the end of the automatic loading control according to the first embodiment.

[0015] FIG. **7** is a view comparing a posture of the work equipment at the start of the automatic loading control and a posture of the work equipment at the end of the automatic loading control in the first embodiment.

[0016] FIG. **8** is a flowchart showing an operation of the control device according to the first embodiment.

[0017] FIG. **9** is a flowchart showing an operation of the control device from the start of the automatic loading control to the start of dumping according to the first embodiment.

[0018] FIG. **10** is a flowchart showing an operation of the control device from the start of dumping to the end of the automatic loading control according to the first embodiment.

[0019] FIG. **11** is a flowchart showing an automatic/manual switching determination operation of the control device according to the first embodiment.

[0020] FIG. **12** is a diagram showing examples of operation signals for the work equipment according to the first embodiment.

DESCRIPTION OF EMBODIMENTS

First Embodiment

[0021] Hereinafter, embodiments will be described in detail with reference to the drawings.

Configuration of Loading Machine **100**

[0022] FIG. **1** is a schematic view illustrating a configuration of a loading machine **100** according to a first embodiment.

[0023] The loading machine **100** operates at a construction site, excavates a work object such as earth, and loads it onto a loading target T such as a dump truck. The loading machine **100** according to the first embodiment is a face excavator. Further, a loading machine **100** according to another embodiment may be a backhoe excavator or a rope excavator. The loading machine **100** includes an undercarriage **110** (support part), a swing body **120**, work equipment **130**, and a cab **140**.

[0024] The undercarriage **110** supports the loading machine **100** to be able to travel. The undercarriage **110** includes two endless tracks **111** provided on the left and right and two traveling motors **112** for driving the endless tracks **111**.

[0025] The swing body **120** is supported by the undercarriage **110** to be able to swing around a swing center.

[0026] The work equipment **130** is driven by a hydraulic pressure. The work equipment **130** is supported by a front portion of the swing body **120** so that it can be driven in a vertical direction. The cab **140** is a space for an operator to be on board and perform an operation of the loading machine **100**. The cab **140** is provided in a left front portion of the swing body **120**.

[0027] Here, a portion of the swing body **120** to which the work equipment **130** is attached is referred to as a front portion. Also, for the swing body **120**, with the front portion as a reference, a portion on an opposite side is referred to as a rear portion, a portion on a left side is referred to as a left portion, and a portion on a right side is referred to as a right portion.

Configuration of Swing Body **120**

[0028] The swing body **120** includes an engine **121**, a hydraulic pump **122**, a control valve **123**, and a swing motor **124**.

[0029] The engine **121** is a prime mover that drives the hydraulic pump **122**. The engine **121** is an example of a power source.

[0030] The hydraulic pump **122** is a variable capacity pump driven by the engine **121**. The hydraulic pump **122** supplies a hydraulic oil to actuators (a boom cylinder **131**C, an arm cylinder **132**C, a bucket cylinder **133**C, a clam cylinder **1332**C, the travel motors **112**, and the swing motor **124**) via the control valve **123**.

[0031] The control valve **123** controls a flow rate of the hydraulic oil supplied from the hydraulic pump **122**.

[0032] The swing motor **124** is driven by the hydraulic fluid supplied from the hydraulic pump **122** via the control valve **123** to swing the swing body **120**.

Configuration of Work Equipment **130**

[0033] The work equipment **130** includes a boom **131**, an arm **132**, a clam bucket **133**, the boom cylinder **131**C, the arm cylinder **132**C, and the bucket cylinder **133**C.

[0034] A base end portion of the boom **131** is attached to the swing body **120** via a boom pin. Further, in the loading machine **100** illustrated in FIG. **1**, the boom **131** is provided at a central portion of a front surface of the swing body **120**, but the present disclosure is not limited thereto, and the boom **131** may be attached with an offset in a left-right direction. In this case, a swing center of the swing body **120** is not positioned on a plane of movement of the work equipment **130**.

[0035] The arm **132** connects the boom **131** and the clam bucket **133**. A base end portion of the arm **132** is attached to a distal end portion of the boom **131** via an arm pin.

[0036] The clam bucket **133** includes a backhaul **1331** attached to a distal end portion of the arm **132** via a pin, a clamshell **1332** having bucket teeth for excavating earth or the like, and the clam cylinder **1332**C for opening and closing the backhaul **1331** and the clamshell **1332**. The backhaul **1331** and the clamshell **1332** are connected via a pin to be openable and closable. When the backhaul **1331** and the clamshell **1332** are closed, the backhaul **1331** and clamshell **1332** function as a container for containing excavated earth. On the other hand, when the backhaul **1331** and the clamshell **1332** open, the accommodated earth can be dumped. A base end portion of the clam cylinder **1332**C is attached to the backhaul **1331**. A distal end portion of the clam cylinder **1332**C is attached to the clamshell **1332**.

[0037] That is, the boom **131**, the arm **132**, the backhaul **1331**, and the clamshell **1332** constitute a linkage. The boom **131**, the arm **132**, the backhaul **1331**, and the clamshell **1332** are each an example of a link part.

[0038] The boom cylinder **131**C is a hydraulic cylinder for operating the boom **131**. A base end portion of the boom cylinder **131**C is attached to the swing body **120**. A distal end portion of the boom cylinder **131**C is attached to the boom **131**.

[0039] The arm cylinder **132**C is a hydraulic cylinder for driving the arm **132**. A base end portion of the arm cylinder **132**C is attached to the boom **131**. A distal end portion of the arm cylinder **132**C is attached to the arm **132**.

[0040] The bucket cylinder **133**C is a hydraulic cylinder for driving the clam bucket **133**. A base end portion of the bucket cylinder **133**C is attached to the arm **132**. A distal end portion of the bucket cylinder **133**C is attached to a link member connected to the backhaul **1331**.

Configuration of Cab **140**

[0041] FIG. **2** is a view illustrating a configuration inside the cab **140** according to the first embodiment.

[0042] A driver's seat **141**, an operation terminal **142**, and an operation device **143** are provided in the cab **140**. The operation terminal **142** is provided in the vicinity of the driver's seat **141** and serves as a user interface with a control device **160** to be described later. The operation terminal **142** may receive an operation from the operator by, for example, a touch panel. Also, the operation terminal **142** may include a display unit such as an LCD. The touch panel is an example of a display unit.
[0043] The operation device **143** is a device for driving the undercarriage **110**, the swing body **120**, and the work equipment **130** by a manual operation of the operator. The operation device **143** includes a left operation lever **143**LO, a right operation lever **143**RO, a left foot pedal **143**LF, a right foot pedal **143**RF, a left travel lever **143**LT, a right travel lever **143**RT, a clam open pedal **143**CO, a clam close pedal **143**CC, a swing brake pedal **143**TB, and a start switch **143**SW.
[0044] The left operation lever **143**LO is provided on a left side of the driver's seat **141**. The right operation lever **143**RO is provided on a right side of the driver's seat **141**.
[0045] The left operation lever **143**LO is an operating mechanism for performing a swing operation of the swing body **120** and an excavating/dumping operation of the arm **132**. Specifically, when the operator of the loading machine **100** tilts the left operation lever **143**LO forward, the arm **132** performs a dumping operation. Also, when the operator of the loading machine **100** tilts the left operation lever **143**LO rearward, the arm **132** performs an excavating operation. Also, when the operator of the loading machine **100** tilts the left operation lever **143**LO in a right direction, the swing body **120** swings rightward. Also, when the operator of the loading machine **100** tilts the left operation lever **143**LO in a left direction, the swing body **120** swings leftward. Further, in another embodiment, the swing body **120** may swing rightward or leftward when the left operation lever **143**LO is tilted in a front-rear direction, and the arm **132** may perform an excavating operation or a dumping operation when the left operation lever **143**LO is tilted in the left-right direction.
[0046] The right operation lever **143**RO is an operation mechanism for performing an excavating/dumping operation of the clam bucket **133** and raising/lowering operations of the boom **131**. Specifically, when the operator of the loading machine **100** tilts the right operation lever **143**RO forward, a lowering operation of the boom **131** is executed. Also, when the operator of the loading machine **100** tilts the right operation lever **143**RO rearward, a raising operation of the boom **131** is executed. Also, when the operator of the loading machine **100** tilts the right operation lever **143**RO in a right direction, a dumping operation of the clam bucket **133** is performed. Also, when the operator of the loading machine **100** tilts the right operation lever **143**RO in a left direction, an excavating operation of the clam bucket **133** is performed. Further, in another embodiment, when the right operation lever **143**RO is tilted in the front-rear direction, the clam bucket **133** may perform a dumping operation or an excavating operation, and when the right operation lever **143**RO is tilted in the left-right direction, the boom **131** may perform a raising operation or a lowering operation.
[0047] The left foot pedal **143**LF is disposed on a left side of a floor in front of the driver's seat **141**. The right foot pedal **143**RF is disposed on a right side of the floor in front of the driver's seat **141**. The left travel lever **143**LT is pivotally supported by the left foot pedal **143**LF, and is configured so that an inclination of the left travel lever **143**LT and a depression of the left foot pedal **143**LF are interlocked. The right travel lever **143**RT is pivotally supported by the right foot pedal **143**RF, and is configured so that an inclination of the right travel lever **143**RT and a depression of the right foot pedal **143**RF are interlocked.
[0048] The left foot pedal **143**LF and the left travel lever **143**LT correspond to a rotational drive of a left crawler track of the undercarriage **110**. Specifically, when the operator of the loading machine **100** tilts the left foot pedal **143**LF or the left travel lever **143**LT forward, the left crawler track rotates in a forward direction. Also, when the operator of the loading machine **100** tilts the left foot pedal **143**LF or the left travel lever **143**LT rearward, the left crawler track rotates in a rearward direction.

[0049] The right foot pedal **143**RF and the right travel lever **143**RT correspond to a rotational drive of a right crawler track of the undercarriage **110**. Specifically, when the operator of the loading machine **100** tilts the right foot pedal **143**RF or the right travel lever **143**RT forward, the right crawler track rotates in a forward direction. Also, when the operator of the loading machine **100** tilts the right foot pedal **143**RF or the right travel lever **143**RT rearward, the right crawler track rotates in a rearward direction.
[0050] The clam open pedal **143**CO and the clam close pedal **143**CC are disposed on a right side of the left foot pedal **143**LF. The clam open pedal **143**CO is disposed adjacent to the left of the clam close pedal **143**CC. When the clam open pedal **143**CO is depressed, the clam bucket **133** opens at a speed in accordance with a depression amount of the clam open pedal **143**CO. When the clam close pedal **143**CC is depressed, the clam bucket **133** closes at a speed in accordance with a depression amount of the clam close pedal **143**CC.
[0051] The swing brake pedal **143**TB is disposed on a right side of the right foot pedal **143**RF. When the swing brake pedal **143**TB is depressed, a relief pressure of a hydraulic circuit connecting the control valve **123** and the swing motor **124** is increased.
[0052] Specifically, when the swing brake pedal **143**TB is depressed, a solenoid of a variable relief valve provided in the hydraulic circuit connecting the control valve **123** and the swing motor **124** is excited, and thereby the relief pressure of the variable relief valve is increased. Thereby, a braking force related to the swing can be increased.
[0053] The start switch **143**SW is provided on, for example, a handle portion of the left operation lever **143**LO. Further, the start switch **143**SW may be disposed to be positioned in the vicinity of the operator seated on the driver's seat **141**. When the start switch **143**SW is depressed, an automatic loading instruction signal is output to the control device **160**. The control device **160** starts an automatic loading control to be described later when it receives an input of the automatic loading instruction signal.
Configuration of Measurement System
[0054] As illustrated in FIG. **1**, the loading machine **100** includes a position/azimuth direction calculator **151**, an inclination measuring device **152**, a boom angle sensor **153**, an arm angle sensor **154**, a bucket angle sensor **155**, and a detection device **156**.
[0055] The position/azimuth direction calculator **151** calculates a position of the swing body **120** and an azimuth direction in which the swing body **120** is directed. The position/azimuth direction calculator **151** includes two receivers that receive positioning signals from artificial satellites that form a global navigation satellite system (GNSS). The two receivers are installed at different positions on the swing body **120**. The position/azimuth direction calculator **151** detects a position of a representative point (origin of an excavator coordinate system) of the swing body **120** in a field coordinate system on the basis of the positioning signals received by the receivers.
[0056] The position/azimuth direction calculator **151** uses the positioning signals received by the two receivers to calculate the azimuth direction in which the swing body **120** is directed as a relationship of an installation position of one receiver with respect to an installation position of the other receiver. The azimuth direction in which the swing body **120** is directed is a direction orthogonal to the front surface of the swing body **120** and is equal to a horizontal component of an extension direction of a straight line extending from the boom **131** to the clam bucket **133** of the work equipment **130**.
[0057] The inclination measuring device **152** measures an acceleration and an angular velocity of the swing body **120** and detects a posture (for example, a roll angle, a pitch angle, and a yaw angle) of the swing body **120** on the basis of the measurement result. The inclination measuring device **152** is installed on, for example, a lower surface of the swing body **120**. The inclination measuring device **152** can use, for example, an inertial measurement unit (IMU).
[0058] The boom angle sensor **153** is attached to the boom **131** and detects an inclination angle of the boom **131**.

[0059] The arm angle sensor **154** is attached to the arm **132** and detects an inclination angle of the arm **132**.
[0060] The bucket angle sensor **155** is attached to the backhaul **1331** of the clam bucket **133** and detects an inclination angle of the clam bucket **133**.
[0061] The boom angle sensor **153**, the arm angle sensor **154**, and the bucket angle sensor **155** according to the first embodiment detect inclination angles with respect to a horizontal plane. Further, angle sensors according to another embodiment are not limited thereto, and may detect inclination angles with respect to another reference plane. For example, in another embodiment, the angle sensors may detect relative rotation angles by a potentiometer provided at base end portions of the boom **131**, the arm **132**, and the clam bucket **133**, or may detect inclination angles by measuring cylinder lengths of the boom cylinder **131**C, the arm cylinder **132**C, and the bucket cylinder **133**C and converting the cylinder lengths into angles.
[0062] The detection device **156** detects a three-dimensional position of an object present around the loading machine **100**. A stereo camera, a laser scanner, an ultra wide band (UWB) ranging device, and the like can be mentioned as examples of the detection device **156**. The detection device **156** is provided in, for example, an upper portion of the cab **140** so that a detection direction is directed forward. Further, the detection device **156** may be provided at any position as long as surroundings of the loading machine **100** can be imaged. For example, the detection device **156** may be provided on a side wall or the like of the swing body **120** outside the cab **140**. Also, the detection direction may not be directed forward. The detection device **156** specifies a three-dimensional position of an object in a coordinate system with a position of the detection device **156** as a reference. Further, the loading machine **100** according to another embodiment may include a plurality of detection devices **156**.
Configuration of Control Device **160**
[0063] FIG. **3** is a schematic block diagram showing a configuration of the control device **160** according to the first embodiment.
[0064] The loading machine **100** includes the control device **160**. The control device **160** may be mounted on the operation terminal **142**, or may be provided separately from the operation terminal **142** and receive input/output from the operation terminal **142**. The control device **160** receives an operation signal from the operation device **143**. The operation signal indicates an object to be operated and a drive speed. Hereinafter, a magnitude of the drive speed indicated by the operation signal is also referred to as an operation amount. The control device **160** drives the work equipment **130**, the swing body **120**, and the undercarriage **110** by outputting a received operation signal or an operation signal for the automatic loading control generated by calculation to the control valve **123**. Hereinafter, the operation signal received from the operation device **143** is also called a manual operation signal, and the operation signal generated by calculation is also called an automatic operation signal.
[0065] The control device **160** is a computer including a processor **610**, main memory **630**, a storage **650**, and an interface **670**. The storage **650** stores a program. The processor **610** reads the program from the storage **650**, decompresses it in the main memory **630**, and executes processing according to the program.
[0066] As examples of the storage **650**, a semiconductor memory, a magnetic disk, a magneto-optical disk, an optical disk, and the like can be mentioned. The storage **650** may be internal media directly connected to a common communication line of the control device **160** or external media connected to the control device **160** via the interface **670**. The main memory **630** and the storage **650** are non-transitory tangible storage media.
[0067] The processor **610** includes, by executing a program, a measurement data acquisition unit **611**, a map generation unit **612**, an operation signal input unit **613**, a work equipment position specifying unit **614**, a loading target specifying unit **615**, a start angle specifying unit **616**, an avoidance angle specifying unit **617**, a target posture determination unit **618**, a movement control

unit **619**, a clam control unit **620**, an output determination unit **621**, and an operation signal output unit **622**.

[0068] The measurement data acquisition unit **611** acquires measurement data from the measurement system of the loading machine **100**. Specifically, the measurement data acquisition unit **611** acquires measurement data from the position/azimuth direction calculator **151**, the inclination measuring device **152**, the boom angle sensor **153**, the arm angle sensor **154**, the bucket angle sensor **155**, and the detection device **156**. The measurement data acquisition unit **611** calculates an angle of the swing body **120** by integrating an angular velocity of the swing body **120** measured by the inclination measuring device **152**.

[0069] The map generation unit **612** generates map data showing surroundings of the loading machine **100** using the measurement data acquired from the detection device **156**. The map generation unit **612** generates the map data by, for example, a simultaneous localization and mapping (SLAM) technology. The map data is expressed by a vehicle body coordinate system. The vehicle body coordinate system is an orthogonal coordinate system expressed by an axis extending in the front-rear direction, an axis extending in the left-right direction, and an axis extending in the vertical direction with the swing center of the swing body **120** as an origin. Since the detection device **156** is fixed to the swing body **120**, the map generation unit **612** can generate map data in the vehicle body coordinate system by translating calculation results of the SLAM on the basis of a positional relationship between the swing center and the detection device **156**. The map data generated by the map generation unit **612** is recorded in the main memory

[0070] The operation signal input unit **613** receives an input of the manual operation signal from the operation device **143**. The manual operation signal includes a rotation operation signal for the boom **131**, a rotation operation signal for the arm **132**, a rotation operation signal for the clam bucket **133**, an open/close operation signal for the clam bucket **133**, a swing operation signal for the swing body **120**, a travel operation signal for the undercarriage **110**, and an automatic loading instruction signal for the loading machine **100**.

[0071] The work equipment position specifying unit **614** specifies a position P (FIG. **5**) of a distal end of the arm **132** in the vehicle body coordinate system with the swing body **120** as a reference and a height H (FIG. **5**) from the distal end of the arm **132** to a lowest point of the clam bucket **133** on the basis of the measurement data acquired by the measurement data acquisition unit **611**. The lowest point of the clam bucket **133** refers to a point of an outer shape of the clam bucket **133** in which a distance from the ground level is the smallest.

[0072] The work equipment position specifying unit **614** obtains a vertical direction component and a horizontal direction component of the length of the boom **131** on the basis of the inclination angle of the boom **131** and a known length (a distance from the pin at the base end portion to the pin at the distal end portion) of the boom **131**. Similarly, the work equipment position specifying unit **614** obtains a vertical direction component and a horizontal direction component of the length of the arm **132**. The work equipment position specifying unit **614** specifies, as the position P of the distal end of the arm **132**, a position away from the position of the loading machine **100** in a direction specified by the azimuth direction and the posture of the loading machine **100**, by a sum of the vertical direction components and a sum of the horizontal direction components of the lengths of the boom **131** and the arm **132**. Also, on the basis of the inclination angle of the clam bucket **133** and a known shape of the clam bucket **133**, the work equipment position specifying unit **614** specifies the lowest point in the vertical direction of the clam bucket **133**, and specifies the height H from the distal end of the arm **132** to the lowest point and a horizontal distance D (FIG. **5**) from the distal end of the arm **132** to the lowest point.

[0073] When the automatic loading instruction signal is input to the operation signal input unit **613**, the loading target specifying unit **615** determines a loading point on the basis of the map data generated by the map generation unit **612**. The loading point refers to a position above the loading target T (for example, a dump body of the dump truck). In the automatic loading control, a dump control is started when the distal end of the arm **132** reaches the loading point. Specifically, the loading target specifying unit **615** specifies a position and shape of the loading target T from the map data and a known shape of the loading target T. For example, the loading target specifying unit **615** specifies a position of the loading target T by three-dimensional pattern matching. The loading target specifying unit **615** determines the loading point on the basis of a center point of an upper surface of the specified loading target T and the shape of the clam bucket **133**.

[0074] The start angle specifying unit **616** specifies, as a start angle, an angle between the azimuth direction in which the swing body **120** is directed when the automatic loading instruction signal is input to the operation signal input unit **613** and the azimuth direction in which the loading point is present. The azimuth direction in which the swing body **120** is directed when the automatic loading instruction signal is input can also be said to be an azimuth direction in which the swing body **120** is directed when the automatic loading control of the loading machine **100** is started. That is, the start angle specifying unit **616** specifies, as the start angle, an angle formed by a line segment extending from the swing center of the swing body **120** to the position of the distal end of the arm **132** specified by the work equipment position specifying unit **614** and a line segment extending from the swing center of the swing body **120** to the loading point when the automatic loading control is started.

[0075] The avoidance angle specifying unit **617** specifies an interference avoidance angle on the basis of the position and shape of the loading target T specified by the loading target specifying unit **615**. The interference avoidance angle refers to a swing angle when the work equipment **130** and the loading target T do not interfere with each other in a plan view from above. Specifically, the avoidance angle specifying unit **617** specifies the interference avoidance angle by the following procedures.

[0076] The avoidance angle specifying unit **617** specifies a rearmost point p**1** (FIG. **5**) of the outer shape of the loading target T in a swing direction of the swing body **120** on the basis of the position and shape of the loading target T specified by the loading target specifying unit **615**. The avoidance angle specifying unit **617** obtains a first angle ϕ**1** (FIG. **5**) formed by a line segment extending from the swing center of the swing body **120** to the position of the distal end of the arm **132** and a line segment extending from the swing center of the swing body **120** to the specified point of the outer shape of the loading target T when the automatic loading control is started. The avoidance angle specifying unit **617** specifies a foremost point p**2** (FIG. **5**) of the outer shape of the clam bucket **133** in the swing direction of the swing body **120** on the basis of the position of the distal end of the arm **132** specified by the work equipment position specifying unit **614** and the known shape of the clam bucket **133**. The avoidance angle specifying unit **617** obtains a second angle ϕ**2** formed by the line segment extending from the swing center of the swing body **120** to the position of the distal end of the arm **132** and a line segment extending from the swing center of the swing body **120** to the specified point of the outer shape of the clam bucket **133**. The avoidance angle specifying unit **617** obtains an interference avoidance angle ϕ**1** (FIG. **5**) by further subtracting a control margin angle ϕ**3** from a difference between the first angle ϕ**1** and the second angle ϕ**2**.

[0077] The target posture determination unit **618** calculates a posture of the work equipment **130** when the distal end of the arm **132** is positioned at the loading point on the basis of a distance and a height from the swing center to the loading point determined by the loading target specifying unit **615**, and determines a target posture when the work equipment **130** starts to dump. Also, the target posture determination unit **618** determines a target posture of the work equipment **130** at the start of excavation by reading a predetermined target posture of the work equipment **130** at the start of excavation from the storage **650** or the main memory **630**. FIG. **4** is a view illustrating an example of the target posture of the work equipment **130** at the start of excavation according to the first embodiment. The target posture at the start of excavation is a posture such that, for example, the clam bucket **133** approaches the undercarriage **110** to the extent that it does not interfere with the undercarriage **110**, and a bottom surface of the clam bucket **133** approaches a plane Z**1** including a bottom surface of the undercarriage **110** to the extent that it does not come into contact with the plane Z**1**. That is, the clam bucket **133** in the target posture at the start of excavation is positioned on an outward side from an interference prohibition region Z**2** formed outside a virtual circular cylinder circumscribing the undercarriage **110** in terms of a distance from the swing center. Such a target posture is a posture that facilitates proceeding to subsequent excavation work. Further, the interference prohibition region Z**2** is defined by a virtual circular cylinder instead of a rectangular parallelepiped corresponding to the undercarriage **110**, and thereby a contact between the undercarriage **110** and the clam bucket **133** can be prevented when the swing body **120** swings. The bottom surface of the clam bucket **133** in the target posture at the start of excavation may be parallel to the plane Z**1** or may form an acute angle with the plane Z**1**. The target posture is represented by, for example, positions of the distal end of the boom **131**, the distal end of the arm **132**, and the bucket teeth of the clam bucket **133** in the vehicle body coordinate system. Further, the posture of the work equipment **130** includes positions and angles of parts constituting the work equipment **130** in the vehicle body coordinate system.

[0078] When the operation signal input unit **613** has received an input of the automatic loading instruction signal, the movement control unit **619** shown in FIG. **3** generates the automatic operation signal that realizes a combined movement of the swing body **120** and the work equipment **130** for moving the clam bucket **133** to the loading point on the basis of the loading point specified by the loading target specifying unit **615** and the interference avoidance angle specified by the avoidance angle specifying unit **617**. Specifically, the movement control unit **619** generates the automatic operation signal for driving the work equipment **130** so that the posture of the work equipment **130** reaches the target posture at the start of dumping determined by the target posture determination unit **618**. Also, the movement control unit **619** adjusts a swing start timing so that the posture of the work equipment **130** reaches the target posture at the start of dumping before the swing angle reaches the interference avoidance angle. That is, when the swing body **120** has started swinging, and if the work equipment **130** does not have the target posture before the swing angle due to the swing reaches the interference avoidance angle, the movement control unit **619** does not generate the swing operation signal for the swing body **120**, and only generates an operation signal for the work equipment **130**. On the other hand, if the work equipment **130** is determined to have the target posture before the swing angle due to the swing reaches the interference avoidance angle, the movement control unit **619** generates the swing operation signal for the swing body **120** and the operation signal for the work equipment **130**, and realizes the combined movement of the swing body **120** and the work equipment **130**.

[0079] Also, after the distal end of the arm **132** has reached the loading point, the movement control unit **619** generates the automatic operation signal for driving the swing body **120** and the work equipment **130** so that the swing body **120** swings to the start angle specified by the start angle specifying unit **616** and the posture of the work equipment **130** reaches the target posture at the start of excavation determined by the target posture determination unit **618**.

[0080] The clam control unit **620** generates the automatic operation signal for opening the clam bucket **133** when the distal end of the arm **132** reaches the loading point. Also, the clam control unit **620** generates the automatic operation signal for closing the clam bucket **133** when the swing angle of the swing body **120** exceeds a difference between the start angle and the interference avoidance angle. Further, even before the distal end of the arm **132** reaches the loading point, the clam control unit **620** may generate the automatic operation signal for opening the clam bucket **133** when the clam bucket **133** and the loading target T overlap in a plan view from above.

[0081] The output determination unit **621** determines whether the swing body **120**, the boom **131**, the arm **132**, the clam bucket **133**, and the clamshell **1332** (controlled objects) are each to be controlled by the manual operation signal or the automatic operation signal on the basis of the manual operation signal that has been input to the operation signal input unit **613** and the automatic operation signal generated by the movement control unit **619**. The output determination unit **621** records and manages a value of an automatic operation flag in the main memory **630** for each controlled object. The output determination unit **621** determines that a controlled object whose automatic operation flag is ON is controlled by the automatic operation signal, and a controlled object whose automatic operation flag is OFF is controlled by the manual operation signal.

[0082] The operation signal output unit **622** outputs the manual operation signal that has been input to the operation signal input unit **613** or the automatic operation signal generated by the movement control unit **619** on the basis of the determination result of the output determination unit **621**.

Operation During Automatic Loading Control

[0083] Here, movement of the loading machine **100** during the automatic loading control according to the first embodiment will be described with reference to the drawings.

[0084] FIG. **5** is a view illustrating an example of movement of the loading machine **100** from the start of the automatic loading control to the start of dumping according to the first embodiment. FIG. **6** is a view illustrating an example of movement of the loading machine **100** from the start of dumping to the end of the automatic loading control according to the first embodiment.

[0085] The automatic loading control according to the first embodiment is started when the start switch **143**SW is depressed in a state in which the work equipment **130** has excavated earth, which is an object to be excavated, by a manual operation by the operator and the earth is held in the clam bucket **133**. When the automatic loading control is started, the loading machine **100** dumps the earth above the loading target T, and moves the work equipment **130** to a subsequent excavation start point. In the first embodiment, at the end of the automatic loading control, the swing body **120** is directed in a direction in which the automatic loading control has been started to facilitate subsequent excavation processing. Also, in order to facilitate the subsequent excavation processing, the work equipment **130** is placed in a posture in which the bottom surface of the clam bucket **133** is lowered close to the ground and the clam bucket **133** is brought closer to a vehicle body side.

[0086] Specifically, when the automatic loading control is started, the control device **160** first starts driving of the work equipment **130** (the boom **131**, the arm **132**, and the clam bucket **133**) and moves the clam bucket **133** upward as illustrated in FIG. **5**. After a delay, the control device **160** causes the swing body **120** to start swinging. The control device **160** adjusts a swing start timing so that the posture of the work equipment **130** reaches the target posture at the start of dumping before the swing angle of the swing body **120** becomes the same as the interference avoidance angle θ.sub.1. Hereinafter, the interference avoidance angle θ.sub.1 is also referred to as a first interference avoidance angle θ.sub.1. Further, if the posture of the work equipment **130** reaches the target posture at the start of dumping before the swing angle of the swing body **120** becomes the same as the first interference avoidance angle θ.sub.1, that is, when a height of the lowest point of the clam bucket **133** is higher than the upper surface of the loading target T, the work equipment **130** does not come into contact with the loading target T due to the swing of the swing body **120**. Thereafter, when the distal end of the arm **132** reaches the loading point, the control device **160** opens the clam bucket **133** and starts dumping.

[0087] After a certain period of time has elapsed since the start of dumping, the control device **160** causes the swing body **120** to start swinging as illustrated in FIG. **6**. The control device **160** does not start driving of the work equipment **130** until the swing angle of the swing body **120** exceeds an angle θ.sub.2 which is a difference between a start angle θ.sub.0 and the interference avoidance angle θ.sub.1. Hereinafter, the angle θ.sub.2 is also referred to as a second interference avoidance angle θ.sub.2. When the swing angle of the swing body **120** exceeds the second interference avoidance angle θ.sub.2, the control device **160** starts driving of the work equipment **130**. When the swing angle of the swing body **120** reaches the start angle θ.sub.0, the control device **160** ends driving of the swing body **120**. Also, when the posture of the work equipment **130** reaches the target posture at the start of excavation, the control device **160** ends driving of the work equipment **130**.

[0088] Further, after the swing angle of the swing body **120** has exceeded the second interference avoidance angle θ.sub.2, the control device **160** receives an operation of the operator from the operation device **143**. For a controlled object that has received an operation by the operator, the control device **160** does not output the automatic operation signal, but outputs the manual operation signal. On the other hand, for a controlled object that has not received an operation by the operator, the control device **160** continues to output the automatic operation signal.

[0089] FIG. **7** is a view comparing a posture of the work equipment **130** at the start of the automatic loading control and a posture of the work equipment **130** at the end of the automatic loading control in the first embodiment. The automatic loading control is started in a state in which the work equipment **130** excavates earth and the earth is held in the clam bucket **133**. Therefore, a posture **133***s* of the clam bucket **133** at the start of the automatic loading control is a posture with the bucket teeth facing upward above the object to be excavated. When excavating the object to be excavated, it is necessary to scoop it up from below with the bucket teeth facing the object to be excavated, and therefore, the position and posture of the clam bucket **133** need to be changed from the posture **133***s* of the clam bucket **133** at the start of the automatic loading control, in order to start the excavation work. On the other hand, a posture **133***e* of the clam bucket **133** at the end of the automatic loading control, that is, the target posture at the start of excavation, is a posture with the bucket teeth facing forward at a height close to the ground level. Thereby, the operator can easily transfer to the subsequent excavation work by bringing the posture of the clam bucket **133** into the target posture at the start of excavation when the automatic loading control ends.

Operation of Control Device **160**

[0090] FIG. **8** is a flowchart showing an operation of the control device **160** according to the first embodiment.

[0091] The control device **160** of the loading machine **100** performs state update processing shown in FIG. **8** at regular control cycles during operation.

[0092] The measurement data acquisition unit **611** acquires measurement data from the position/azimuth direction calculator **151**, the inclination measuring device **152**, the boom angle sensor **153**, the arm angle sensor **154**, the bucket angle sensor **155**, and the detection device **156** (step SS**1**). The map generation unit **612** updates the map data recorded in the main memory **630** using the measurement data acquired from the detection device **156** in step SS**1** (step SS**2**). Thereby, the control device **160** can always keep a latest state of the map data representing a situation in the vicinity of the loading machine **100** so that a latest position of the loading target T appears in the map data.

[0093] The work equipment position specifying unit **614** specifies the position P of the distal end of the arm **132** in the vehicle body coordinate system with the swing body **120** as a reference and the height H from the distal end of the arm **132** to the lowest point of clam bucket **133** on the basis of the measurement data acquired in step SS**1** (step SS**3**). Thereby, the control device **160** can constantly specify a current posture of the work equipment **130**.

[0094] FIG. **9** is a flowchart showing an operation of the control device **160** from the start of the automatic loading control to the start of dumping according to the first embodiment. FIG. **10** is a flowchart showing an operation of the control device **160** from the start of dumping to the end of the automatic loading control according to the first embodiment. FIG. **11** is a flowchart showing an automatic/manual switching determination operation of the control device according to the first embodiment.

[0095] When the start switch **143**SW is depressed by the operator, the operation signal input unit **613** of the control device **160** receives an input of the automatic loading instruction signal. The control device **160** starts the automatic loading control from step S**0** in FIG. **9** with the automatic loading instruction signal as a trigger.

[0096] When the automatic loading instruction signal is input, the output determination unit **621** of the control device **160** resets all values of automatic operation flags related to the swing body **120**, the boom **131**, the arm **132**, clam bucket **133**, and the clamshell **1332** to ON (step S**0**). The control device **160** updates the measurement data, the map data, and the posture of the work equipment **130** to a latest state by the state update processing shown in FIG. **8** (step S**1**). The loading target specifying unit **615** specifies the position and shape of the loading target T on the basis of the map data updated in step S**1** (step S**2**). The loading target specifying unit **615** determines the loading point on the basis of the position of the loading target T specified in step S**2** and the height H from the distal end of the arm **132** to the lowest point of the clam bucket **133** specified in step S**1** (step S**3**).

[0097] The start angle specifying unit **616** specifies the start angle θ.sub.0 on the basis of the position of the loading point in the map data determined in step S**3** (step S**4**). Since the map data is expressed by the vehicle body coordinate system, the start angle specifying unit **616** specifies, for example, an angle of a position vector of the loading point with respect to a coordinate axis extending forward of the swing body **120** as the start angle θ.sub.0. The avoidance angle specifying unit **617** specifies the first interference avoidance angle θ.sub.1 on the basis of the position and shape of the loading target T specified in step S**2** (step S**5**). The target posture determination unit **618** determines postures of the boom **131** and the arm **132** when the distal end of the arm **132** is positioned at the loading point as the target posture (step S**6**).

[0098] Next, the control device **160** updates the measurement data, the map data, and the posture of the work equipment **130** to the latest state by the state update processing shown in FIG. **8** (step S**7**). Next, the movement control unit **619** determines whether or not the posture of the work equipment **130** specified in step S**7** approximates the target posture determined in step S**6** (step S**8**). For example, when a difference between the position of the distal end of the arm **132** in the target posture and a current position of the distal end of the arm **132** is equal to or less than a predetermined value, the movement control unit **619** determines that the posture of the work equipment **130** approximates the target posture.

[0099] If the posture of the work equipment **130** does not approximate the target posture (step S**8**: NO), the movement control unit **619** generates the automatic operation signal for bringing the boom **131** and the arm **132** closer to the target posture (step S**9**). At this time, the movement control unit **619** generates the automatic operation signal on the basis of the positions and speeds of the boom **131** and the arm **132** specified in step S**7**.

[0100] Also, the movement control unit **619** calculates a sum of angular velocities of the boom **131** and the arm **132** on the basis of the generated automatic operation signals for the boom **131** and the arm **132**, and generates the automatic operation signal for rotating the clam bucket **133** at the same speed as the sum of the angular velocities (step S**10**). Thereby, the movement control unit **619** can generate the automatic operation signal for holding a ground angle of the clam bucket **133**.

[0101] The movement control unit **619** determines whether or not the work equipment **130** is swinging (step S**11**). The movement control unit **619** determines that the swing body **120** is swinging when, for example, a swing speed is equal to or higher than a predetermined speed. If the work equipment **130** is not swinging (step S**11**: NO), the movement control unit **619** calculates a completion time until the work equipment **130** has the target posture on the basis of the speeds of the boom **131** and the arm **132** specified in step S**7** (step S**12**). Also, the movement control unit **619** calculates a reaching time until the swing angle reaches the first interference avoidance angle θ.sub.1 specified in step S**5** when the swing body **120** starts swinging (step S**13**). The movement control unit **619** determines whether or not the completion time calculated in step S**12** is less than the reaching time calculated in step S**13** (step S**14**). That is, the movement control unit **619** determines whether or not the work equipment **130** has the target posture when the swing angle reaches the first interference avoidance angle θ.sub.1.

[0102] If the completion time is equal to or more than the reaching time (step S**14**: NO), that is, when the work equipment **130** does not have the target posture before the swing angle reaches the first interference avoidance angle θ.sub.1, the movement control unit **619** does not generate the swing operation signal for the swing body **120**. On the other hand, if the completion time is less than the reaching time (step S**14**: YES), that is, when the work equipment **130** has the target posture before the swing angle reaches the first interference avoidance angle θ.sub.1, the movement control unit **619** generates the swing operation signal for the swing body **120** (step S**15**). Thereby, the control device **160** can prevent the work equipment **130** from coming into contact with the loading target T.

[0103] Since the values of all the automatic operation flags recorded in the main memory **630** are ON, the output determination unit **621** determines that all the controlled objects are controlled by the automatic operation signals. Thereby, the operation signal output unit **622** outputs the automatic operation signal generated in at least one of steps S**9**, S**10**, and S**15** to the control valve **123** (step S**16**). The loading machine **100** is thereby driven. Then, the control device **160** returns the processing to step S**7** and continues the control.

[0104] On the other hand, if it is determined in step S**11** that the work equipment **130** is swinging (step S**11**: YES), the movement control unit **619** determines whether or not the distal end of the arm **132** reaches the loading point due to inertial swing when the operation signal for the swing is stopped, on the basis of the swing speed of the work equipment **130** specified in step S**7** (step S**17**). If the distal end of the arm **132** does not reach the loading point due to the inertial swing (step S**17**: NO), the movement control unit **619** generates the swing operation signal in step S**15**, and the operation signal output unit **622** outputs the swing operation signal to the control valve **123** in step S**16**.

[0105] On the other hand, if it is determined that the distal end of the arm **132** reaches the loading point due to the inertial swing (step S**17**: YES), the control device **160** updates the measurement data, the map data, and the posture of the work equipment **130** to the latest state by the state update processing shown in FIG. **8** (step S**18** in FIG. **10**). The movement control unit **619** determines whether or not the distal end of the arm **132** has reached the loading point on the basis of the map data updated in step S**18** (step S**19**). If the distal end of the arm **132** has not reached the loading point (step S**19**: NO), the control device **160** returns the processing to step S**18** and waits for the distal end of the arm **132** to reach the loading point. At this time, since the values of the automatic operation signals recorded in the main memory **630** are all ON, the control device **160** does not receive the manual operation of the operation device **143**.

[0106] If the distal end of the arm **132** has reached the loading point (step S**19**: YES), the clam control unit **620** generates an opening operation signal for the clam bucket **133** (step S**20**). The operation signal output unit **622** outputs the opening operation signal generated in step S**20** to the control valve **123** (step S**21**). The clam control unit **620** waits for the elapse of a certain period of time after outputting the opening operation signal for the clam bucket **133** (step S**22**). This time is a time required for a certain amount of earth to fall from the open clam bucket **133**. Further, this time may be shorter than a time required for all the earth to fall from the clam bucket **133**.

[0107] After a certain period of time, the target posture determination unit **618** determines the target posture of the work equipment **130** at the start of excavation by reading the predetermined target posture of the work equipment **130** at the start of excavation from the storage **650** or the main memory **630** (step S**23**). The target posture at the start of excavation is a posture such that, for example, the clam bucket **133** approaches the undercarriage **110** to the extent that it does not interfere with the undercarriage **110** and the bottom surface of the clam bucket **133** approaches a plane passing through the bottom surface of the undercarriage **110** to the extent that it does interfere with the plane.

[0108] Next, the control device **160** updates the measurement data, the map data, and the posture of the work equipment **130** to the latest state by the state update processing shown in FIG. **8** (step S**24**). Next, the movement control unit **619** determines whether or not the swing angle of the swing body **120** from the start of dumping to the present time is less than the second interference avoidance angle θ.sub.2 which is a difference between the start angle θ.sub.0 and the first interference avoidance angle θ.sub.1 (step S**25**). If the swing angle is less than the second interference avoidance angle θ.sub.2 (step S**25**: YES), since the work equipment **130** may come into contact with the loading target T, the movement control unit **619** generates the automatic operation signal (neutral signal) for maintaining the posture of the work equipment **130**.

[0109] In step S**25**, if the swing angle is equal to or larger than the second interference avoidance angle θ.sub.2 (step S**25**: NO), the movement control unit **619** determines whether or not the posture of the work equipment **130** specified in step S**24** approximates the target posture determined in step S**23** (step S**26**). If the posture of the work equipment **130** does not approximate the target posture (step S**26**: NO), the movement control unit **619** generates the automatic operation signal for bringing the boom **131**, the arm **132**, and the clam bucket **133** closer to the target posture (step S**27**). Also, the clam control unit **620** also generates a closing operation signal for the clam bucket (step S**28**). If the posture of the work equipment **130** approximates the target posture (step S**26**: YES), the movement control unit **619** does not generate the automatic operation signal for the work equipment **130**.

[0110] Also, the movement control unit **619** determines whether or not the distal end of the arm **132** can swing to the start angle θ.sub.0 specified in step S**4** due to inertial swing when the operation signal for the swing has stopped, on the basis of the swing speed of the work equipment **130** specified in step S**24** (step S**29**). If the distal end of the arm **132** cannot swing to the start angle θ.sub.0 due to the inertial swing (step S**29**: NO), the movement control unit **619** generates a swing operation signal (step S**30**). On the other hand, if the distal end of the arm **132** can swing to the start angle θ.sub.0 due to the inertial swing (step S**29**: YES), the movement control unit **619** does not generate the swing operation signal.

[0111] Next, as shown in FIG. **11**, the output determination unit **621** selects the controlled object (the swing body **120**, the boom **131**, the arm **132**, the clam bucket **133**, or the clamshell **1332**) one by one (step S**31**), and executes the processing from step S**31** to step S**42** for the selected controlled object.

[0112] The output determination unit **621** determines whether or not a value of the automatic operation flag related to the controlled object selected in step S**31** is ON (step S**32**). If the value of the automatic operation flag is ON (step S**32**: YES), the output determination unit **621** determines whether or not the operation signal input unit **613** has received an input of the manual operation signal for operating the controlled object selected in step S**31** (step S**33**). The output determination unit **621** determines that the input of the manual operation signal has been received when an operation amount of the manual operation signal is equal to or larger than a threshold value corresponding to an allowance.

[0113] Further, the manual operation signal related to the swing body **120** is an operation signal in the left-right direction by the left operation lever **143**LO and an operation signal of the swing brake pedal **143**TB. The manual operation signal related to the boom **131** is an operation signal in the front-rear direction by the right operation lever **143**RO. The manual operation signal related to the arm **132** is an operation signal in the front-rear direction by the left operation lever **143**LO. The manual operation signal related to rotation of the clam bucket **133** is an operation signal of the right operation lever **143**RO in the left-right direction. The manual operation signals related to opening and closing of the clamshell **1332** are operation signals of the clam open pedal **143**CO and the clam close pedal **143**CC.

[0114] If there is an input of the manual operation signal related to the controlled object selected in step S**31** (step S**33**: YES), the output determination unit **621** determines whether or not the manual operation signal indicates an operation resisting the automatic operation signal related to the controlled object generated in step S**27**, S**28**, or S**30** (step S**34**). Specifically, if an operation direction of the manual operation signal is a direction opposite to an operation direction of the automatic operation signal, or if the operation of the manual operation signal is a brake operation, the output determination unit **621** determines that the manual operation signal indicates an operation resisting the automatic operation signal. For example, if the automatic operation signal indicates a counterclockwise swing operation and the manual operation signal indicates a clockwise swing operation, the output determination unit **621** determines that the manual operation signal indicates an operation resisting the automatic operation signal. Also, for example, if the automatic operation signal indicates a closing operation of the clamshell **1332** and the manual operation signal indicates an opening operation of the clamshell **1332**, the output determination unit **621** determines that the manual operation signal indicates an operation resisting the automatic operation signal. Also, for example, if the automatic operation signal indicates a counterclockwise swing operation and the manual operation signal indicates depression of the swing brake pedal **143**TB, the output determination unit **621** determines that the manual operation signal indicates an operation resisting the automatic operation signal.

[0115] If the manual operation signal is not an operation that resists the automatic operation signal (step S**34**: NO), the output determination unit **621** determines whether or not an operation amount of the manual operation signal is less than an operation amount of the automatic operation signal (step S**35**).

[0116] If the operation amount of the manual operation signal is less than the operation amount of the automatic operation signal (step S**35**: YES), or if it is determined in step S**33** that there is no input of the manual operation signal (step S**33**: NO), the output determination unit **621** determines whether or not a control amount of the controlled object selected in step S**31** has reached a target value (step S**36**). If the controlled object is the swing body **120**, the output determination unit **621** determines whether or not the swing angle has reached the start angle θ.sub.0. If the controlled object is the boom **131**, the arm **132**, or the clam bucket **133**, the output determination unit **621** determines whether or not the rotation angle has reached an angle related to the target posture determined in step S**23**. If the controlled object is the clamshell **1332**, the output determination unit **621** determines whether or not a degree of opening has reached zero.

[0117] When the control amount of the controlled object selected in step S**31** has not reached the target value (step S**36**: NO), the output determination unit **621** determines that the controlled object selected in step S**31** is controlled by the automatic operation signal. That is, the value of the automatic operation flag related to the controlled object selected in step S**31** is maintained ON. The operation signal output unit **622** outputs the automatic operation signal related to the controlled object selected in step S**31** among the automatic operation signals generated in steps S**27**, S**28**, and S**30** (step S**37**).

[0118] On the other hand, if the manual operation signal is an operation that resists the automatic operation signal (step S**34**: YES), if an operation amount of the manual operation signal is not less than an operation amount of the automatic operation signal (step S**35**: NO), or if a control amount of the controlled object has reached the target value (step S**36**: YES), the output determination unit **621** performs the following processing. The output determination unit **621** determines whether or not the controlled object selected in step S**31** is the link member (the boom **131**, the arm **132**, and the clam bucket **133**) constituting the work equipment **130** (step S**38**).

[0119] If the controlled object that switches from the automatic operation to the manual operation is the link member constituting the work equipment **130** (step S**38**: YES), the output determination unit **621** determines whether or not the swing angle of the swing body **120** from the start of dumping to the present time is less than the second interference avoidance angle θ.sub.2 which is a difference between the start angle θ.sub.0 and the first interference avoidance angle θ.sub.1 (step S**39**). If the swing angle is less than the second interference avoidance angle θ.sub.2 (step S**39**: YES), there is a possibility that the work equipment **130** may come into contact with the loading target T, and therefore the output determination unit **621** determines that the controlled object selected in step S**31** is controlled by the automatic operation signal. That is, the value of the automatic operation flag related to the controlled object selected in step S**31** is maintained ON. Then, the operation signal output unit **622** outputs the automatic operation signal related to the controlled object selected in step S**31** (step S**37**).

[0120] On the other hand, if the swing angle is equal to or larger than the second interference avoidance angle θ.sub.2 (step S**39**: NO), the movement control unit **619** specifies, among the plurality of link members, a link member which is other than the link member selected in step S**31** and whose automatic operation flag is ON. For example, if the boom **131** is selected in step S**31**, the movement control unit **619** specifies one whose automatic operation flag is ON among the arm **132** and the clam bucket **133**. The movement control unit **619** reduces an operation amount of the automatic operation signal related to the specified link member at a certain rate from the operation amount determined in step S**27** (step S**40**).
[0121] FIG. **12** is a diagram showing examples of operation signals for the work equipment according to the first embodiment. In FIG. **12**, an operation amount of the output operation signal is indicated by a solid line, an operation amount of the automatic operation signal determined in step S**27** is indicated by a dotted line, and an operation amount of the manual operation signal is indicated by a dashed-dotted line. In the example shown in FIG. **12**, outputs of the automatic operation signals for the boom **131**, the arm **132**, and the clam bucket **133** start at time t.sub.1. Thereafter, at time t.sub.2, the operator starts inputting the manual operation signal for operating the arm **132** in a direction opposite to the automatic control. Also, following the arm **132**, the operator also starts inputting the manual operation signal for operating the clam bucket **133** in a direction opposite to the automatic control. On the other hand, since operation amounts of both the arm **132** and the clam bucket **133** are less than a threshold value from time t.sub.2 to time t.sub.3, the output determination unit **621** determines in step S**33** that no manual operation signal has been input. Therefore, the automatic operation signals are output as operation signals for the boom **131**, the arm **132**, and the clam bucket **133** from time t.sub.1 to time t.sub.3.
[0122] At time t.sub.3, when the operation amount of the manual operation signal for the arm **132** becomes equal to or larger than the threshold value, since operation directions of the automatic operation signal and the manual operation signal are opposite to each other, the output determination unit **621** determines in step S**34** that the manual operation signal is an operation resisting the automatic operation signal. Thereby, the automatic operation flag of the arm **132** is turned off, and thereafter, the manual operation signal is output as the operation signal for the arm **132**. At this time, in step S**40**, the movement control unit **619** reduces operation amounts of the automatic operation signals for the boom **131** and the clam bucket **133** at a certain rate. That is, after time t.sub.3, the operation amount of the output automatic operation signal (solid line in FIG. **12**) reduces at a certain rate from the operation amount (dotted line in FIG. **12**) determined in step S**27**.
[0123] Thereafter, at time t.sub.4, when the operation amount of the manual operation signal for the clam bucket **133** is equal to or larger than the threshold value, since operation directions of the automatic operation signal and the manual operation signal are opposite to each other, the output determination unit **621** determines in step S**34** that the manual operation signal is an operation resisting the automatic operation signal. Thereby, the automatic operation flag of the clam bucket **133** is turned off. Thereafter, the manual operation signals are output as the operation signals for the arm **132** and the clam bucket **133**. Further, at time t.sub.4, the operator starts inputting the manual operation signal for operating the boom **131** in the same direction as the automatic control. However, from time t.sub.4 to time t.sub.5, the operation amount is less than the operation amount of the automatic operation signal, and therefore the automatic operation signal is output as the operation signal for the boom **131**.
[0124] Thereafter, at time t.sub.5, when the operation amount of the manual operation signal for the boom **131** becomes equal to or larger than the operation amount of the automatic operation signal (step S**35**), the automatic operation flag of the boom **131** is turned off. Thereafter, the manual operation signal is output as the operation signal for the work equipment **130**. In this way, in the example shown in FIG. **12**, the movement control unit **619** switches the output signals to the manual operation signals in the order of the arm **132**, the clam bucket **133**, and the boom **131**.

Finally, operations of all the axes of the work equipment **130** are switched to manual operations.

[0125] Further, the processing shown in FIG. **12** is merely an example, and the order and timing of switching the automatic operation signals may differ according to an operation order of the operator.

[0126] That is, when only a part of the link members of the work equipment **130** are operated, the movement control unit **619** gradually brings operation amounts related to automatic operations of other link members closer to the output related to the manual operation. Thereby, the control device **160** can smoothly switch control of the work equipment **130** from the automatic operation to the manual operation.

[0127] Then, as shown in FIG. **11**, the output determination unit **621** rewrites a value of the automatic operation flag related to the controlled object selected in step S**31** to OFF (step S**41**). The output determination unit **621** thereby switches an output source of the operation signal from the automatic operation signal to the manual operation signal. Next, the movement control unit **619** outputs the manual operation signal related to the controlled object selected in step S**31** (step S**42**).

[0128] When the automatic operation signal or the manual operation signal is output for each controlled object by the processing from step S**31** to step S**42**, the output determination unit **621** determines whether or not all the values of the automatic operation flags recorded in the main memory **630** are OFF (step S**43**). That is, the output determination unit **621** determines whether or not all the controlled objects have been switched to the manual operation.

[0129] If a value of at least one automatic operation flag is ON (step S**43**: NO), the control device **160** returns the processing to step S**24** in FIG. **10** to continue the automatic loading control. On the other hand, if values of all the automatic operation flags are OFF (step S**43**: YES), the control device **160** ends the automatic loading control.

Operation and Effects

[0130] As described above, the control device **160** according to the first embodiment determines which of the manual operation signal and the automatic operation signal is to be output for each of the swing body **120** and the work equipment **130** on the basis of the manual operation signal input from the operation device **143**. When the operator operates the operation device **143** during the automatic control of the loading machine **100**, there is a possibility that the operator wishes to continue the automatic control for a controlled object to which an operation is not applied. Therefore, if all the controlled objects are switched to manual operations when there has been a manual operation by the operator, the operator may not recognize that all the operations have been switched to manual operations, and there is a possibility that the swing or the operation of the work equipment will stop, thereby lowering work efficiency. In contrast, according to the control device **160** of the first embodiment, the control device **160** determines which of the manual operation signal and the automatic operation signal is to be output for each of the swing body **120** and the work equipment **130**, and therefore the automatic control can be continued for a controlled object to which the operation is not applied. Thereby, the control device **160** can prevent the work efficiency of the loading machine **100** from being lowered.

[0131] Also, according to the control device **160** of the first embodiment, when the manual operation signal is output for at least one link part among the plurality of link parts constituting the work equipment **130**, an operation amount of the automatic operation signal for another link part is brought close to an operation amount of the manual operation signal at a certain rate. Thereby, the control device **160** can smoothly switch the control of the work equipment **130** from the automatic operation to the manual operation.

[0132] Also, the control device **160** according to the first embodiment outputs the automatic operation signal for any of the swing body **120** and the work equipment **130** in which an operation amount of the manual operation signal is less than an operation amount of the automatic operation signal. That is, the control device **160** does not switch to the manual operation signal for a controlled object whose operation amount of the manual operation signal is less than an operation

amount of the automatic operation signal. Thereby, the control device **160** can prevent occurrence of sudden switching from the automatic operation signal to the manual operation signal.
[0133] Also, during the automatic control of moving the clam bucket **133** from above the loading target to an excavation point, the control device **160** according to the first embodiment outputs the automatic operation signal regardless of the manual operation signal until the swing angle of the swing body **120** reaches the interference avoidance angle. Thereby, even if there is an input of the manual operation of the work equipment **130** or the swing body **120** when the clam bucket **133** is positioned above the loading target, it is possible to prevent the work equipment **130** and the loading target from coming into contact with each other.
Another Embodiment
[0134] The embodiments have been described above in detail with reference to the drawings; however, the specific configurations are not limited to the above-described configurations, and various design changes or the like can be made. That is, in another embodiment, the order of the above-described processing may be appropriately changed. In addition, some of the processing may be executed in parallel.
[0135] The control device **160** according to the above-described embodiment may be configured by a single computer, or may be configured such that the configurations of the control device **160** are divided and disposed in a plurality of computers and the plurality of computers cooperate with each other to function as the control device **160**. At this time, a portion of the computers configuring the control device **160** may be mounted inside the loading machine **100** and the other computers may be provided outside the loading machine **100**.
[0136] The loading machine **100** according to the above-described embodiment is a face excavator, but the present disclosure is not limited thereto. For example, the loading machine **100** according to another embodiment may be a backhoe. Further, if the loading machine **100** is a backhoe, a target posture of work equipment **130** at the start of excavation differs from that in the first embodiment. Since the backhoe performs excavation by pulling the work equipment **130** to the near side thereof, the position of the bucket in the target posture at the start of excavation is preferably away from the swing body **120**. For example, the loading machine **100** may specify, as the target posture at the start of excavation, the shape of the object to be excavated from map data and determine a posture of the work equipment **130** which is moved away from the swing body **120** and come close to the object to be excavated and in which bucket teeth have an angle facing the object to be excavated.
[0137] The loading machine **100** according to the above-described embodiment has the clam bucket **133**, but the present disclosure is not limited thereto. For example, the loading machine **100** according to another embodiment may include an ordinary bucket. In this case, the loading machine **100** has a dump control unit instead of the clam control unit **620**. The dump control unit outputs a rotation operation signal in a dump direction instead of the opening operation signal. Further, in order to reduce a cycle time, the control device **160** may output a swing operation signal for the swing body **120** while the rotation operation signal in the dump direction is being output.
[0138] The target posture according to the above-described embodiment is set in advance and recorded in the main memory **630** or the storage **650**, but the present disclosure is not limited thereto. For example, the loading machine **100** according to another embodiment may be configured such that the target posture can be changed by operating the operation terminal **142**. For example, the loading machine **100** according to another embodiment may change the target posture by inputting numerical values representing positions and angles of the boom **131**, the arm **132**, and the a clam bucket **133** to the operation terminal **142**. Also, in the loading machine **100** according to another embodiment, after controlling the work equipment **130** to a preferable posture by an operation of an operator, the work equipment position specifying unit **614** may specify a posture of the work equipment **130** by operating the operation terminal **142** and update the target posture with the above-described posture.
[0139] The control device **160** according to the above-described embodiment specifies the loading

target on the basis of map data of the SLAM based on the measurement data of the detection device **156**, but the present disclosure is not limited thereto. For example, the control device **160** according to another embodiment may receive an input of latitude, longitude, and an azimuth direction of the loading target and calculate a position and shape of the loading target in the vehicle body coordinate system from the measurement results of the position/azimuth direction calculator **151**. Also, the control device **160** according to another embodiment may control the loading machine **100** on the basis of a global coordinate system represented by latitude, longitude, and an altitude instead of the vehicle body coordinate system. In this case, the control device **160** may calculate angles such as a start angle and a swing angle as angles relative to a reference azimuth direction of the global coordinate system.

[0140] The control device **160** according to the above-described embodiment calculates an angle of the swing body **120** by integrating the angular velocity of the swing body **120** measured by the inclination measuring device **152**, but the present disclosure is not limited thereto. For example, the control device **160** according to another embodiment may calculate an angle of the swing body **120** on the basis of a difference in the azimuth direction measured by the position/azimuth direction calculator **151**. Also, in another embodiment, the angle of the swing body **120** may be specified using a detection value of a rotation angle sensor provided in the swing motor **124**.

[0141] The control device **160** according to the above-described embodiment performs the automatic loading control on the basis of a comparison between the swing angle and the interference avoidance angle, but the present disclosure is not limited thereto. For example, the control device **160** according to another embodiment may perform the automatic loading control on the basis of a comparison between the position of the clam bucket **133** and the rearmost point p**1** (FIG. **5**) of the outer shape of the loading target T in a swing direction of the swing body **120**. For example, the control device **160** according to another embodiment may adjust a swing start timing so that the clam bucket **133** is positioned in a region in the vicinity of the point p**1**.

[0142] The loading machine **100** according to the above-described embodiment is directly operated by the operator who is on board the cab **140**, but the present disclosure is not limited thereto. For example, the loading machine **100** according to another embodiment may be operated by a remote operation. That is, in another embodiment, an operation signal may be transmitted to the control device **160** by communication from the operation device **143** provided remotely. In this case, some or all of the configurations of the control device **160** may be provided in a remote operation room in which the operation device **143** is provided. For example, configurations of the operation signal input unit **613**, the movement control unit **619**, the output determination unit **621**, the operation signal output unit **622**, and the like may be included in a computer provided in the remote operation room.

[0143] The automatic loading control according to the above-described embodiment is configured such that the clam bucket **133** is moved from the position at the completion of excavation to the loading point and then is moved to the position for starting the subsequent excavation, but the present disclosure is not limited thereto. For example, in another embodiment, the clam bucket **133** may be moved from the position at the completion of excavation to the loading point and perform a dumping operation by a manual operation, and only movement of the loading machine **100** from the loading point to the position for starting the subsequent excavation may be automatically controlled. In this case, after the clam bucket **133** has reached the loading point, the operator may output a signal for driving the work equipment to the position for starting the subsequent excavation to the control device **160** by operating a switch provided in an operation lever or the like. The control device **160** controls the work equipment **130** according to the signal from the switch described above so that the posture of the work equipment **130** becomes a preset target posture different from that at the start of excavation as in the case of the automatic loading control according to the above-described embodiment.

[0144] The control device **160** according to the above-described embodiment controls the work equipment **130** on the basis of the position P of the distal end of the arm **132**, but the position P of the distal end of the arm **132** may be a center of the distal end of the arm **132** or may be a position shifted to the left or right. Also, in another embodiment, the work equipment **130** may be controlled on the basis of an arbitrary position of the clam bucket **133** instead of the position P of the distal end of the arm **132**.

REFERENCE SIGNS LIST

[0145] **100** Loading machine [0146] **110** Undercarriage (support part) [0147] **111** Endless track [0148] **120** Swing body [0149] **121** Engine [0150] **122** Hydraulic pump [0151] **123** Control valve [0152] **124** Swing motor [0153] **130** Work equipment [0154] **131** Boom [0155] **131**C Boom cylinder [0156] **132** Arm [0157] **132**C Arm cylinder [0158] **133** Clam bucket [0159] **1331** Backhaul [0160] **1332** Clamshell [0161] **1332**C Clam cylinder [0162] **133**C Bucket cylinder [0163] **140** Cab [0164] **141** Driver's seat [0165] **142** Operation terminal [0166] **143** Operation device [0167] **143**SW Start switch [0168] **151** Position/azimuth direction calculator [0169] **152** Inclination measuring device [0170] **153** Boom angle sensor [0171] **154** Arm angle sensor [0172] **155** Bucket angle sensor [0173] **156** Detection device [0174] **160** Control device [0175] **610** Processor [0176] **611** Measurement data acquisition unit [0177] **612** Map generation unit [0178] **613** Operation signal input unit [0179] **614** Work equipment position specifying unit [0180] **615** Loading target specifying unit [0181] **616** Start angle specifying unit [0182] **617** Avoidance angle specifying unit [0183] **618** Target posture determination unit [0184] **619** Movement control unit [0185] **620** Clam control unit [0186] **621** Output determination unit [0187] **622** Operation signal output unit [0188] **630** Main memory [0189] **650** Storage [0190] **670** Interface

Claims

1. A control system for a loading machine including a swing body swinging around a swing center, a support part supporting the swing body, and work equipment having a bucket and attached to the swing body, the control system for a loading machine comprising: an operation signal input unit configured to receive an input of a manual operation signal for the swing body and the work equipment on the basis of an operation of an operation device configured to operate the swing body and the work equipment; a movement control unit configured to generate an automatic operation signal for driving the swing body and the work equipment; an output determination unit configured to determine to output the manual operation signal for any of the swing body and the work equipment for which there has been an input of the manual operation signal and determine to output the automatic operation signal for any thereof for which there has been no input of the manual operation signal, on the basis of the input manual operation signal; and an operation signal output unit configured to output the manual operation signal or the automatic operation signal for each of the swing body and the work equipment on the basis of a result of the determination.

2. The control system for a loading machine according to claim 1, wherein the work equipment is provided with a plurality of link parts including the bucket, and if the result of the determination indicates that the manual operation signal is output for at least one link part among the plurality of link parts, the movement control unit generates the automatic operation signal for another link part, which is other than the at least one link part, among the plurality of link parts such that an operation amount thereof approaches an operation amount of the manual operation signal related to the another link part.

3. The control system for a loading machine according to claim 1, wherein the output determination unit determines to output the automatic operation signal for any of the swing body and the work equipment in which the operation amount of the manual operation signal is less than an operation amount of the automatic operation signal.

4. The control system for a loading machine according to claim 1, further comprising: an avoidance angle specifying unit configured to specify an interference avoidance angle, which is a swing angle of the swing body at which the bucket and a loading target do not overlap in a plan view from above, during an automatic control of moving the bucket from above the loading target to an excavation start point, wherein the operation signal output unit outputs the automatic operation signal for the work equipment regardless of the manual operation signal until the swing angle of the swing body reaches the interference avoidance angle.

5. A control method for a loading machine including a swing body swinging around a swing center, a support part supporting the swing body, and work equipment having a bucket and attached to the swing body, the control method for a loading machine comprising: a step of receiving an input of a manual operation signal for the swing body and the work equipment on the basis of an operation of an operation device configured to operate the swing body and the work equipment; a step of generating an automatic operation signal for driving the swing body and the work equipment; a step of determining to output the manual operation signal for any of the swing body and the work equipment for which there has been an input of the manual operation signal and determining to output the automatic operation signal for any thereof for which there has been no input of the manual operation signal, on the basis of the input manual operation signal; and a step of outputting the manual operation signal or the automatic operation signal for each of the swing body and the work equipment on the basis of a result of the determination.