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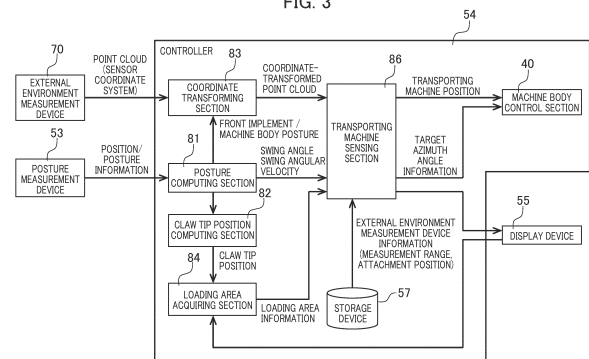
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(54) **WORK MACHINE**

(57) The posture of a work machine at a work site is computed on the basis of posture information about the work machine output from a posture measurement device. A loading area which is an area where a transporting machine stops and where loading work by the work machine to load the transporting machine is performed is set. On the basis of the posture of the work machine, it is assessed whether or not the work machine can sense, with an external environment measurement device, the transporting machine having stopped in the loading area. When it is assessed that the work machine can sense the transporting machine, the transporting machine is sensed on the basis of measurement information output from the external environment measurement device. Accordingly, it is possible to more accurately sense the position of the vessel of the stopped transporting machine and to appropriately assist loading work by the work machine.

FIG. 3



Description

Technical Field

5 **[0001]** The present invention relates to a work machine.

Background Art

10 **[0002]** There is a known articulated work machine (e.g., a hydraulic excavator) having a front work device (e.g., a boom, an arm, and an attachment such as a bucket) driven by hydraulic actuators, and the like. This type of work machine performs loading work of objects such as excavated earth and sand by performing a transporting action (e.g., a swing action) to transport the objects toward a to-be-loaded machine such as a transporting machine (e.g., a dump truck), and a dumping action (e.g., an earth/sand dumping action) to dump the objects transported by the transporting action onto the to-be-loaded machine.

15 **[0003]** When performing the loading work, if the front work device is swung in a state where its height (e.g., the height of a bucket) is at a position lower than the to-be-loaded machine, there is a possibility that the front work device interferes with the to-be-loaded machine in the transporting action. In view of this, an operator of the work machine who performs the loading work needs to coordinate a swing action of an upper swing structure with a pivot action (raising action) of the front work device while checking the position of the to-be-loaded machine, and needs to have mastered skills.

20 **[0004]** For example, there is a technology described in Patent Document 1 as a conventional technology to assist loading work. Patent Document 1 discloses a controller that controls a loading machine including a swing structure that can swing about its center of swing, a work implement provided to the swing structure, a posture measurement device that measures the posture of the swing structure, and a depth sensor that is provided to the swing structure and senses the depth of at least part of the surrounding environment of the swing structure in a sensing range, in which the controller
25 includes a posture information acquiring section that acquires posture information representing the posture measured by the posture measurement device, a sensing information acquiring section that acquires depth information representing the depth sensed by the depth sensor, a target azimuth deciding section that decides a target azimuth for swing control on the basis of the posture information and the depth information acquired when the swing structure has stopped swinging,
30 and an output section that outputs a swing operation signal on the basis of the target azimuth.

Prior Art Document

Patent Document

35 **[0005]** Patent Document 1: JP-2020-33825-A

Summary of the Invention

Problem to be Solved by the Invention

40 **[0006]** In the conventional technology described above, in order to precisely decide the target azimuth to be used when loading work is assisted, an external environment measurement device is attached to a side surface of the work machine, and the target azimuth for the swing control is decided on the basis of the posture information and the depth information that are acquired when the swing structure of the work machine is not being swung, for example, during excavation. However,
45 since an operator of the work machine checks a stop position of a transporting machine when the transporting machine is measured with the external environment measurement device attached to the work machine, it is not possible to accurately determine before the loading work whether the work machine is stopped at an appropriate position for loading the transporting machine.

50 **[0007]** In a case where the transporting machine is not stopped at an appropriate position when the operator of the work machine performs loading onto the transporting machine, it is necessary to correct the stop position of the transporting machine or adjust the position of the work machine, and the efficiency of the loading work by the work machine lowers undesirably. However, since, when the position of the transporting machine is sensed with the depth sensor, the operator of the work machine cannot determine whether the transporting machine is positioned within a measurement range of the external environment measurement device attached to the work machine, it is possible that the transporting machine
55 cannot be measured with the external environment measurement device of the work machine before loading by the work machine, and that the loading work cannot be assisted appropriately.

[0008] The present invention has been made in view of the matters described above, and an object thereof is to provide a work machine that can more accurately sense the position of a vessel of a stopped transporting machine and can

appropriately assist loading work by the work machine.

Means for Solving the Problem

[0009] The present application includes a plurality of means for solving the problem described above, and an example thereof is a work machine that has an articulated front work device and performs loading work to load a transporting machine with a transporting target object. The work machine includes an external environment measurement device that is provided to the work machine, measures an object existing in a predetermined measurement area around the work machine and a position of the object, and outputs information about the object and the position as object position information, a posture measurement device that measures a state quantity related to a posture of the work machine and outputs information about the state quantity as posture information, and a controller configured to compute a position and a posture of a transporting machine relative to the work machine on the basis of the posture information about the work machine and the object position information and perform loading assist control of the work machine on the basis of the computed position and posture of the transporting machine. The controller is configured to compute the posture of the work machine on the basis of the posture information about the work machine output from the posture measurement device, set a loading area that is an area where the transporting machine stops and where loading work by the work machine to load the transporting machine is performed, assess whether or not the work machine is at such a posture that the external environment measurement device can compute the transporting machine having stopped in the loading area, on the basis of the posture of the work machine, the measurement area, and the loading area, and compute the position and posture of the transporting machine in the loading area on the basis of the object position information output from the external environment measurement device, when it is assessed that the work machine is at such a posture that the transporting machine can be computed.

Advantages of the Invention

[0010] According to the present invention, it is possible to more accurately sense the position of a vessel of a stopped transporting machine and can appropriately assist loading work by a work machine.

Brief Description of the Drawings

[0011]

FIG. 1 is a side view schematically depicting an external appearance of a hydraulic excavator depicted as an example of a work machine.

FIG. 2 is a functional block diagram depicting functions of a hydraulic system and a control system of the hydraulic excavator that are extracted along with related configuration.

FIG. 3 is a functional block diagram depicting functions of a controller that are extracted along with related configuration.

FIG. 4 is a side view depicting a reference coordinate system along with the hydraulic excavator.

FIG. 5 is a top view depicting the reference coordinate system along with the hydraulic excavator.

FIG. 6 is a figure depicting an example of an action of the hydraulic excavator.

FIG. 7 is a figure depicting an example of a loading area setting method.

FIG. 8 is a flowchart depicting processing contents of a transporting machine sensing process.

FIG. 9 is a flowchart depicting processing contents of transporting machine sensing assessment in the transporting machine sensing process.

FIG. 10 is a figure depicting an example of calculation of an area overlap degree.

FIG. 11 is a figure depicting an example of output of a swing action instruction to a display device.

FIG. 12 is a figure depicting an example of a process of calculating a stop tolerance range.

FIG. 13 is a functional block diagram depicting functions of the hydraulic system and the control system of the hydraulic excavator according to a third embodiment that are extracted along with related configuration.

FIG. 14 is a functional block diagram depicting functions of the controller according to the third embodiment that are extracted along with related configuration.

FIG. 15 is a figure depicting an overview of a loading area acquisition process.

FIG. 16 is a flowchart depicting processing contents of the loading area acquisition process according to the third embodiment.

FIG. 17 is a figure illustrating a state of an external environment measurement device azimuth output process performed by a transporting machine sensing section according to a fourth embodiment.

FIG. 18 is a flowchart depicting processing contents of the transporting machine sensing assessment in the

transporting machine sensing process according to the fourth embodiment.

FIG. 19 is a flowchart depicting processing contents of a measurement azimuth calculation process according to the fourth embodiment.

FIG. 20 is a figure depicting an example of the transporting machine sensing assessment according to a fifth embodiment.

FIG. 21 is a flowchart depicting processing contents of the transporting machine sensing assessment in the transporting machine sensing process according to the fifth embodiment.

FIG. 22 is a figure depicting an example of output to the display device according to the fifth embodiment.

Modes for Carrying Out the Invention

[0012] Hereinbelow, embodiments of the present invention are explained with reference to the figures.

<First Embodiment>

[0013] A first embodiment of the present invention is explained in detail with reference to FIG. 1 to FIG. 11.

[0014] FIG. 1 is a side view schematically depicting an external appearance of a hydraulic excavator depicted as an example of a work machine according to the present embodiment.

[0015] In FIG. 1, a hydraulic excavator 1 (work machine) is one that performs, at a work site, excavation work to excavate an excavation target surface such as a ground, loading work to load to-be-loaded machines such as transporting machines including dump trucks (mentioned later) with transporting target objects such as excavated earth and sand, and the like. In addition, the transporting machines such as dump trucks perform a transporting action to transport the earth and sand or the like loaded in the loading work to a predetermined location and a dumping action to dump the earth and sand at the predetermined location. The hydraulic excavator 1 includes an articulated front work device 2 (work arm) that retains the objects and pivots up and down or forward and backward and a machine body 3 on which the front work device 2 is mounted.

[0016] The machine body 3 includes a lower track structure 5 that travels by using a travel right hydraulic motor 4a and a travel left hydraulic motor 4b provided at a right portion and a left portion of the lower track structure 5, and an upper swing structure 7 that is attached to an upper portion of the lower track structure 5 via a swing device and swings by using a swing hydraulic motor 6 of the swing device.

[0017] The front work device 2 is an articulated work device including a plurality of front implement members attached to a front portion of the upper swing structure 7. The upper swing structure 7 swings with the front work device 2 mounted thereon. The front work device 2 includes a boom 8 vertically pivotably coupled with the front portion of the upper swing structure 7, an arm 9 vertically pivotably coupled with a front end portion of the boom 8, and a bucket 10 vertically pivotably coupled with a front end portion of the arm 9.

[0018] The boom 8 is coupled with the upper swing structure 7 by a boom pin 8a and pivots due to extension and retraction of a boom cylinder 11. The arm 9 is coupled with the front end portion of the boom 8 by an arm pin 9a and pivots due to extension and retraction of an arm cylinder 12. The bucket 10 is coupled with the front end portion of the arm 9 by a bucket pin 10a and a bucket link 16 and pivots due to extension and retraction of a bucket cylinder 13.

[0019] A boom angle sensor 14 that senses the pivot angle of the boom 8 is attached to the boom pin 8a. An arm angle sensor 15 that senses the pivot angle of the arm 9 is attached to the arm pin 9a. A bucket angle sensor 17 that senses the pivot angle of the bucket 10 is attached to the bucket link 16. Note that FIG. 1 depicts reference characters of the boom angle sensor 14, the arm angle sensor 15, and the bucket angle sensor 17 in parentheses.

[0020] Note that the pivot angle of each of the boom 8, the arm 9, and the bucket 10 may be acquired by sensing, with an inertial measurement unit, the angle of the boom 8, the arm 9, or the bucket 10 relative to a reference plane such as a horizontal plane and converting the sensed angle into the pivot angle. Alternatively, the pivot angle of each of the boom 8, the arm 9, and the bucket 10 may be acquired by sensing, with a stroke sensor, the stroke of the boom cylinder 11, the arm cylinder 12, or the bucket cylinder 13 and converting the sensed stroke into the pivot angle.

[0021] An inclination angle sensor 18 that senses the inclination angle of the machine body 3 relative to a reference plane such as a horizontal plane is attached to the upper swing structure 7. A swing angle sensor 19 that senses the swing angle, which is a relative angle of the upper swing structure 7 relative to the lower track structure 5, is attached to the swing device provided between the lower track structure 5 and the upper swing structure 7. An angular velocity sensor 20 that senses the angular velocity of the upper swing structure 7 is attached to the upper swing structure 7.

[0022] Here, the boom angle sensor 14, the arm angle sensor 15, the bucket angle sensor 17, the inclination angle sensor 18, and the swing angle sensor 19 are included in a posture measurement device 53 that measures state quantities related to the posture of the front work device 2, for example, each pivot angle, the swing angle of the upper swing structure 7, and the like, and that outputs information about the posture of the front work device 2 as posture information.

[0023] Operation devices that are used to operate a plurality of hydraulic actuators 4a, 4b, 6, 11, 12, and 13 are installed

in an operation room provided to the upper swing structure 7. Specifically, the operation devices include a travel right lever 23a for operating the travel right hydraulic motor 4a, a travel left lever 23b for operating the travel left hydraulic motor 4b, an operation right lever 22a for operating the boom cylinder 11 and the bucket cylinder 13, and an operation left lever 22b for operating the arm cylinder 12 and the swing hydraulic motor 6. The operation levers 22 and 23 are of the electric lever type. Hereinafter, the travel right lever 23a, the travel left lever 23b, the operation right lever 22a, and the operation left lever 22b are collectively referred to as the operation levers 22 and 23 in some cases.

[0024] In addition, an external environment measurement device 70 that senses the depths to objects existing around the hydraulic excavator 1 is attached to the upper swing structure 7. For example, the external environment measurement device 70 may be a LiDAR (Light Detection And Ranging) device or may be a stereo camera. The external environment measurement device 70 has, as a measurement area 220 (mentioned later), a predetermined range around the hydraulic excavator 1 and can acquire depth information about objects in the area. A plurality of the external environment measurement devices 70 may be attached to the hydraulic excavator 1.

<Control System>

[0025] FIG. 2 is a functional block diagram depicting functions of a hydraulic system and a control system of the hydraulic excavator that are extracted along with related configuration.

[0026] In FIG. 2, an engine 103 which is a prime mover mounted on the upper swing structure 7 drives a hydraulic pump 102 and a pilot pump 104. A machine body control section 40 (mentioned later) of a controller 54 controls a pivot action of the front work device 2, a travel action of the lower track structure 5, and a swing action of the upper swing structure 7 according to operation information (operation amounts and operation directions) about the operation levers 22 and 23 operated by an operator. Specifically, the machine body control section 40 of the controller 54 senses, with sensors 52a to 52f such as rotary encoders or potentiometers, operation information (operation amounts and operation directions) of the operation levers 22 and 23 operated by the operator and outputs control commands according to the sensed operation information to solenoid proportional valves 47a to 47i. The solenoid proportional valves 47a to 47i are provided on a pilot line 100, are actuated when control commands from the machine body control section 40 of the controller 54 are input, and output pilot pressures to a flow control valve 101 to actuate the flow control valve 101. Hereinafter, the solenoid proportional valves 47a to 47i are collectively referred to as solenoid proportional valves 47 in some cases.

[0027] According to the pilot pressures from the solenoid proportional valves 47a to 47i, the flow control valve 101 controls a hydraulic fluid supplied from the hydraulic pump 102 to each of the swing hydraulic motor 6, the arm cylinder 12, the boom cylinder 11, the bucket cylinder 13, the travel right hydraulic motor 4a, and the travel left hydraulic motor 4b. Note that the solenoid proportional valves 47a and 47b output, to the flow control valve 101, pilot pressures for controlling the hydraulic fluid supplied to the swing hydraulic motor 6. The solenoid proportional valves 47c and 47d output, to the flow control valve 101, pilot pressures for controlling the hydraulic fluid supplied to the arm cylinder 12. The solenoid proportional valves 47e and 47f output, to the flow control valve 101, pilot pressures for controlling the hydraulic fluid supplied to the boom cylinder 11. The solenoid proportional valves 47g and 47h output, to the flow control valve 101, pilot pressures for controlling the hydraulic fluid supplied to the bucket cylinder 13. The solenoid proportional valves 47i and 47j output, to the flow control valve 101, pilot pressures for controlling the hydraulic fluid supplied to the travel right hydraulic motor 4a. The solenoid proportional valves 47k and 47l output, to the flow control valve 101, pilot pressures for controlling the hydraulic fluid supplied to the travel left hydraulic motor 4b.

[0028] Each of the boom cylinder 11, the arm cylinder 12, and the bucket cylinder 13 is extended and retracted by the supplied hydraulic fluid and causes the boom 8, the arm 9, or the bucket 10 to pivot. Thus, the position and posture of the bucket 10 change. The swing hydraulic motor 6 rotates due to the supplied hydraulic fluid and causes the upper swing structure 7 to swing. The travel right hydraulic motor 4a and the travel left hydraulic motor 4b rotate due to the supplied hydraulic fluid and cause the lower track structure 5 to travel.

[0029] The controller 54 is a computer in which a CPU (Central Processing Unit) 73, a RAM (Random Access Memory) 72, a ROM (Read Only Memory) 71, an external I/F (Interface) 74, and the like are interconnected by a bus 75. The external I/F 74 is connected to a display device 55, the external environment measurement device 70, the posture measurement device 53, and a storage device 57 (e.g., a hard disk drive, a large-capacity flash memory, etc.) and, in addition to these, is connected to the operation levers 22 and 23, the solenoid proportional valves 47, and the like.

<Functional Blocks>

[0030] FIG. 3 is a functional block diagram depicting functions of the controller that are extracted along with related configuration. In addition, FIG. 4 is a side view depicting a reference coordinate system along with the hydraulic excavator. FIG. 5 is a top view.

[0031] In FIG. 3, the controller 54 includes a posture computing section 81, a claw tip position computing section 82, a coordinate transforming section 83, a loading area acquiring section 84, a transporting machine sensing section 86, and

the machine body control section 40.

[0032] A machine body coordinate system 400 is preset for the controller 54 as a reference coordinate system for identifying the position and posture of each constituent element of the hydraulic excavator 1. As depicted in FIG. 4 and FIG. 5, the machine body coordinate system 400 of the present embodiment is defined as a right-handed coordinate system having, as its origin, the intersection of a swing center line 120, which is the axis of rotation of the upper swing structure 7, and a surface on which the lower track structure 5 and a ground G contact each other. In the machine body coordinate system 400, the forward movement direction of the lower track structure 5 is defined as the positive direction of the X axis. In the machine body coordinate system 400 of the present embodiment, the upward extending direction of the swing center line 120 is defined as the positive direction of the Z axis. In the machine body coordinate system 400 of the present embodiment, the Y axis is orthogonal to both the X axis and the Z axis, and the leftward direction is defined as the positive direction of the Y axis.

[0033] In addition, in the present embodiment, a reference coordinate system of the external environment measurement device 70 is a sensor coordinate system 300, a reference coordinate system of the hydraulic excavator 1 is the machine body coordinate system 400, and a reference coordinate system of a site is a site coordinate system 500. In the machine body coordinate system 400 of the present embodiment, a swing angle θ_{sw} of the upper swing structure 7 is defined as such an angle that it becomes 0 degrees when the front work device 2 becomes parallel to the X axis.

<Overview of Actions>

[0034] First, an overview of actions of the hydraulic excavator 1 in the present embodiment is explained.

[0035] FIG. 6 is a figure depicting an example of an action of the hydraulic excavator.

[0036] As depicted in FIG. 6, first, the hydraulic excavator 1 appropriately sets such a loading area 210 which serves as a general indication of a stop position of a transporting machine 200 that the transporting machine 200 stops in the measurement area 220, which is an area where the external environment measurement device 70 can measure depth information about the surrounding environment, and the external environment measurement device 70 can acquire depth information about the transporting machine 200. Then, the hydraulic excavator 1 gives an instruction about a swing action to the operator through the display device 55 or the like such that, when the hydraulic excavator 1 waits for the transporting machine 200 which is about to stop in the set loading area 210, the swing angle θ_{sw} of the hydraulic excavator 1 becomes such a swing angle that the measurement area 220 covers the loading area 210. Then, by sensing the transporting machine 200 having stopped in the loading area 210, it becomes possible to surely implement loading assist mentioned later when the hydraulic excavator 1 loads the transporting machine 200 with earth and sand.

[0037] As depicted in FIG. 6, it is assumed in the present embodiment that the transporting machine 200 stops in the loading area 210 designated by the hydraulic excavator 1 (here, the loading area 210 is set in the machine body coordinate system). Specifically, it is assumed that, at a work site, a position/assignment management system for transporting machines like an FMS (Fleet Management System) is managing the position of the transporting machine 200. In addition, it is assumed in the present embodiment that the transporting machine 200 travels autonomously and stops accurately in the loading area 210 designated by the hydraulic excavator 1.

[0038] As depicted in FIG. 6, the loading area 210 is represented by a quadrangle in the machine body coordinate system 400, and coordinate values (Xpd1, Ypd1) to (Xpd4, Ypd4) of vertices Pd1 to Pd4 of the area on the X-Y plane are stored on the storage device 57. Note that the shape of the loading area 210 is not limited to a quadrangle and, for example, may be a polygon with three or five sides or more (including a reentrant polygon), a circular shape, or the like.

[0039] In addition, it is assumed that the measurement area 220 is a sector on the X-Y plane that is represented by X and Y coordinates of the attachment position of the external environment measurement device 70 in the machine body coordinate system 400, a measurable distance Lsr, and a measurable horizontal angle of view θ_{sr} . Note that the shape of the measurement area 220 is not limited to a sector, and, for example, the measurement area 220 may be a polygonal area obtained by projecting, onto the X-Y plane in the machine body coordinate system 400, the effective measurement area 220 of the external environment measurement device 70 taking the attachment angle of view into consideration. It is assumed in the present embodiment that the attachment angle of the external environment measurement device 70 is measured in advance before an action of the hydraulic excavator 1, and the measurement area 220 is retained in advance in a predetermined area of the storage device 57.

[0040] Hereinbelow, a process performed by the controller 54 of the hydraulic excavator 1 is explained in detail.

<Posture Computing Section 81>

[0041] The posture computing section 81 computes the postures and the like of constituent elements of the hydraulic excavator 1 in the machine body coordinate system 400 from sensing signals of the posture measurement device 53. Specifically, the posture computing section 81 computes a pivot angle θ_{bm} of the boom 8 relative to the X axis from a sensing signal about the pivot angle of the boom 8 output from the boom angle sensor 14. The posture computing section

81 computes a pivot angle θ_{am} of the arm 9 relative to the boom 8 from a sensing signal about the pivot angle of the arm 9 output from the arm angle sensor 15. The posture computing section 81 computes a pivot angle θ_{bk} of the bucket 10 relative to the arm 9 from a sensing signal about the pivot angle of the bucket 10 output from the bucket angle sensor 17. The posture computing section 81 computes the swing angle θ_{sw} of the upper swing structure 7 relative to the X axis (the lower track structure 5) from a sensing signal about the swing angle of the upper swing structure 7 output from the swing angle sensor 19.

[0042] Further, the posture computing section 81 computes an inclination angle θ of the machine body 3 (the lower track structure 5) relative to a reference plane DP from a sensing signal about the inclination angle of the machine body 3 output from the inclination angle sensor 18. For example, the reference plane DP is a horizontal plane orthogonal to the direction of gravity. The inclination angle θ includes θ_p , which is the rotation angle about the Y axis, and θ_r , which is the rotation angle about the X axis.

[0043] Furthermore, the posture computing section 81 computes a swing angular velocity w_{sw} of the upper swing structure 7 from a sensing signal of the posture measurement device 53.

<Claw Tip Position Computing Section 82>

[0044] On the basis of the computed pivot angles θ_{bm} , θ_{am} , and θ_{bk} of the front work device 2, the computed swing angle θ_{sw} of the upper swing structure 7, a dimension L_{bm} of the boom 8, a dimension L_{am} of the arm 9, and a dimension L_{bk} of the bucket 10, the claw tip position computing section 82 computes a position (claw tip position) 130 of the front end of the bucket 10. Note that the dimension L_{bm} of the boom 8 is the length from the boom pin 8a to the arm pin 9a. The dimension L_{am} of the arm 9 is the length from the arm pin 9a to the bucket pin 10a. The dimension L_{bk} of the bucket 10 is the length from the bucket pin 10a to the front end portion (e.g., the front end portion of the tooth) of the bucket 10.

<Coordinate Transforming Section 83>

[0045] Using the posture information about the machine body output by the posture computing section 81, the coordinate transforming section 83 transforms the reference coordinate system of the depth information acquired by the external environment measurement device 70, from the sensor coordinate system 300 to the machine body coordinate system 400. It is assumed that the depth information output by the external environment measurement device 70 is given as a set (point cloud data) of three-dimensional point data represented in the sensor coordinate system 300.

[0046] For example, the transformation from point data (X_p, Y_p, Z_p) in the sensor coordinate system 300 output by the external environment measurement device 70 to point data $P_v (X_{pv}, Y_{pv}, Z_{pv})$ in the machine body coordinate system 400 uses (Formula 1) to (Formula 3) described below.

[Math. 1]

$$P_v = R_{sv} \cdot P_s + T_{sv} \dots \text{(Formula 1)}$$

[Math. 2]

$$R_{sv} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \alpha_s & -\sin \alpha_s \\ 0 & \sin \alpha_s & \cos \alpha_s \end{pmatrix} \begin{pmatrix} \cos \beta_s & 0 & \sin \beta_s \\ 0 & 1 & 0 \\ -\sin \beta_s & 0 & \cos \beta_s \end{pmatrix} \begin{pmatrix} \cos(\gamma_s + \theta_{sw}) & -\sin(\gamma_s + \theta_{sw}) & 0 \\ \sin(\gamma_s + \theta_{sw}) & \cos(\gamma_s + \theta_{sw}) & 0 \\ 0 & 0 & 1 \end{pmatrix} \dots \text{(Formula 2)}$$

[Math. 3]

$$T_{sv} = (L_{sx}, L_{sy}, L_{sz}) \dots \text{(Formula 3)}$$

[0047] Here, in (Formula 1) to (Formula 3) described above, R_{sv} denotes a rotation matrix for transformation from the sensor coordinate system 300 to the machine body coordinate system 400, and α_s , β_s , and γ_s denote angles of the axes of the external environment measurement device 70 in the machine body coordinate system 400.

[0048] In a case where the external environment measurement device 70 is fixed to the hydraulic excavator 1, it is sufficient if, for example, the posture of the external environment measurement device 70 in the machine body coordinate system 400 is measured in advance and the angles are stored in advance on the storage device 57. In addition, in a case where the external environment measurement device 70 performs measurement while changing its posture relative to the hydraulic excavator 1, a posture measurement sensor may be installed on the external environment measurement device 70, for example, and a coordinate transformation matrix may be calculated by using angles sensed by the posture

measurement sensor. θ_{sw} denotes the swing angle of the upper swing structure 7 and is output by the posture computing section 81.

[0049] Tsv denotes a translation vector from the origin of the machine body coordinate system 400 to the sensor coordinate system 300. Lsx, Lsy, and Lsz are equal to the coordinates of the origin of the sensor coordinate system 300 as seen from the machine body coordinate system 400. The attachment position of the external environment measurement device 70 is fixed to the hydraulic excavator 1 in many cases. Accordingly, in that case, it is sufficient if the attachment position of the external environment measurement device 70 on the hydraulic excavator 1 is measured in advance and the value of this measurement is stored in advance on the storage device 57.

<Loading Area Acquiring Section 84>

[0050] The loading area acquiring section 84 acquires the loading area 210, which is a stop area of the transporting machine 200, and stores the loading area 210 on the storage device 57.

[0051] The operator of the hydraulic excavator 1 performs operation for designating the loading area 210 via the display device 55. The controller 54 performs a process of accepting the operation and setting the loading area 210.

[0052] FIG. 7 is a figure depicting an example of a loading area setting method.

[0053] As depicted in FIG. 7, the claw tip position 130 output by the claw tip position computing section 82 is displayed on the display device 55, and the operator performs operation of pressing a loading area setting button 230 displayed on the display device 55 at a loading position. When the operation input is performed, the controller 54 sets the loading area 210. Note that the decision button may not be present on a screen, but may be based on particular lever operation or the like. In addition, for example, the rotation angle of the loading area 210 at this time is set such that the longitudinal direction of the rectangle of the loading area 210 matches the direction of the front work device 2 of the hydraulic excavator 1. In addition, the loading area 210 is calculated such that the claw tip position 130 matches the center of the rear wheel axis of the transporting machine 200. Note that the method of calculating the loading area 210 from the claw tip position 130 is not limited to this, and the operator may set the longitudinal direction of the rectangle via the display device 55.

[0054] Note that, when the loading area 210 has been set at the hydraulic excavator 1, the hydraulic excavator 1 may share the loading area 210 with the transporting machine 200 by using wireless communication or the like. It is possible to designate the stop position of the transporting machine 200 by allowing the hydraulic excavator 1 and the transporting machine 200 to share information about the loading area 210. In addition, the position of the work machine in the site coordinate system 500 may be measured by using a position measurement device such as a GNSS or a device that calculates positions such as a TS (Total Station), and the position of the work machine may be transmitted to the transporting machine 200, or an FMS or the like provided at the work site, along with the information about the loading area 210. Further, vehicle-to-vehicle communication may be used to allow the hydraulic excavator 1 and the transporting machine 200 to share the loading area 210. The method for communication of information about the loading area 210 between the hydraulic excavator 1 and the transporting machine 200 is not limited to those mentioned before in the present embodiment.

[0055] In addition, the loading area 210 may be designated by a site manager or the like by using an FMS or the like. In this case, it is possible to designate the stop position of the transporting machine 200 by allowing the hydraulic excavator 1 and the transporting machine 200 to share the information about the loading area 210 by using a communication device or the like.

<Transporting Machine Sensing Section 86>

[0056] The transporting machine sensing section 86 assesses whether the loading area 210 acquired by the loading area acquiring section 84 is covered by the measurement area 220 of the external environment measurement device 70 in a case where the swing speed of the hydraulic excavator 1 is equal to or lower than a predetermined speed. The transporting machine sensing section 86 performs a transporting machine sensing process when the loading area 210 is covered by the measurement area 220, and outputs information for giving an instruction about the swing angle of the hydraulic excavator 1 when the loading area 210 is not covered by the measurement area 220.

[0057] In addition, the transporting machine sensing section 86 calculates the position and posture of the transporting machine 200 by using point cloud data which is a measurement result of the external environment measurement device 70 in the machine body coordinate system 400 output by the coordinate transforming section 83. In a method of calculation regarding the transporting machine 200, for example, a three-dimensional mesh model obtained by measuring the transporting machine 200 is retained in advance on the storage device 57, and the point cloud data that has been transformed to the machine body coordinate system 400 and acquired from the coordinate transforming section 83 and the three-dimensional mesh model are collated with each other regarding positions, so that the position and posture of the target transporting machine 200 can be calculated. Note that the sensing method is not limited to this. For example, the transporting machine 200 may be sensed by a process of extracting a particular plane of the transporting machine 200 from

the point cloud data obtained from the external environment measurement device 70. The method of sensing the transporting machine is not limited to the one mentioned before in the present embodiment.

<Loading Assist Control>

[0058] At the machine body control section 40, on the basis of position/posture information about the transporting machine, action control of the hydraulic excavator 1, for example, control to assist the operator in a loading action, is performed.

[0059] For example, in a method of the loading assist control, when the operator of the hydraulic excavator 1 inclines a swing operation lever in order to start loading onto the transporting machine 200 in a state where the transporting machine 200 has successfully been sensed, interference with the transporting machine 200 can be avoided by performing boom raising automatically to such a height that the hydraulic excavator 1 does not interfere with the transporting machine 200 on the basis of the position/posture information about the transporting machine.

<Transporting Machine Sensing Process>

[0060] FIG. 8 is a flowchart depicting processing contents of the transporting machine sensing process, and FIG. 9 is a flowchart depicting processing contents of transporting machine sensing assessment in the transporting machine sensing process. In addition, FIG. 10 is a figure depicting an example of calculation of an area overlap degree, and FIG. 11 is a figure depicting an example of output of a swing action instruction to the display device.

[0061] In the transporting machine sensing process, first, the controller 54 acquires the loading area 210 (Step S111). The loading area acquiring section 84 acquires the loading area 210, which is an area where the transporting machine 200 stops and the hydraulic excavator 1 performs work to load the transporting machine 200.

[0062] Subsequently, the controller 54 performs the transporting machine sensing assessment (Step S112). As explained regarding the process performed by the transporting machine sensing section 86, in the transporting machine sensing assessment, it is assessed whether the measurement area 220 covers the loading area 210 set at Step S111. When the measurement area 220 does not cover the loading area 210, a swing action instruction is given to the operator such that an appropriate swing angle is attained. Details of the transporting machine sensing assessment are mentioned later.

[0063] Subsequently, the controller 54 assesses whether or not the transporting machine sensing assessment at Step S112 is completed (Step S113). When the assessment result of Step S113 is YES, that is, when the transporting machine sensing assessment is completed, the procedure proceeds to a next process (Step S114). When the assessment result is NO, that is, when the transporting machine sensing assessment is not ended, the procedure returns to the process at Step S112.

[0064] When the result of the assessment at Step S113 is YES, the controller 54 waits for the transporting machine 200 to complete stopping in the loading area 210 (Step S114).

[0065] Subsequently, the controller 54 performs the transporting machine sensing process (Step S115). The transporting machine sensing section 86 senses the transporting machine 200 having stopped in the loading area 210, on the basis of the depth information output from the external environment measurement device 70.

[0066] Next, the controller 54 performs loading assist control start assessment by sensing an operation command for a loading action from the operator (Step S116). For example, in the start assessment, it is assessed that a loading action by the operator is started, that is, the loading assist control is to be started, when the operator operates the operation right lever 22a for operating the boom 8 by a predetermined amount, for example.

[0067] When it is assessed at Step S116 that a loading action by the operator is started, the controller 54 performs the loading assist control for the operation by the operator (Step S117).

[0068] Subsequently, the controller 54 performs assessment regarding the end of loading onto the transporting machine 200 (Step S118). For example, the loading end assessment is made on the basis of whether the operator has output a loading end command by using a horn sound or predetermined communication equipment to the transporting machine 200. When the result of the assessment at Step S118 is YES, that is, when it is assessed that the loading has ended, the procedure proceeds to a next process (Step S119). In addition, when the result of the assessment at Step S118 is NO, that is, when it is assessed that the loading has not ended, the procedure returns to the process at Step S114, operation of the operation lever 22 by the operator is sensed, and the loading assist control is performed. Note that it may be assessed that the loading has ended when the external environment measurement device 70 senses that the transporting machine 200 has moved.

[0069] When the result of the assessment at Step S118 is YES, the controller 54 performs work end assessment (Step S119). For example, the work end assessment is made on the basis of whether or not the engine of the hydraulic excavator 1 has stopped. When the result of the assessment at Step S119 is YES, that is, when it is assessed that the work has ended, the hydraulic excavator 1 ends the series of processing. In addition, when the result of the assessment at Step S119 is NO,

that is, when it is assessed that the work has not ended, the procedure returns to the process at Step S112, the transporting machine sensing assessment is performed before a next transporting machine 200 stops, and loading onto the transporting machine 200 is performed.

<Transporting Machine Sensing Assessment: Step S112>

[0070] Here, the processing contents of the transporting machine sensing assessment in the transporting machine sensing process are explained.

[0071] In FIG. 9, first, the transporting machine sensing section 86 assesses whether or not the swing angular velocity ω_{sw} output by the posture computing section 81 is smaller than a predetermined angular velocity Q_{sw} (Step S201). When the assessment result of Step S201 is YES, that is, when the swing angular velocity ω_{sw} of the hydraulic excavator 1 is smaller than the predetermined angular velocity Q_{sw} , it is determined that the transporting machine 200 is being waited for to stop, and the procedure proceeds to a next process (Step S202). In addition, when the assessment result of Step S201 is NO, that is, when the swing angular velocity ω_{sw} of the hydraulic excavator 1 is equal to or greater than the predetermined angular velocity Q_{sw} , the transporting machine sensing section 86 assesses that the hydraulic excavator 1 is performing loading work, and repeats the assessment until the swing angular velocity ω_{sw} becomes smaller than Q_{sw} .

[0072] When the result of the assessment at Step S201 is YES, the transporting machine sensing section 86 acquires the measurement area 220 from a predetermined location in the storage device 57 (Step S202).

[0073] Subsequently, the transporting machine sensing section 86 acquires the loading area 210 acquired by the loading area acquiring section 84, from the predetermined location in the storage device 57 (Step S203).

[0074] Subsequently, the transporting machine sensing section 86 performs an overlap degree calculation process (Step S204). An overlap degree A_{cover} between the measurement area 220 and the loading area 210 is calculated in reference to the storage device 57. A_{cover} is given by (Formula 4) described below.

[Math. 4]

$$A_{cover} = S_{cover}/S_0 \dots \text{(Formula 4)}$$

[0075] Here, in (Formula 4) described above, S_0 denotes the area size of the loading area 210, and S_{cover} denotes the area size of a range where the loading area 210 and the measurement area 220 overlap.

[0076] For example, as in FIG. 10, assuming that the measurement area 220 approximates to a polygon (P_{s0} to P_{sn}), determination of the area size S_{cover} of the range where the loading area 210 and the measurement area 220 overlap can be reduced to a problem for determining the area size of a crossing area of two convex polygons, and accordingly, S_{cover} can be determined by solving a numerical calculation problem. Accordingly, it is sufficient if it is assumed first that the loading area 210 and the measurement area 220 approximate to polygons, the vertex coordinates of a common area of both of them are calculated, and thereafter, on the basis of information about the calculated vertices of the common area, the area size S_{cover} of the common area is determined.

[0077] Subsequently, the transporting machine sensing section 86 assesses whether or not the overlap degree A_{cover} determined at Step S205 is greater than a threshold A_{th} (Step S205). When the assessment result of Step S205 is YES, that is, when A_{cover} is greater than A_{th} , the procedure proceeds to a next process (Step S206). When the assessment result is NO, that is, when A_{cover} is equal to or lower than A_{th} , the procedure proceeds to another next process (Step S207).

[0079] When the result of the assessment at Step S205 is YES, the transporting machine sensing section 86 gives an assessment result for starting the transporting machine sensing process (Step S206), and the transporting machine sensing assessment process is ended.

[0080] In addition, when the result of the assessment at Step S205 is NO, the transporting machine sensing section 86 outputs the swing action instruction (Step S207). For example, the swing action instruction is given by causing the display device 55 to display the loading area 210 and the measurement area 220 as well as an indication that prompts the operator to perform operation for a swing action as depicted in FIG. 11. Thereafter, the procedure returns to the process at Step S201, and the processes from Step S201 to Step S205 are repeated until an appropriate swing angle is attained.

[0081] Advantages of the thus configured present embodiment are explained.

[0082] In conventional technologies, in a case where a transporting machine is not stopped at an appropriate position when an operator of a work machine performs loading onto the transporting machine, it is necessary to correct the stop position of the transporting machine or adjust the position of the work machine, and the efficiency of the loading work by the work machine lowers undesirably. In addition, since, when the position of the transporting machine is to be sensed with a depth sensor, the operator of the work machine cannot determine whether the transporting machine is positioned in a measurement area of an external environment measurement device attached to the work machine, the transporting machine may not be able to be sensed with the external environment measurement device of the work machine before

loading by the work machine, and the loading work may not be able to be assisted appropriately.

[0083] In contrast, in the present embodiment, the hydraulic excavator 1 waits for the transporting machine 200 at such a swing angle that the measurement area 220 covers the loading area 210. Thus, when the transporting machine 200 has stopped in the loading area 210, the position of the vessel of the transporting machine 200 stopped at a loading position can be sensed accurately, and the loading assist control appropriately assists loading work by the work machine, thereby making it possible to enhance the operability of the hydraulic excavator 1.

<Second Embodiment>

[0084] A second embodiment of the present invention is explained with reference to FIG. 12. In the figures, members similar to their counterparts in other embodiments are given the same reference characters, and explanations are omitted.

[0085] In the first embodiment, the loading area 210 is set supposing that the transporting machine 200 stops surely in the loading area 210, for example, in a case where the transporting machine 200 is caused to autonomously travel/stop by a control system or the like. However, for example, in a case where the transporting machine 200 operated by the operator stops in the loading area 210, it is possible that the actual stop position of the transporting machine 200 does not coincide with a predetermined stop position. In view of this, in a case depicted in the present embodiment, a stop tolerance range 211 taking into consideration the distance between the predetermined stop position and the actual stop position is calculated for the manually operated transporting machine 200 which an operator gets in, and is used as the loading area 210 for the transporting machine sensing assessment.

[0086] FIG. 12 is a figure depicting an example of a process of calculating the stop tolerance range.

[0087] In the present embodiment, in addition to the loading area 210 of the transporting machine 200, the loading area acquiring section 84 calculates the stop tolerance range 211 taking into consideration the difference between the predetermined stop position and the actual stop position, stores the stop tolerance range 211 on the storage device 57, and uses the stop tolerance range 211 for the transporting machine sensing assessment process instead of the loading area 210.

[0088] As depicted in FIG. 12, the stop tolerance range 211 is represented by a quadrangle in the machine body coordinate system 400, and coordinate values (Xa1, Ya1) to (Xa4, Ya4) of vertices Pa1 to Pa4 of the area on the X-Y plane are stored on the storage device 57.

[0089] As with the first embodiment, in the present embodiment, the stop tolerance range 211 is set by adding Dr in the longitudinal direction and Dθ in the lateral direction to the loading area 210 that is set via the display device 55 by the operator of the excavator, as depicted in FIG. 12. Predetermined values are used for Dr and Dθ. For example, Dr is a length corresponding to a position where the claw tip position can be, taking into consideration an arm angle at which the hydraulic excavator 1 can dump earth and sand. In addition, for example, θdump is set in advance regarding the swing direction of the loading position, and Dθ is $L_{tip} \cdot \tan(\theta_{dump}/2)$ according to the length L_{tip} from the current position of the center of swing of the hydraulic excavator 1 to the claw tip position.

[0090] The configuration is similar to that in the first embodiment in other respects.

[0091] In the thus configured present embodiment, too, advantages similar to those in the first embodiment can be attained.

[0092] In addition, in the present embodiment, the stop tolerance range 211 is set, and the stop tolerance range 211 is used as the loading area 210 even in a case where the actual stop position of the transporting machine 200 is at a distance from the predetermined stop position when an operator manually operates the transporting machine 200. Accordingly, the position of the vessel of the transporting machine 200 stopped in the stop tolerance range 211 can be sensed accurately, and the loading assist control can enhance the operability of the hydraulic excavator 1.

<Third Embodiment>

[0093] A third embodiment of the present invention is explained with reference to FIG. 13 to FIG. 16. In the figures, members similar to their counterparts in other embodiments are given the same reference characters, and explanations are omitted.

[0094] In the present embodiment, the loading area 210 is set at the loading area acquiring section 84 by using a result of sensing by the transporting machine sensing section 86, and the loading area 210 acquired by the loading area acquiring section 84 is moved along with a movement amount of the hydraulic excavator 1.

[0095] It is assumed in the first and second embodiments that the transporting machine stops at a position designated by the hydraulic excavator 1. However, systems like an FMS (Fleet Management System) for position/assignment management of transporting machines are not introduced to some work sites, and the hydraulic excavator 1 cannot designate the stop position of a transporting machine 200.

[0096] The present embodiment pays attention to a fact that, at such a site, an operator of a transporting machine 200 visually checks the position of the hydraulic excavator 1, determines a position suited for loading, and stops the

transporting machine 200, and in many cases, every time a transporting machine 200 stops, the positional relation between the hydraulic excavator 1 and the stopped transporting machine 200 is substantially the same. That is, an area where a transporting machine 200 which is the target of the last loading cycle has been sensed can be regarded as a stop position of another transporting machine 200 which is the target of the next loading cycle. Accordingly, in the present embodiment, when a transporting machine 200 is approaching to stop, the hydraulic excavator 1 is caused to swing to have such an azimuth that the measurement area 220 of the external environment measurement device 70 can cover the loading area 210, so that the sensing rate of transporting machines 200 can be enhanced.

[0097] FIG. 13 is a functional block diagram depicting functions of the hydraulic system and the control system of the hydraulic excavator according to the present embodiment that are extracted along with related configuration.

[0098] The external I/F 74 of the controller 54 is connected to the display device 55, a position measurement device 60, the external environment measurement device 70, the posture measurement device 53, and the storage device 57 (a hard disk drive, a large-capacity flash memory, etc.) and, in addition to these, is connected to the operation levers 22 and 23, the solenoid proportional valves 47, and the like.

[0099] FIG. 14 is a functional block diagram depicting functions of an information processing device according to the present embodiment that are extracted along with related configuration.

[0100] The controller 54 includes a position information computing section 87 in addition to the posture computing section 81, the claw tip position computing section 82, the coordinate transforming section 83, the loading area acquiring section 84, and the transporting machine sensing section 86.

<Coordinate Systems>

[0101] Since a movement of the hydraulic excavator 1 is taken into consideration in the present embodiment, the loading area 210 and the measurement area 220 are treated in the site coordinate system 500. For example, transformation of point data represented by coordinate values $P_v (X_v, Y_v, Z_v)$ in the machine body coordinate system 400 into data $P_g (X_g, Y_g, Z_g)$ in the site coordinate system 500 uses (Formula 5) to (Formula 7) described below.

[Math. 5]

$$P_g = R_{vg} \cdot (P_v + T_{sv}) + T_{vg} \dots \text{(Formula 5)}$$

[Math. 6]

$$R_{vg} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \theta_r & -\sin \theta_r \\ 0 & \sin \theta_r & \cos \theta_r \end{pmatrix} \begin{pmatrix} \cos \theta_p & 0 & \sin \theta_p \\ 0 & 1 & 0 \\ -\sin \theta_p & 0 & \cos \theta_p \end{pmatrix} \begin{pmatrix} \cos \theta_y & -\sin \theta_y & 0 \\ \sin \theta_y & \cos \theta_y & 0 \\ 0 & 0 & 1 \end{pmatrix} \dots \text{(Formula 6)}$$

[Math. 7]

$$T_{vg} = (x_0, y_0, z_0) \dots \text{(Formula 7)}$$

[0102] Here, in (Formula 5) to (Formula 7) described above, R_{vg} denotes a rotation matrix for transformation from the machine body coordinate system 400 to the site coordinate system 500, and θ_r , θ_p , and θ_y denote angles of the axes of the machine body coordinate system 400 in the site coordinate system 500. These values can be calculated by using a value calculated by the posture computing section 81 from an output of the posture measurement device 53, an azimuth angle calculated by the position information computing section 87, a swing angle output by the posture computing section 81, and the inclination angle of the machine body.

[0103] In addition, T_{vg} denotes a translation vector from the origin of the site coordinate system 500 to the origin of the machine body coordinate system 400. An output result of the position information computing section 87 can be used as T_{vg} .

<Position Information Computing Section 87>

[0104] From the position information acquired from the position measurement device 60, the position information computing section 87 outputs the position of the origin of the machine body coordinate system 400 of the hydraulic excavator 1 in the site coordinate system 500 and an azimuth θ_{dir} of the front work device 2 in the site coordinate system 500. For example, a position measurement device such as a GNSS, a TS (Total Station), or the like may be used as the position measurement device 60. The position sensing method is not limited to this, and, for example, the position may be

calculated on the basis of information about the hydraulic excavator 1 sensed by a camera fixed at a site. In addition, at least two position measurement devices are used for calculating the azimuth of the hydraulic excavator 1.

<Loading Area Acquiring Section 84>

[0105] The loading area acquiring section 84 calculates the loading area 210 by using a sensing result of the position information computing section 87.

<Loading Area Acquisition Process>

[0106] FIG. 15 is a figure depicting an overview of a loading area acquisition process. In addition, FIG. 16 is a flowchart depicting processing contents of the loading area acquisition process according to the present embodiment.

[0107] In FIG. 15, the loading area acquiring section 84 assesses whether position/posture information about a transporting machine 200 sensed by the transporting machine sensing section 86 immediately before is retained (Step S301). For example, the assessment can be performed by referring to a predetermined location in the storage device 57 of the information processing device and using the presence or absence of position/posture information about the transporting machine 200 sensed immediately before. When the assessment result of Step S301 is YES, that is, when it is assessed that position/posture information about the transporting machine 200 is retained, the procedure proceeds to a next process (Step S302). When the assessment result is NO, that is, when it is assessed that position/posture information about the transporting machine 200 is not retained, the procedure proceeds to another next process (Step S303).

[0108] When the result of the assessment at Step S301 is YES, the loading area acquiring section 84 acquires the position/posture information about the transporting machine 200 sensed by the transporting machine sensing section 86 (Step S302).

[0109] In addition, when the result of the assessment at Step S301 is NO, the loading area acquiring section 84 sets an initial loading area 210 assuming that there is no position/posture information about the transporting machine 200 in the storage device 57 (Step S303). In a method of setting the initial loading area 210, for example, as in FIG. 7 referred to in the first embodiment, the operator may set the initial loading area 210 by pressing the loading area setting button 230 of the display device 55 by using claw tip position information about the hydraulic excavator 1. In addition, this method is not the sole example, and a position predetermined for the hydraulic excavator 1 may be set in advance on the basis of operational use of a work site where the hydraulic excavator 1 operates.

[0110] When the process at Step S302 ends, subsequently, the loading area acquiring section 84 acquires information about the current position/posture of the hydraulic excavator 1 in the site coordinate system 500 calculated by the position information computing section 87 (Step S304).

[0111] Subsequently, the loading area acquiring section 84 performs machine body movement assessment (Step S305). The machine body movement assessment is made by comparing, on the X-Y plane in the site coordinate system 500, the position/azimuth information about the hydraulic excavator 1 acquired at Step S304 and previous position/azimuth information retained on the storage device 57 at Step S308 mentioned later. In a case where position/azimuth information is not retained on the storage device 57, it is assessed that there has not been a machine body movement. When the result of the assessment at Step S305 is YES, that is, when it is assessed that there has been a machine body movement, the procedure proceeds to a next process (Step S307). In addition, when the result of the assessment at Step S305 is NO, that is, when it is assessed that there has not been a machine body movement, the procedure proceeds to another next process (Step S306).

[0112] When the result of the assessment at Step S305 is NO, the loading area acquiring section 84 sets the loading area 210 on the basis of a sensing result of the transporting machine sensing section 86 (Step S306). In a method of setting the loading area 210, for example, the four vertices of the loading area 210 on the X-Y plane are calculated on the basis of the position/posture of the transporting machine 200 output by the transporting machine sensing section 86.

[0113] In addition, when the result of the assessment at Step S305 is YES, the loading area acquiring section 84 sets the loading area 210 on the basis of a sensing result of the transporting machine sensing section 86 taking into consideration the machine body movement (Step S307). In a method of setting the loading area 210, for example, after the four vertices of a rectangle as seen on the X-Y plane are calculated on the basis of the position/posture of the transporting machine 200 output by the transporting machine sensing section 86, as depicted in FIG. 15, a machine body movement amount L_{move} (X_m , Y_m) is added to each of the output four vertices.

[0114] When the process of any of Steps S303, S306, and S307 ends, subsequently, the loading area acquiring section 84 outputs, to the storage device 57, the position/azimuth information about the hydraulic excavator 1 acquired at Step S304 (Step S308), and the process is ended.

[0115] The configuration is similar to that in the first embodiment in other respects.

[0116] In the thus configured present embodiment, too, advantages similar to those in the first embodiment can be

attained.

[0117] In addition, in the present embodiment, the loading area 210 is set by using the sensing result of the transporting machine sensing section 86 and the movement amount of the hydraulic excavator 1, and therefore, it becomes possible to set the loading area 210 even at a site where a system for position/assignment management of the transporting machine 200 is not introduced. Accordingly, it becomes possible for the hydraulic excavator 1 to wait for the transporting machine 200 at such a swing angle that the measurement area 220 covers the loading area 210. When the transporting machine 200 comes to a stop in the loading area 210, the position of the vessel of the transporting machine 200 can be sensed accurately, so that the loading assist can enhance the operability of the hydraulic excavator 1.

<Fourth Embodiment>

[0118] The third embodiment of the present invention is explained with reference to FIG. 17 to FIG. 19. In the figures, members similar to their counterparts in other embodiments are given the same reference characters, and explanations are omitted.

[0119] In a case depicted in the present embodiment, the attachment angle of the external environment measurement device 70 can be changed, and the measurement angle can thus be changed. It is assumed in the present embodiment that the external environment measurement device 70 has an actuator that can control the attachment angle such that it becomes a designated attachment angle. Note that the present embodiment can be applied to both a transporting machine 200 operated by an operator and an autonomously traveling transporting machine 200, and can be used in combination with any of the first to third embodiments.

[0120] FIG. 17 is a figure illustrating a state of an external environment measurement device azimuth output process performed by a transporting machine sensing assessing section in the present embodiment.

<Transporting Machine Sensing Section 86>

[0121] The transporting machine sensing section 86 in the present embodiment assesses whether the loading area 210 acquired by the loading area acquiring section 84 is covered by the measurement area 220 of the external environment measurement device 70. The transporting machine sensing section 86 performs the transporting machine sensing process when the loading area 210 is covered by the measurement area 220. When the loading area 210 is not covered by the measurement area 220, the transporting machine sensing section 86 calculates such an attachment angle γ_s of the external environment measurement device 70 about the Z axis that the measurement area 220 can cover the loading area 210 as depicted in FIG. 17, and sends a control command to the external environment measurement device 70.

<Transporting Machine Sensing Assessment>

[0122] FIG. 18 is a flowchart depicting processing contents of the transporting machine sensing assessment in the transporting machine sensing process according to the present embodiment.

[0123] In FIG. 18, processes at Steps S201 to S204 are similar to processes depicted by FIG. 9 regarding the first embodiment, and explanations thereof are omitted.

[0124] When the process at Step S204 ends, subsequently, the transporting machine sensing section 86 assesses whether or not the overlap degree A_{cover} is greater than the threshold A_{th} (Step S245). When the assessment result of Step S245 is YES, that is, when A_{cover} is greater than A_{th} , the procedure proceeds to a next process (Step S206). When the assessment result is NO, that is, when A_{cover} is equal to or lower than A_{th} , the procedure proceeds to another next process (Step S247).

[0125] The process at Step S206 is similar to the process depicted by FIG. 9 regarding the first embodiment, and an explanation thereof is omitted.

[0126] When the result of the assessment at Step S245 is NO, the transporting machine sensing section 86 performs a process of calculating the measurement azimuth of the external environment measurement device 70 (Step S247).

<Process of Calculating Measurement Azimuth of External Environment Measurement Device>

[0127] FIG. 19 is a flowchart depicting processing contents of the measurement azimuth calculation process according to the present embodiment.

[0128] In the present embodiment, as depicted in FIG. 17, when the overlap degree A_{cover} between the loading area 210 and the measurement area 220 is equal to or lower than the threshold A_{th} , such an angle γ_s of the external environment measurement device 70 about the Z axis that the overlap degree A_{cover} becomes greater than the threshold A_{th} is calculated, and is output to the external environment measurement device 70. Note that the process of calculating the measurement azimuth of the external environment measurement device 70 may include not only an angle adjustment

of γ_s but also an angle α_s about the X axis or an angle β_s about the Y axis, for example.

[0129] In FIG. 19, first, the transporting machine sensing section 86 updates the attachment angle γ_s of the external environment measurement device 70 about the Z axis to $\gamma_s + \delta\gamma_s$ by using predetermined $\delta\gamma_s$, and performs a process at Step S402 (Step S401).

[0130] Subsequently, the transporting machine sensing section 86 calculates the overlap degree A_{cover} by using (Formula 4) (Step S402).

[0131] Subsequently, the transporting machine sensing section 86 assesses whether or not A_{cover} is greater than the threshold A_{th} (Step S403). When the result of the assessment at Step S403 is YES, that is, when A_{cover} is greater than the threshold A_{th} , the procedure proceeds to a next process (Step S404). In addition, when the result of the assessment at Step S403 is NO, that is, when A_{cover} is equal to or lower than the threshold A_{th} , the procedure returns to Step S401, and γ_s is updated.

[0132] When the result of the assessment at Step S403 is YES, the transporting machine sensing section 86 outputs the updated attachment angle γ_s of the external environment measurement device 70 about the Z axis to the external environment measurement device 70 (Step S404), and the process is ended.

[0133] The configuration is similar to that in the first embodiment in other respects.

[0134] In the thus configured present embodiment, too, advantages similar to those in the first embodiment can be attained.

[0135] In addition, in the present embodiment, in a case where the attachment angle of the external environment measurement device 70 attached to the hydraulic excavator 1 can be changed, the external environment measurement device 70 rotates such that the measurement area 220 covers the loading area 210 independently of the state of the hydraulic excavator 1. Accordingly, when the transporting machine 200 comes to a stop in the loading area 210, the position of the vessel of the transporting machine 200 can be sensed accurately, and the loading assist control can enhance the operability of the hydraulic excavator 1. In addition, since an action for adjusting the swing angle is not necessary for the hydraulic excavator 1 to sense the transporting machine 200, the productivity of the hydraulic excavator 1 is enhanced.

<Fifth Embodiment>

[0136] A fifth embodiment of the present invention is explained with reference to FIG. 20 to FIG. 22. In the figures, members similar to their counterparts in other embodiments are given the same reference characters, and explanations are omitted.

[0137] In a case depicted in the present embodiment, a plurality of the external environment measurement devices 70 are attached to the hydraulic excavator 1, and the transporting machine sensing process is performed for measurement areas of the plurality of external environment measurement devices 70 (e.g., measurement areas 220a, 220b, and 220c of the plurality of external environment measurement devices 70 depicted in FIG. 20). That is, in the present embodiment, while the hydraulic excavator 1 is waiting for the transporting machine 200 to stop, an external environment measurement device 70 most suitable for sensing the transporting machine 200 with the current posture of the hydraulic excavator 1 (i.e., one of the plurality of measurement areas 220a, 220b, and 220c) is selected, and it is assessed whether the hydraulic excavator 1 is oriented at a swing angle suitable for sensing the transporting machine 200 with the measurement area of the selected external environment measurement device 70. If the front work device 2 is included in the measurement area (e.g., the measurement area 220a) of the external environment measurement device 70, the controller 45 performs the transporting machine sensing process after an instruction for moving the front work device 2 out of the measurement area of the external environment measurement device 70 is output.

[0138] Note that the present embodiment can be applied to both a transporting machine 200 operated by an operator and an autonomously traveling transporting machine 200, and can be used in combination with any of the first to third embodiments.

[0139] FIG. 20 is a figure depicting an example of the transporting machine sensing assessment according to the present embodiment. In addition, FIG. 21 is a flowchart depicting processing contents of the transporting machine sensing assessment in the transporting machine sensing process according to the present embodiment. In addition, FIG. 22 is a figure depicting an example of output to the display device according to the present embodiment.

[0140] As depicted in FIG. 20, the plurality of external environment measurement devices that sense the depths to objects around the hydraulic excavator 1 (e.g., those similar to the external environment measurement device 70 in FIG. 1) are attached to the upper swing structure 7 of the hydraulic excavator 1, and can acquire depth information about objects in each area of the measurement area 220a, which is a predetermined range in front of the upper swing structure 7 where the front work device 2 is installed, the measurement area 220b, which is a predetermined range to the left of the upper swing structure 7, and the measurement area 220c, which is a predetermined range to the right of the upper swing structure 7.

<Transporting Machine Sensing Section 86>

[0141] In the present embodiment, the transporting machine sensing section 86 calculates the overlap degree A_{cover} between the measurement area 220 of each of all the external environment measurement devices 70 attached to the hydraulic excavator 1 and the loading area 210, and assesses whether the hydraulic excavator 1 has such an azimuth that the measurement area 220 of the external environment measurement device 70 with the highest value of A_{cover} covers the loading area 210.

<Transporting Machine Sensing Assessment>

[0142] In FIG. 21, first, the transporting machine sensing section 86 assesses whether or not the swing angular velocity ω_{sw} output by the posture computing section 81 is smaller than the predetermined angular velocity Q_{sw} (Step S201). When the assessment result of Step S201 is YES, that is, when the swing angular velocity ω_{sw} of the hydraulic excavator 1 is smaller than the predetermined angular velocity Q_{sw} , it is determined that the transporting machine 200 is being waited for to stop, and the procedure proceeds to a next process (Step S252). In addition, when the assessment result of Step S201 is NO, that is, when the swing angular velocity ω_{sw} of the hydraulic excavator 1 is equal to or greater than the predetermined angular velocity Q_{sw} , the transporting machine sensing section 86 assesses that the hydraulic excavator 1 is performing loading work, and repeats the assessment until the swing angular velocity ω_{sw} becomes smaller than Q_{sw} .

[0143] When the result of the assessment at Step S201 is YES, the transporting machine sensing section 86 acquires the measurement areas 220 of all the external environment measurement devices 70 attached to the hydraulic excavator 1 (Step S252).

[0144] Subsequently, the transporting machine sensing section 86 acquires the loading area 210 acquired by the loading area acquiring section 84 (Step S253).

[0145] Subsequently, the transporting machine sensing section 86 calculates the overlap degree A_{cover} between the measurement area 220 of each of all the external environment measurement devices 70 attached to the hydraulic excavator 1 and the loading area 210 (Step S254). A_{cover} is given by (Formula 4).

[0146] Subsequently, the transporting machine sensing section 86 selects an external environment measurement device 70 with the greatest value of the overlap degree A_{cover} determined at Step S254 (Step S255).

[0147] Subsequently, the transporting machine sensing section 86 assesses whether or not the overlap degree A_{cover} of the external environment measurement device 70 selected at Step S255 is greater than the threshold A_{th} (Step S256). When the assessment result of Step S256 is YES, that is, when A_{cover} is greater than A_{th} , the procedure proceeds to a next process (Step S256). When the assessment result is NO, that is, when A_{cover} is equal to or lower than A_{th} , the procedure proceeds to another next process (Step S257).

[0148] When the result of the assessment at Step S256 is YES, the transporting machine sensing section 86 assesses whether or not the front work device 2 is included in the measurement area of the external environment measurement device 70 selected at Step S255 (Step S257). Whether or not the front work device 2 is included in the measurement area of the external environment measurement device 70 can be assessed by retaining, on the storage device 57 in advance, combinations of external environment measurement devices 70 whose measurement areas include the front work device 2 and ranges of the joint angles of the front work device 2 at the time when the measurement areas include the front work device 2, and comparing a calculation result of the posture computing section 81 with the combinations. When the result of the assessment at Step S257 is YES, that is, when the front work device 2 is included in the measurement area, the procedure proceeds to a next process (Step S259). When the assessment result is NO, that is, when the front work device 2 is not included in the measurement area, the procedure proceeds to another next process (Step S258).

[0149] When the result of the assessment at Step S257 is YES, the transporting machine sensing section 86 gives an assessment result for starting the transporting machine sensing process with the external environment measurement device 70 whose value of A_{cover} is the greatest (Step S258), and the transporting machine sensing assessment process is ended.

[0150] In addition, when the result of the assessment at Step S257 is NO, the transporting machine sensing section 86 outputs an instruction for moving the front work device 2 out of the measurement area of the external environment measurement device 70 (Step S259), and the transporting machine sensing assessment process is ended. In an instruction method, for example, as in FIG. 22, a front implement raising command 240 is displayed on the display device 55 to prompt the operator to perform operation. Note that the command method is not limited to this, and an operation amount of the front implement may be output as a control command to the machine body control section 40.

[0151] In addition, when the result of the assessment at Step S256 is NO, the transporting machine sensing section 86 outputs a swing action instruction (Step S260), and the transporting machine sensing assessment process is ended. For example, a swing command is given by causing the display device 55 to display the loading area 210 and the measurement area 220 as well as an indication that prompts the operator to perform operation for a swing action as depicted in FIG. 11.

[0152] The configuration is similar to that in the first embodiment in other respects.

[0153] In the thus configured present embodiment, too, advantages similar to those in the first embodiment can be attained.

[0154] In addition, in the present embodiment, even in a case where the plurality of external environment measurement devices 70 are attached to the hydraulic excavator 1, an external environment measurement device 70 most suitable for sensing the transporting machine 200 can be selected. In addition, since such a swing angle that the measurement area 220 of the selected external environment measurement device 70 covers the loading area 210 can be calculated, the position of the vessel of the transporting machine 200 can be sensed accurately when the transporting machine 200 comes to a stop in the loading area 210, and the loading assist control can enhance the operability of the hydraulic excavator 1. In addition, since the transporting machine 200 can be sensed with an appropriate one of the plurality of external environment measurement devices 70, the process efficiency of the transporting machine sensing process is enhanced.

<Supplementary Notes>

[0155] Note that the present invention is not limited to the embodiments described above and includes various modification examples and combinations within the scope not departing from the gist of the present invention.

[0156] For example, while it is assumed in the embodiments described above that an operator gets in the hydraulic excavator 1 and performs earth and sand excavation, and a loading action to load a transporting machine, this is not the sole example. For example, the present invention may be applied to a case where a hydraulic excavator 1 is operated from a remote operation room. In addition, it is also possible to apply the embodiments described above to a work machine that operates autonomously. In configuration in this case, a command is sent to the machine body control section 40 such that a swing action is performed to make the measurement area 220 cover the loading area 210.

[0157] In addition, the present invention is not limited to those including all the constituent elements explained in the embodiments described above, and also includes those from which some of the constituent elements are deleted. Further, some or all of the constituent elements, functions, and the like described above may be realized by designing them in an integrated circuit, for example. Moreover, the constituent elements, functions, and the like described above may be realized by software by a processor interpreting and executing a program to realize the functions.

Description of Reference Characters

[0158]

- 1: Hydraulic excavator
- 2: Front work device
- 3: Machine body
- 4a: Travel right hydraulic motor
- 4b: Travel left hydraulic motor
- 5: Lower track structure
- 6: Swing hydraulic motor
- 7: Upper swing structure
- 8: Boom
- 8a: Boom pin
- 9: Arm
- 9a: Arm pin
- 10: Bucket
- 10a: Bucket pin
- 11: Boom cylinder
- 12: Arm cylinder
- 13: Bucket cylinder
- 14: Boom angle sensor
- 15: Arm angle sensor
- 16: Bucket link
- 17: Bucket angle sensor
- 18: Inclination angle sensor
- 19: Swing angle sensor
- 20: Angular velocity sensor
- 22: Operation lever
- 22a: Operation right lever
- 22b: Operation left lever

23: Operation lever
 23a: Travel right lever
 23b: Travel left lever
 40: Machine body control section
 5 47a to 47l: Solenoid proportional valve
 52a to 52f: Sensor
 53: Posture measurement device
 54: Controller
 55: Display device
 10 57: Storage device
 60: Position measurement device
 70: External environment measurement device
 74: External I/F
 75: Bus
 15 81: Posture computing section
 82: Claw tip position computing section
 83: Coordinate transforming section
 84: Loading area acquiring section
 86: Transporting machine sensing section
 20 87: Position information computing section
 100: Pilot line
 101: Flow control valve
 102: Hydraulic pump
 103: Engine
 25 104: Pilot pump
 120: Swing center line
 130: Claw tip position
 200: Transporting machine
 210: Loading area
 30 211: Stop tolerance range
 220: Measurement area
 230: Loading area setting button
 240: Command
 300: Sensor coordinate system
 35 400: Machine body coordinate system
 500: Site coordinate system

Claims

- 40
1. A work machine that has an articulated front work device and performs loading work to load a transporting machine with a transporting target object, the work machine comprising:
- 45 an external environment measurement device that is provided to the work machine, measures an object existing in a predetermined measurement area around the work machine and a position of the object, and outputs information about the object and the position as object position information;
 a posture measurement device that measures a state quantity related to a posture of the work machine and outputs information about the state quantity as posture information; and
 a controller configured to compute a position and a posture of a transporting machine relative to the work machine
 50 on a basis of the posture information about the work machine and the object position information and perform loading assist control of the work machine on a basis of the computed position and posture of the transporting machine, wherein
 the controller is configured to
- 55 compute the posture of the work machine on a basis of the posture information about the work machine output from the posture measurement device,
 set a loading area that is an area where the transporting machine stops and where loading work by the work machine to load the transporting machine is performed,

assess whether or not the work machine is at such a posture that the external environment measurement device can compute the transporting machine having stopped in the loading area, on a basis of the posture of the work machine, the measurement area, and the loading area, and
compute the position and posture of the transporting machine in the loading area on a basis of the object position information output from the external environment measurement device, when it is assessed that the work machine is at such a posture that the transporting machine can be computed.

2. The work machine according to claim 1, wherein
the controller is configured to assess whether or not the work machine is at such a posture that the position and posture of the transporting machine can be computed, on a basis of an overlap degree representing a degree to which the loading area and the measurement area overlap.

3. The work machine according to claim 2, wherein the controller is configured to
calculate a position of a front end of the front work device of the work machine on a basis of the posture information about the work machine output from the posture measurement device, and
set the loading area on a basis of the position of the front end of the front work device.

4. The work machine according to claim 3, wherein
the controller is configured to
calculate a tolerance range of a stop position of the transporting machine as a stop tolerance range when the loading area is set, and
assess that the work machine has such an azimuth that the position and posture of the transporting machine can be computed, when an overlap degree between the stop tolerance range and the measurement area is equal to or greater than a predetermined degree.

5. The work machine according to claim 3, comprising:
a position measurement device that outputs own machine position information about a position of the work machine in a site coordinate system, wherein
the controller is configured to assess whether or not the work machine has moved on a basis of the own machine position information, and move a position of the loading area according to a movement amount of the work machine when it is assessed that the work machine has moved.

6. The work machine according to claim 3, wherein
the controller is configured to externally acquire, as own machine position information, position information about the work machine in a site coordinate system by using a communication device, assess whether or not the work machine has moved on a basis of the acquired own machine position information, and move a position of the loading area according to a movement amount of the work machine when it is assessed that the work machine has moved.

7. The work machine according to claim 3, wherein
the measurement area of the external environment measurement device can be adjusted, and
the controller is configured to assess that the work machine has such an azimuth that the position and posture of the transporting machine can be computed, when an overlap degree between the loading area and a range over which the measurement area of the external environment measurement device can be adjusted is equal to or greater than a predetermined degree, and compute the position and posture of the transporting machine after the measurement area is adjusted such that the overlap degree between the loading area and the measurement area is maximized.

8. The work machine according to claim 3, wherein
the external environment measurement device has a plurality of mutually different measurement areas, and
the controller is configured to assess that the work machine has such an azimuth that the position and posture of the transporting machine can be computed, when an overlap degree between the loading area and at least one measurement area of the plurality of measurement areas of the external environment measurement device is equal to or greater than a predetermined degree, and sense the position and posture of the transporting machine

by using a measurement area having a high overlap degree with the loading area in the plurality of measurement areas.

9. The work machine according to claim 3, wherein
the controller is configured to

calculate the position of the front end of the front work device of the work machine on the basis of the posture information about the work machine output from the posture measurement device, and
assess whether or not the front end of the front work device is positioned above the measurement area of the external environment measurement device, and sense the position and posture of the transporting machine when it is assessed that the front end of the front work device is positioned outside the measurement area.

FIG. 1

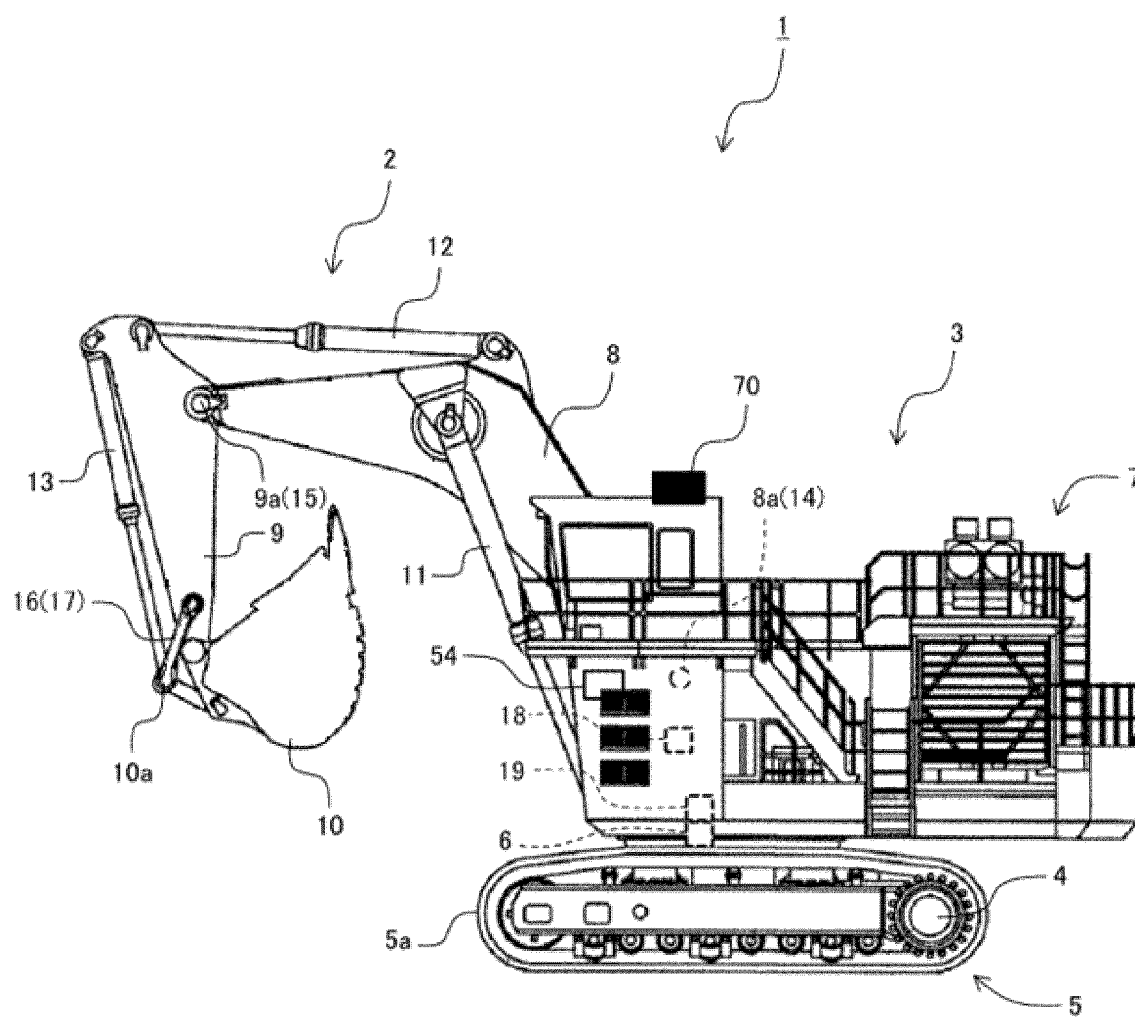


FIG. 2

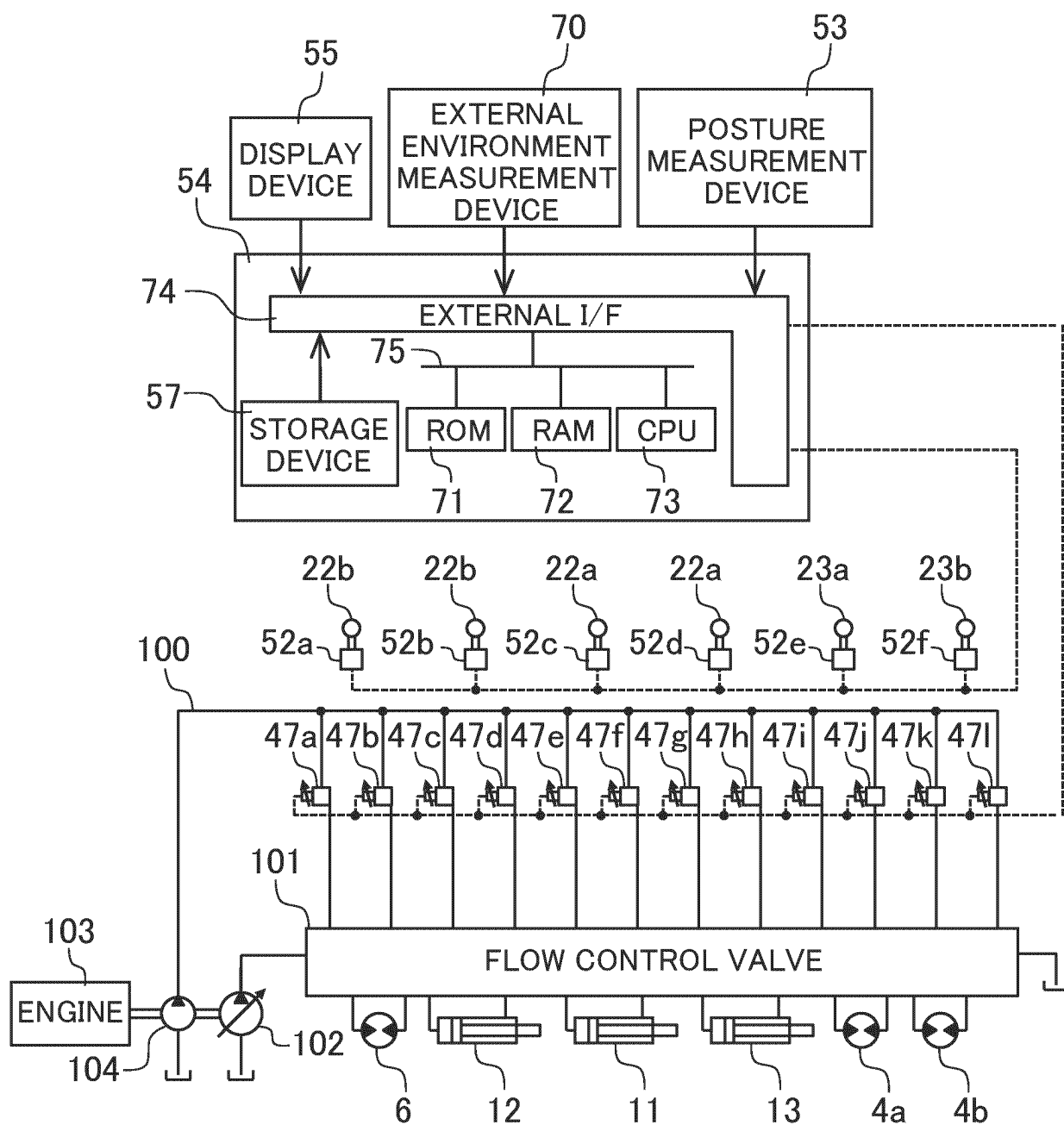


FIG. 3

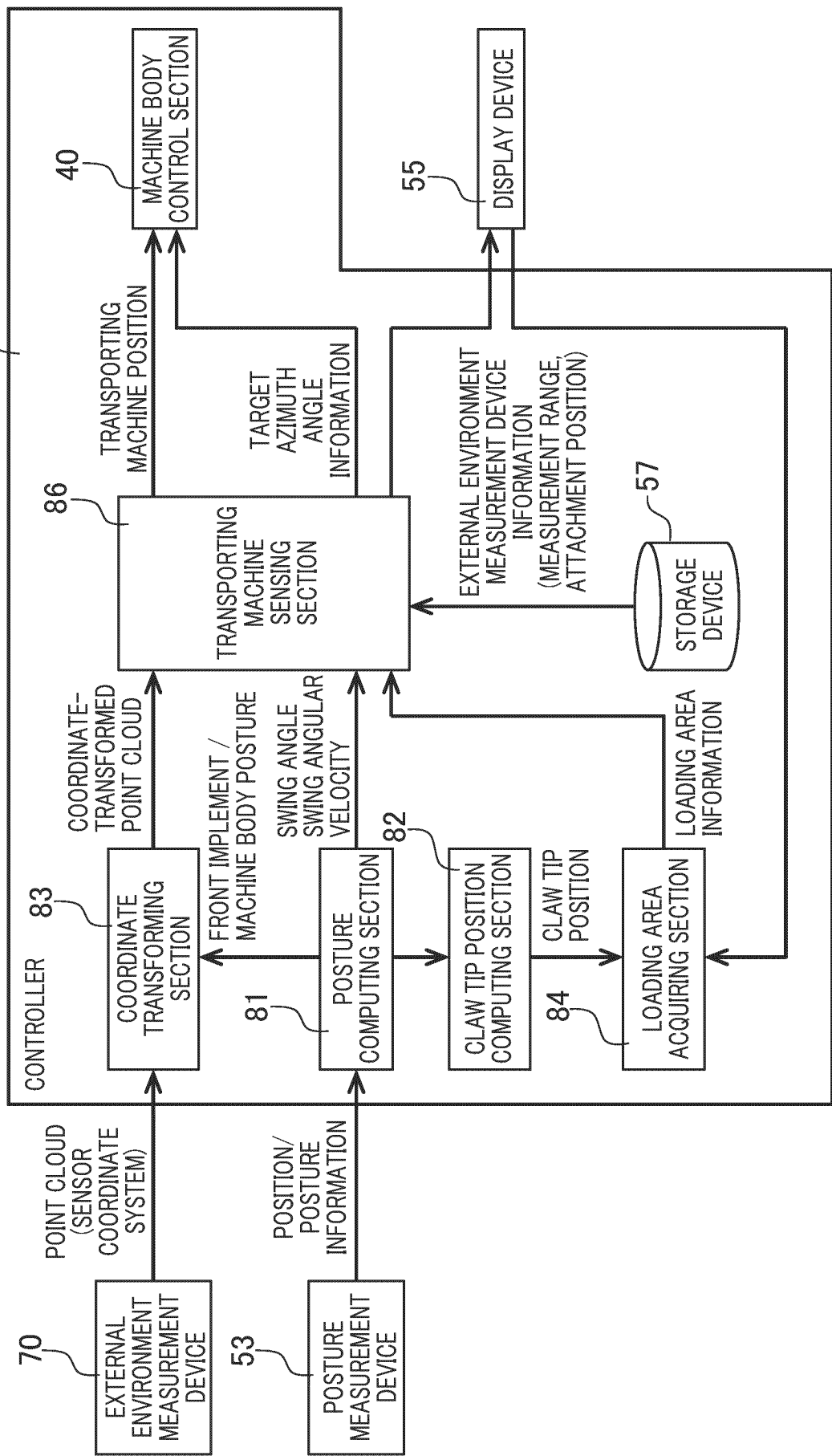


FIG. 4

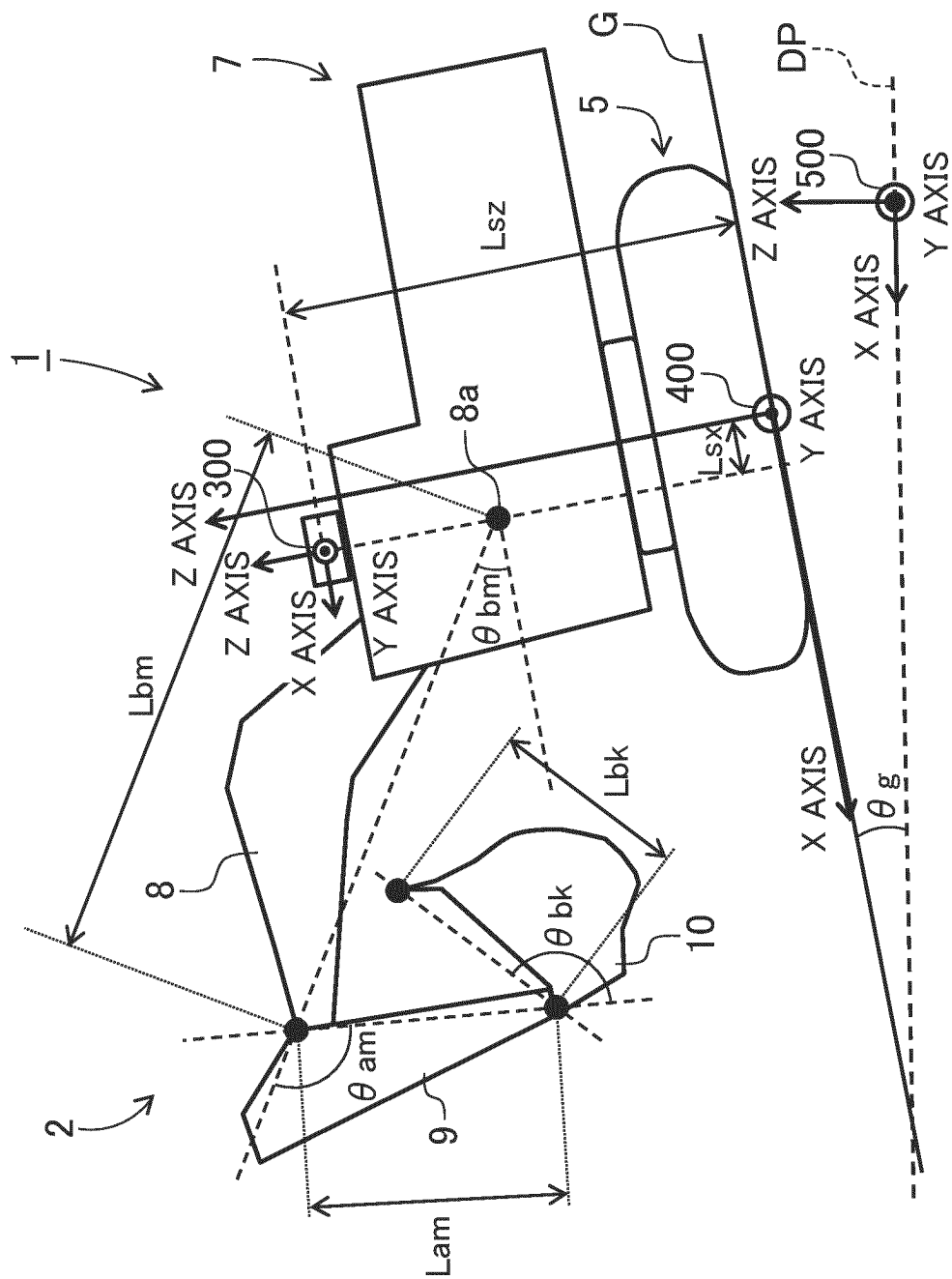


FIG. 5

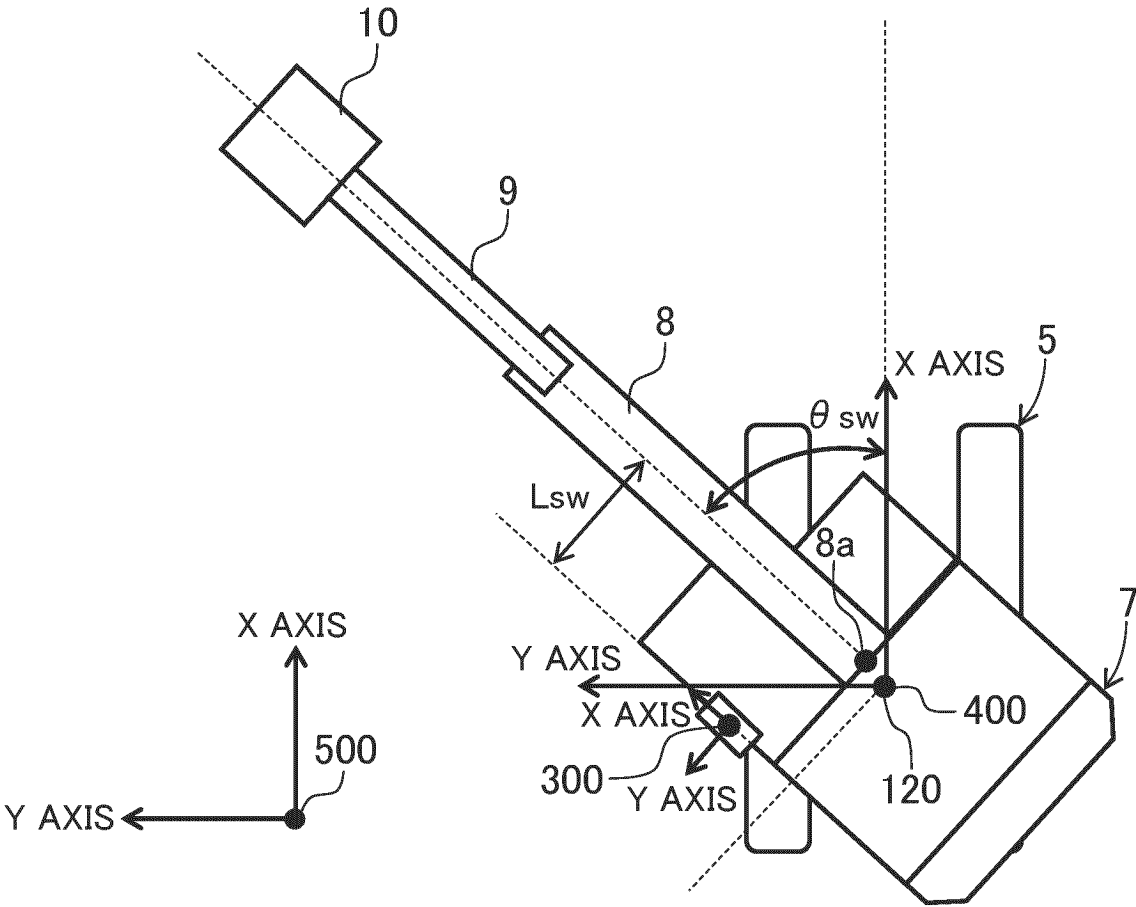


FIG. 6

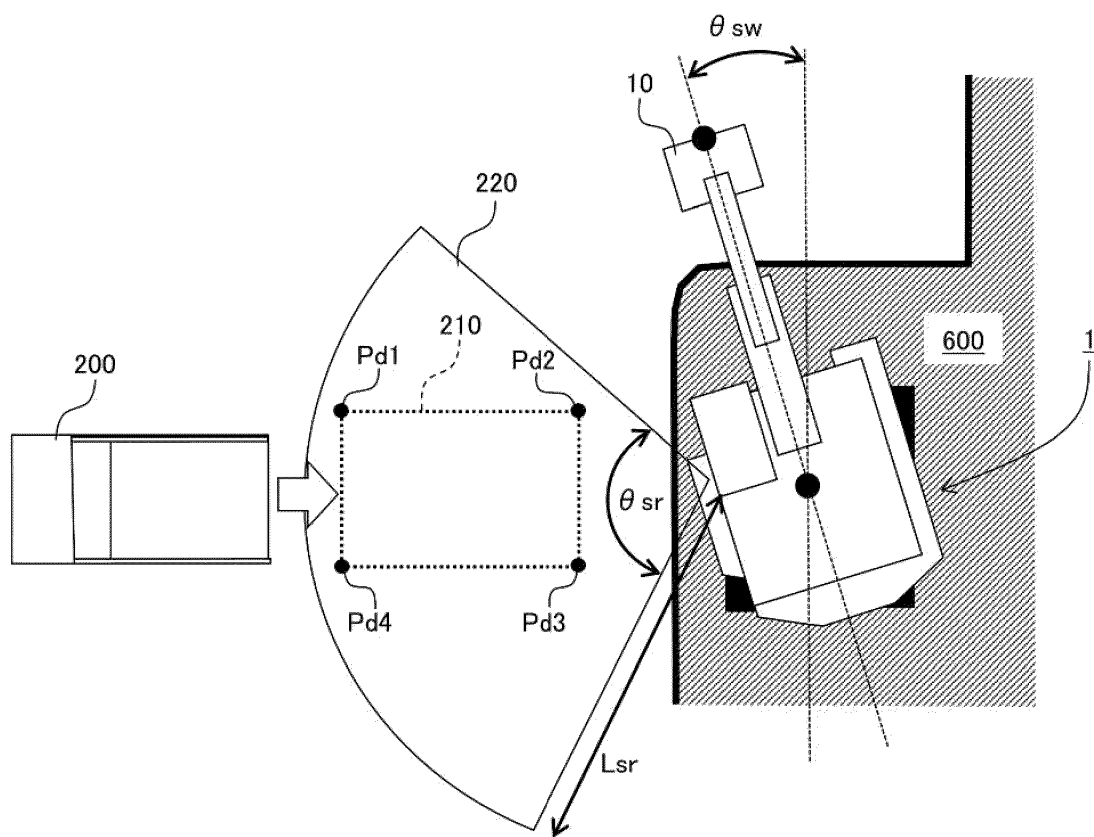


FIG. 7

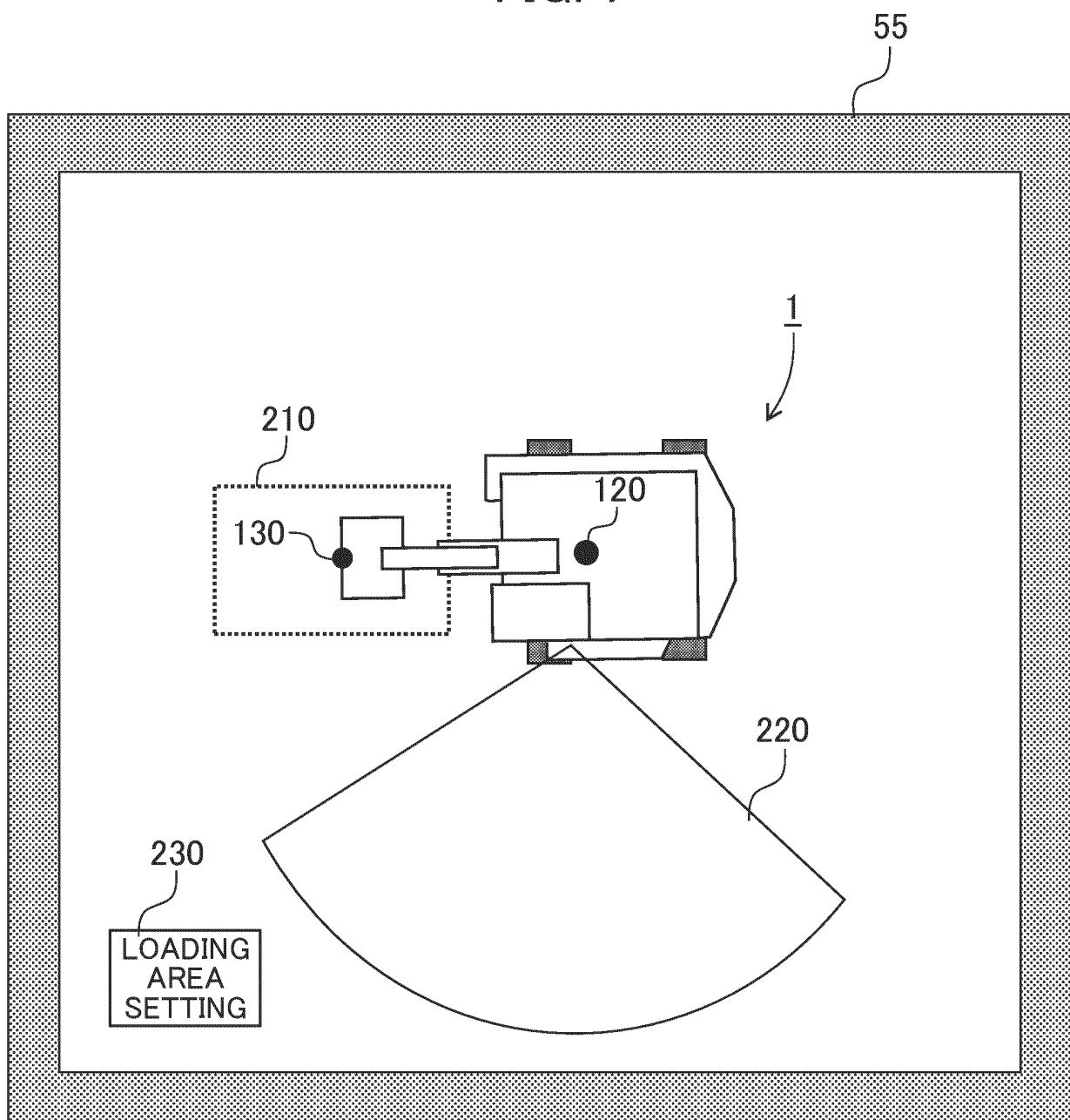


FIG. 8

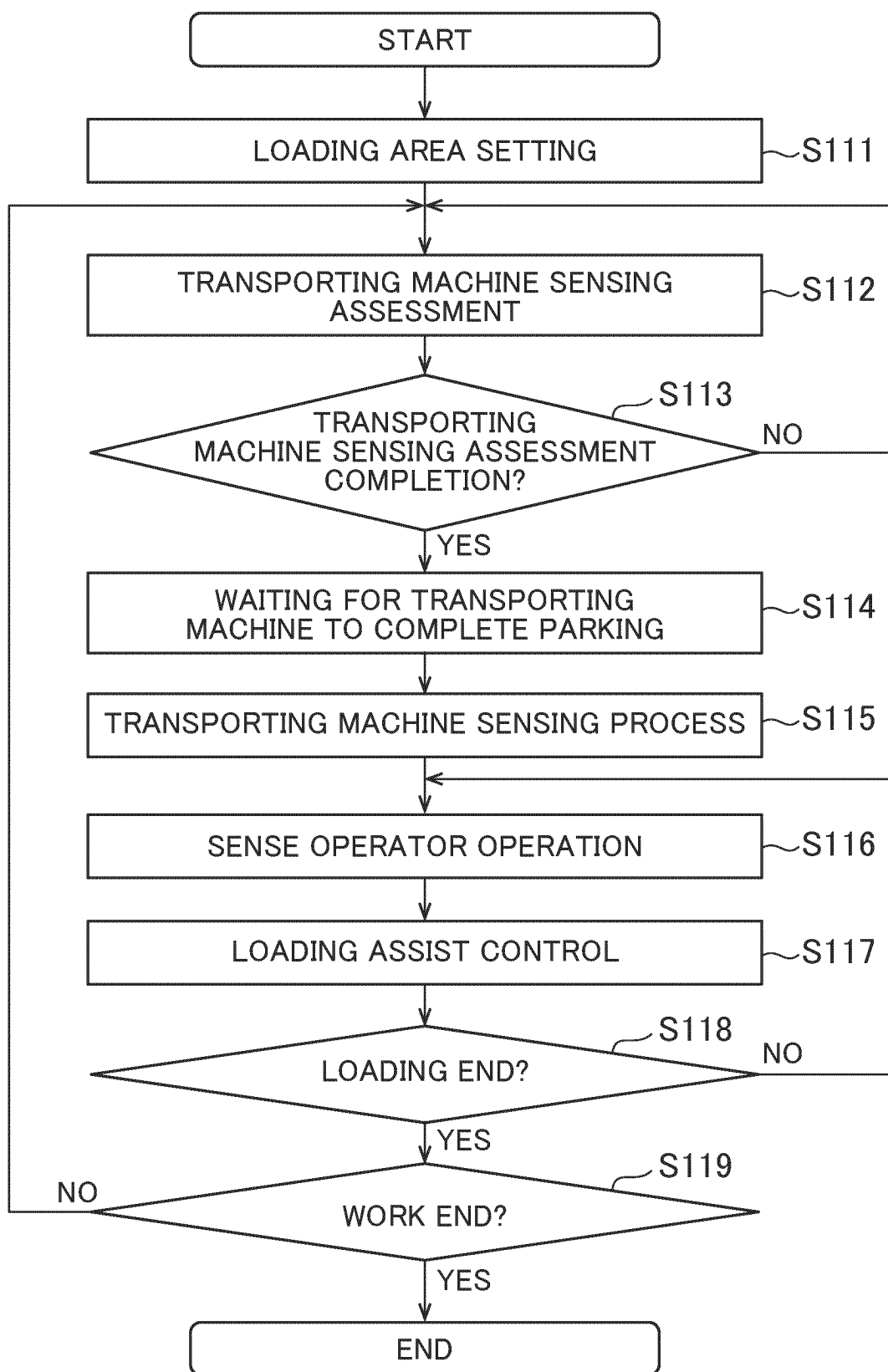


FIG. 9

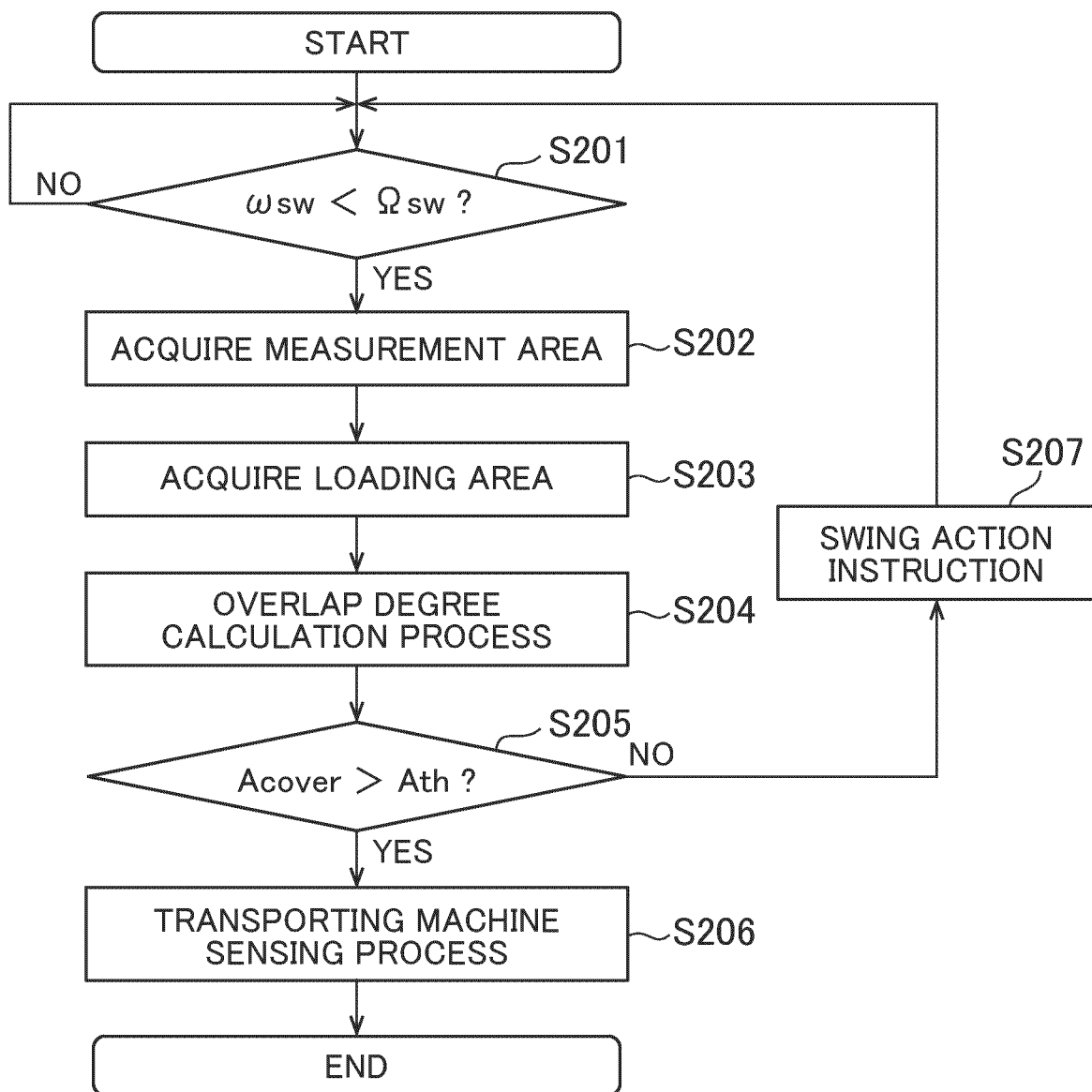


FIG. 10

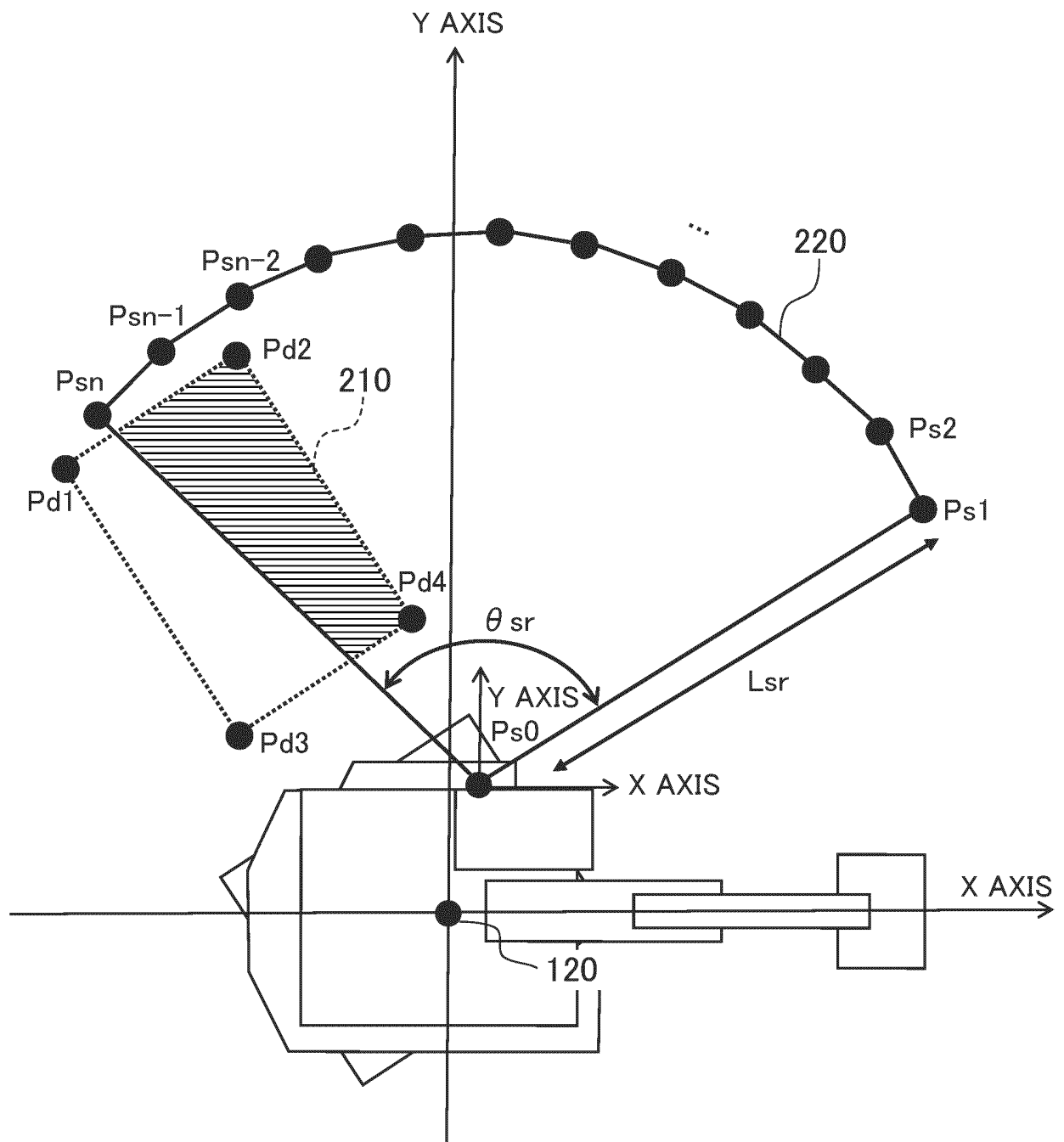


FIG. 11

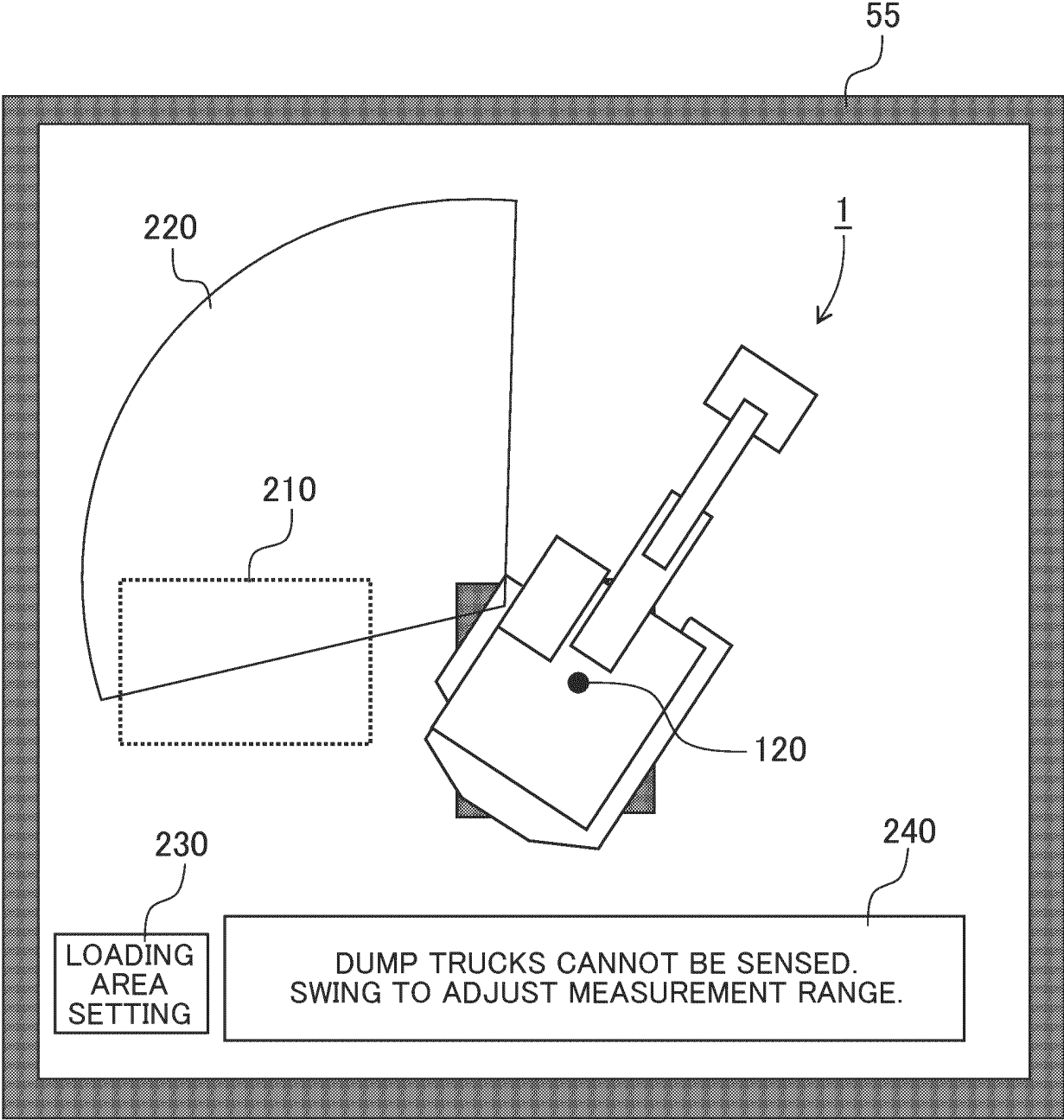


FIG. 12

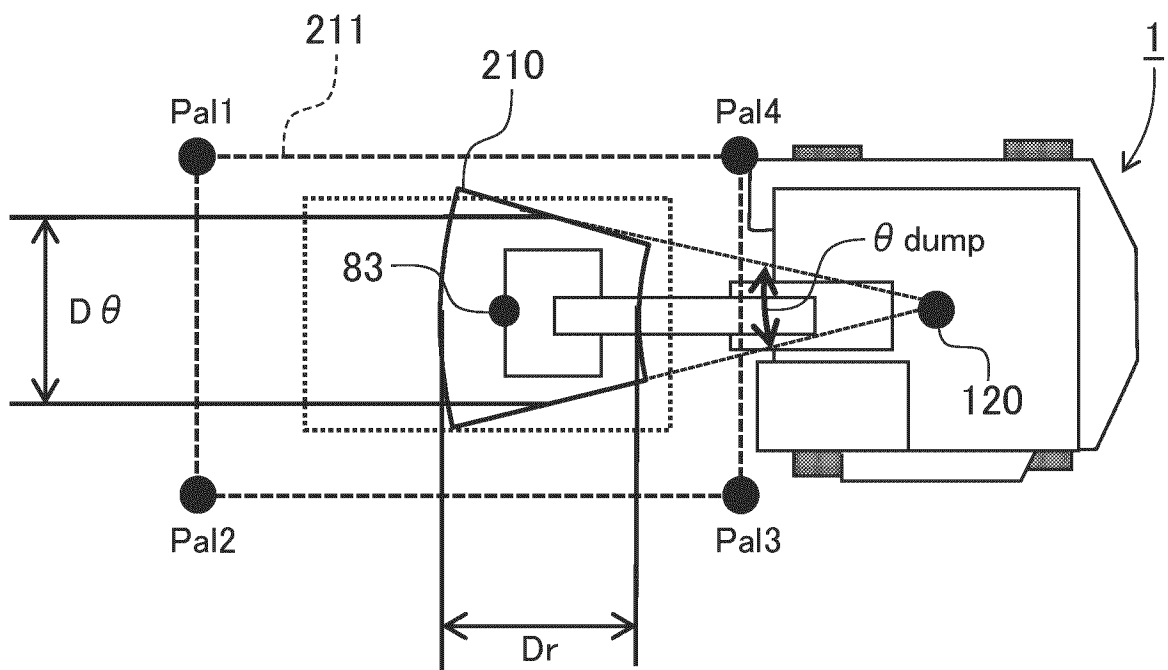


FIG. 13

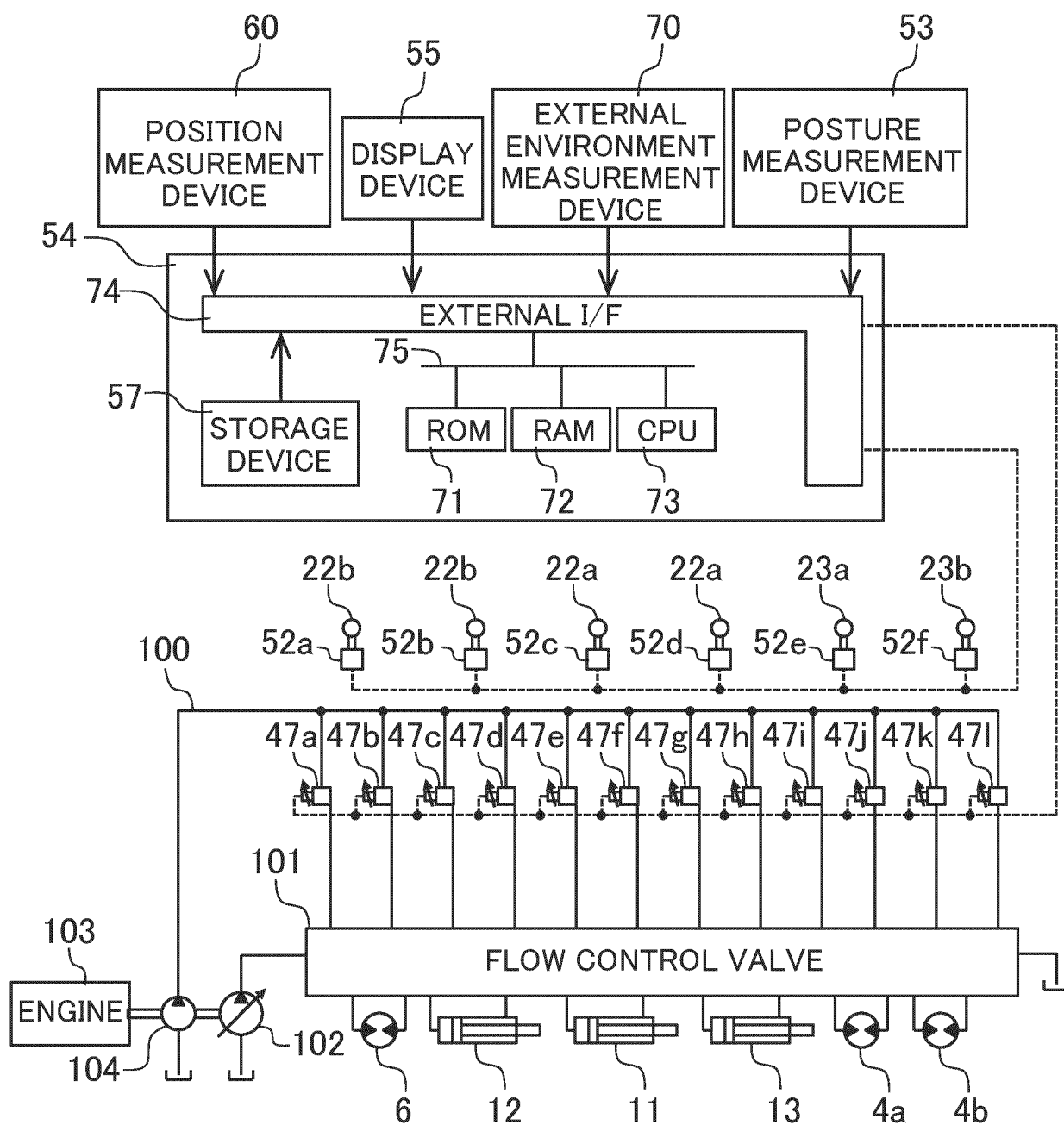


FIG. 14

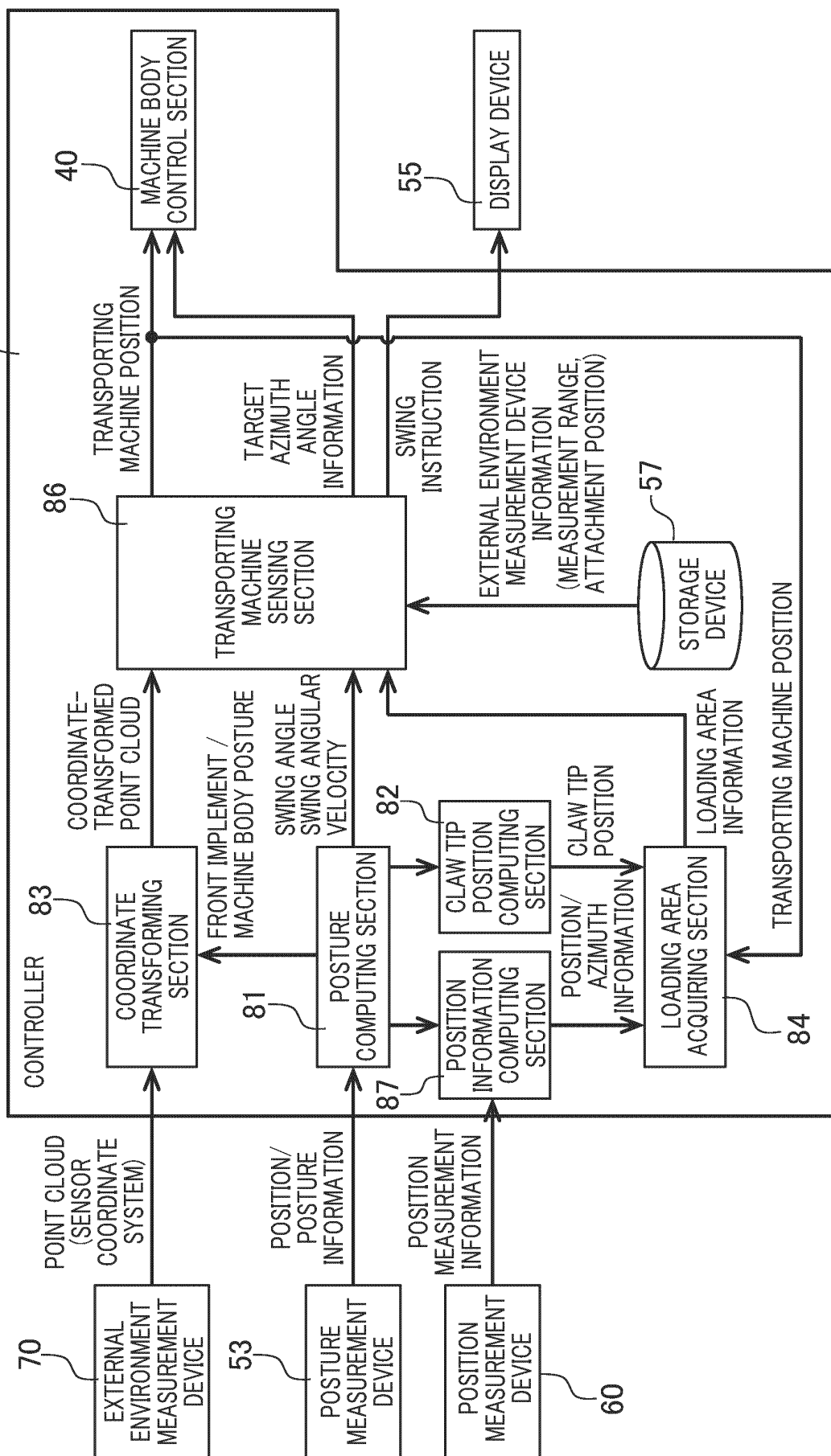


FIG. 15

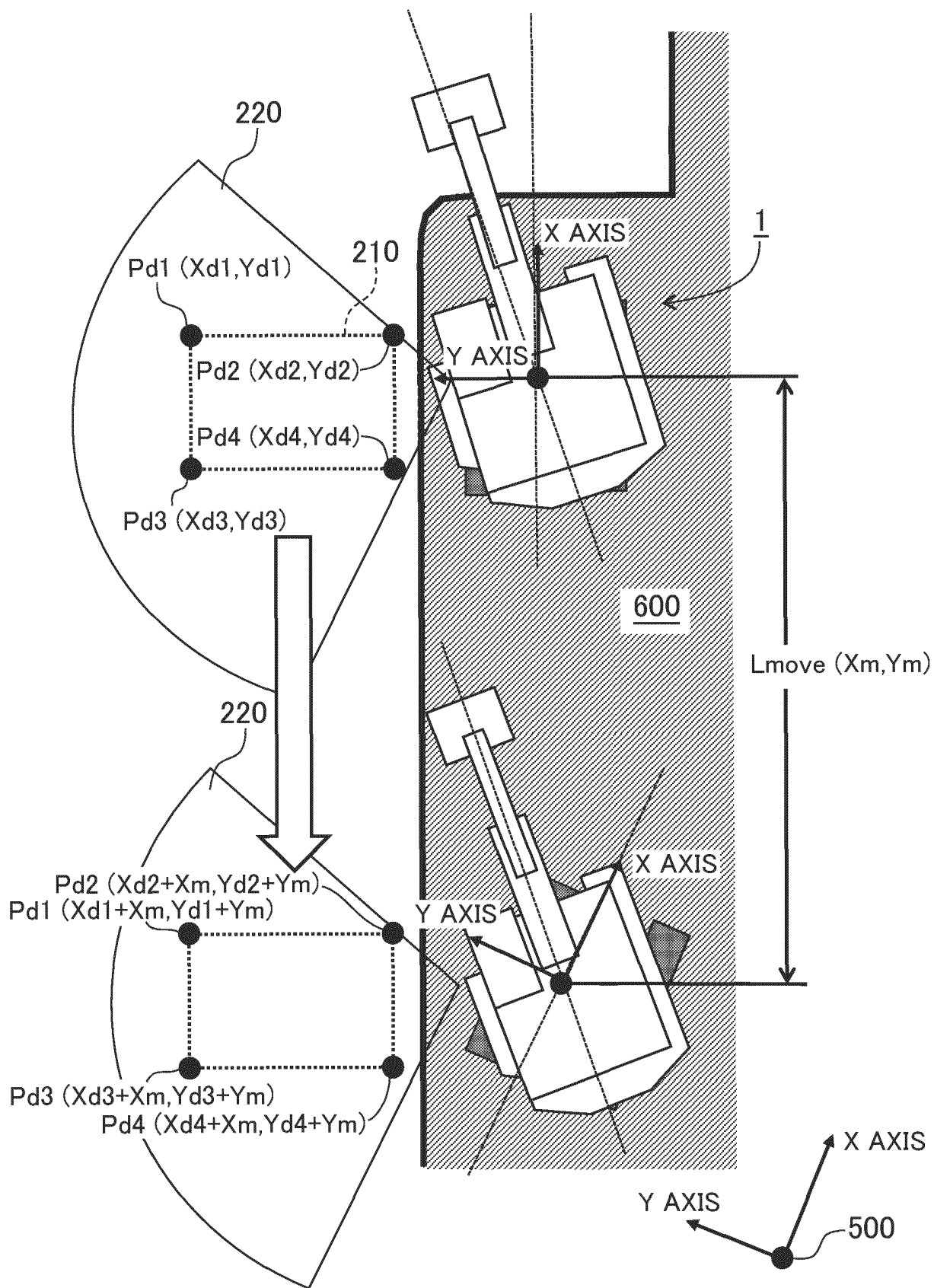


FIG. 16

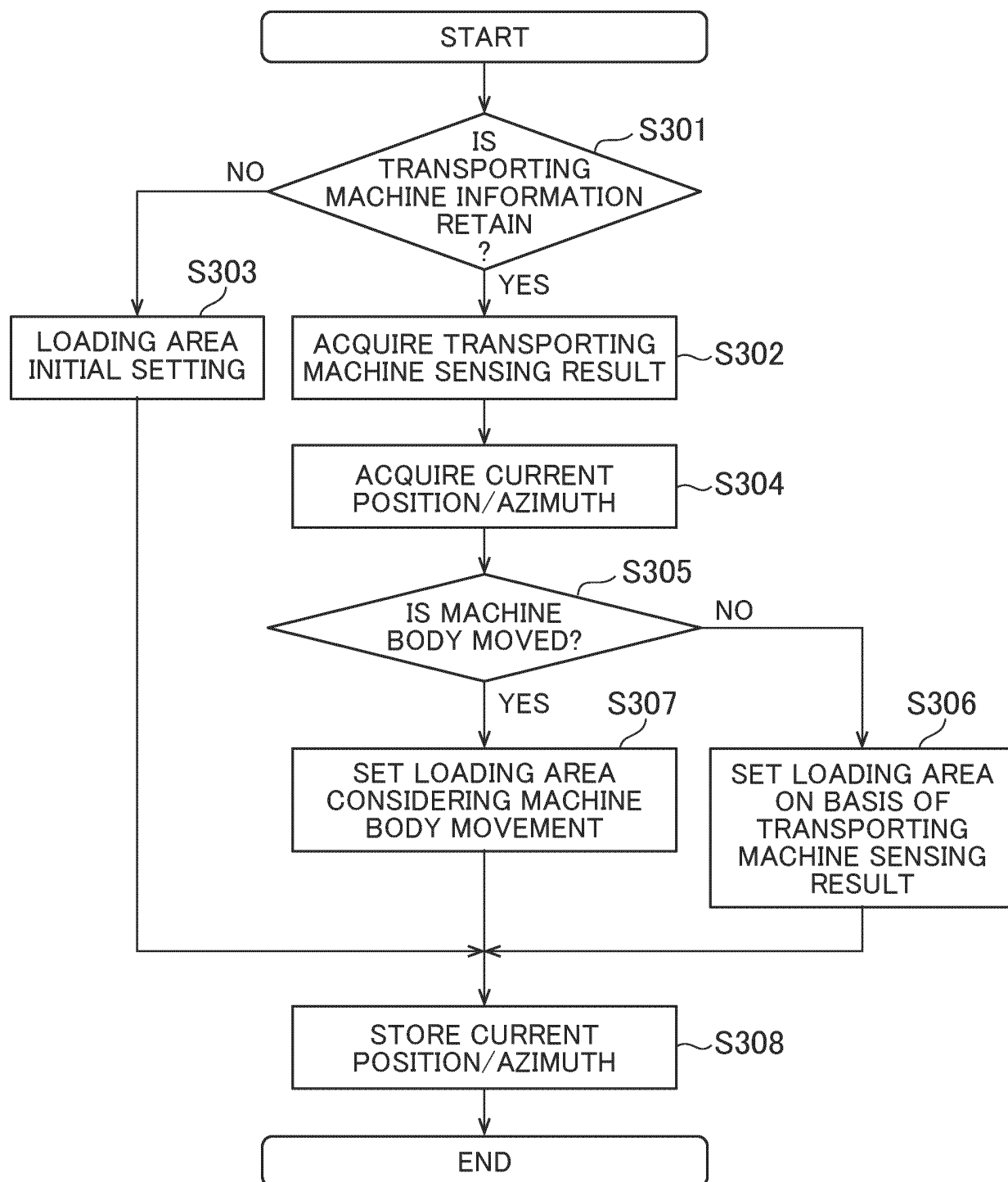


FIG. 17

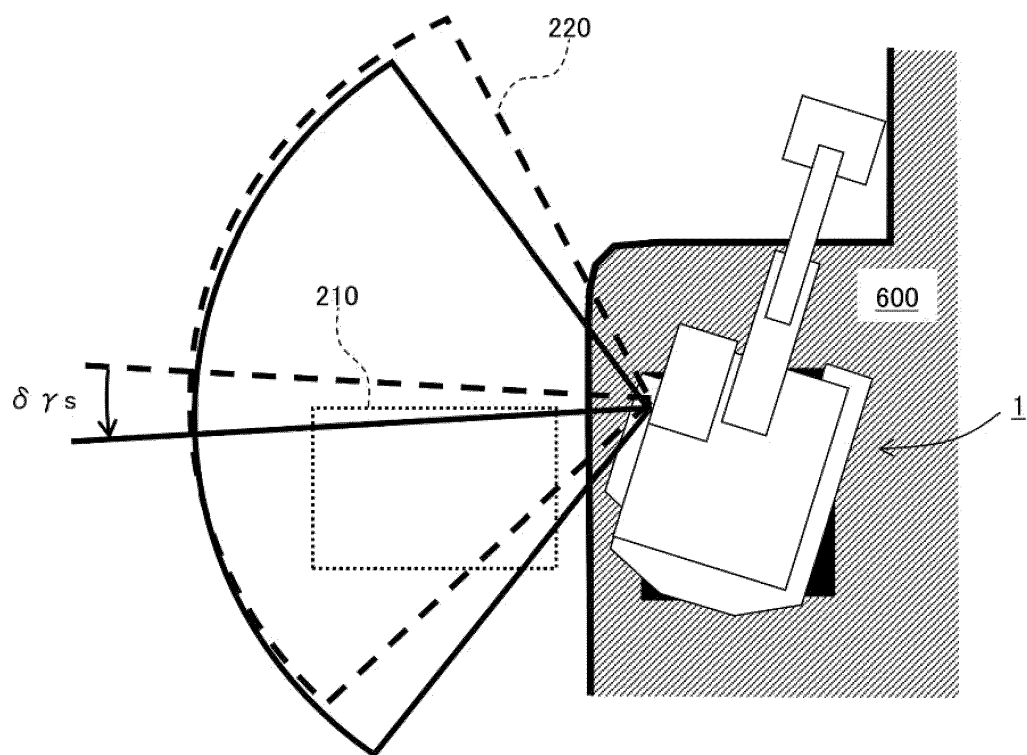


FIG. 18

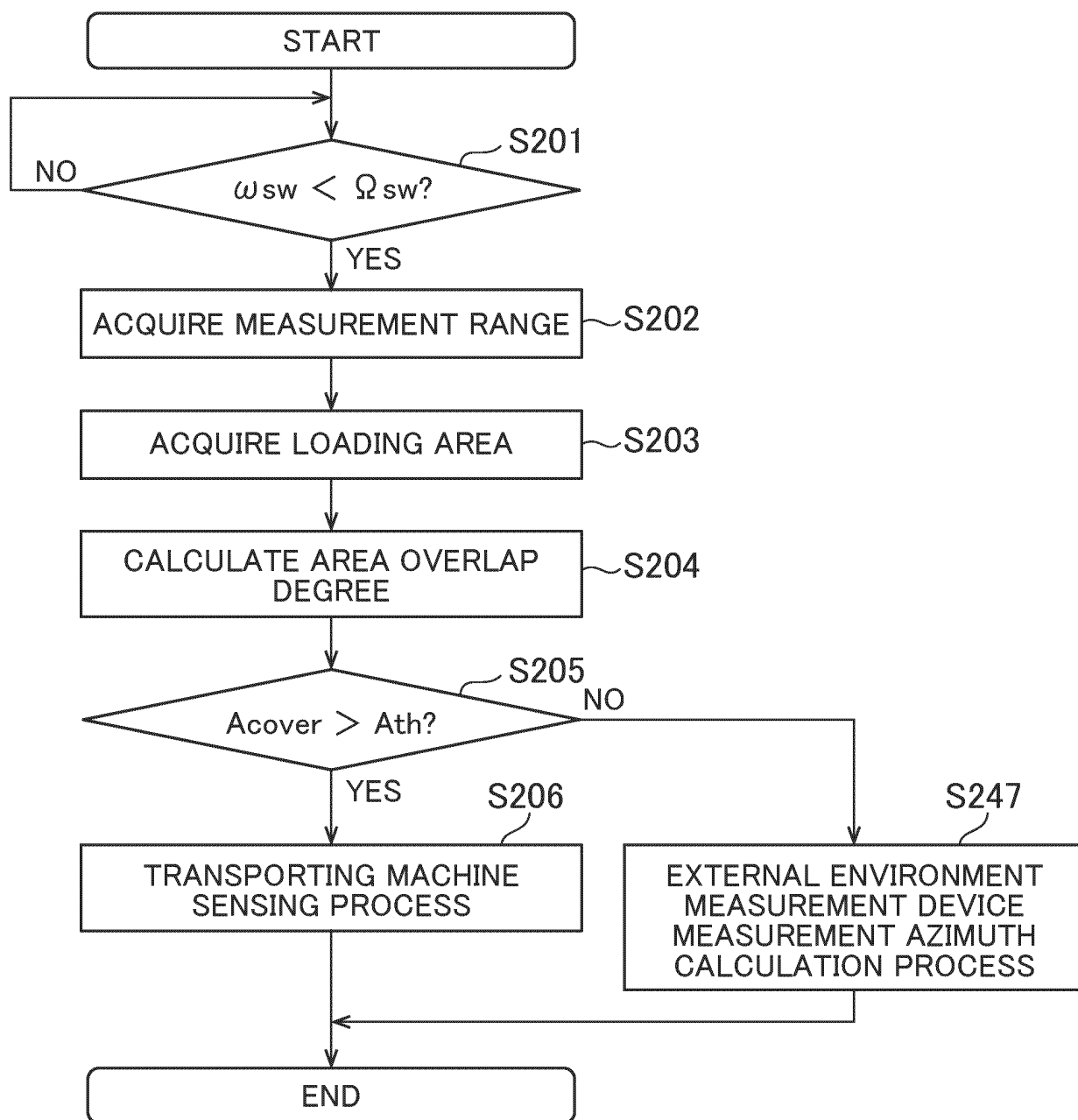


FIG. 19

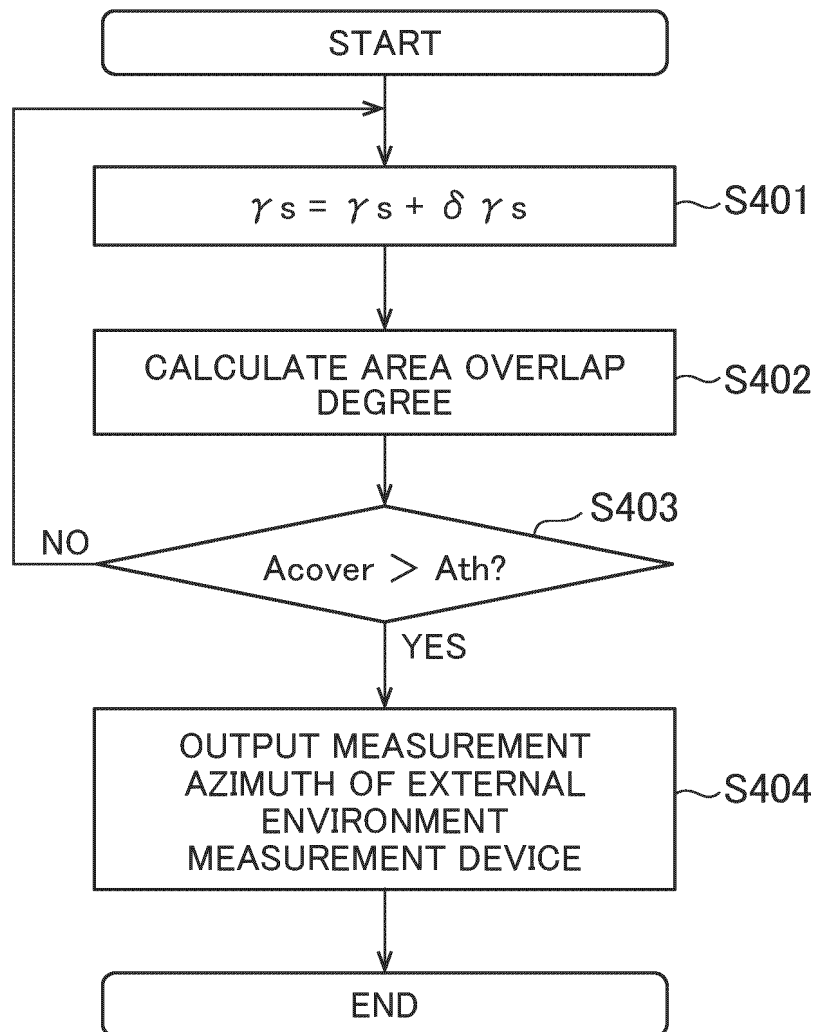


FIG. 20

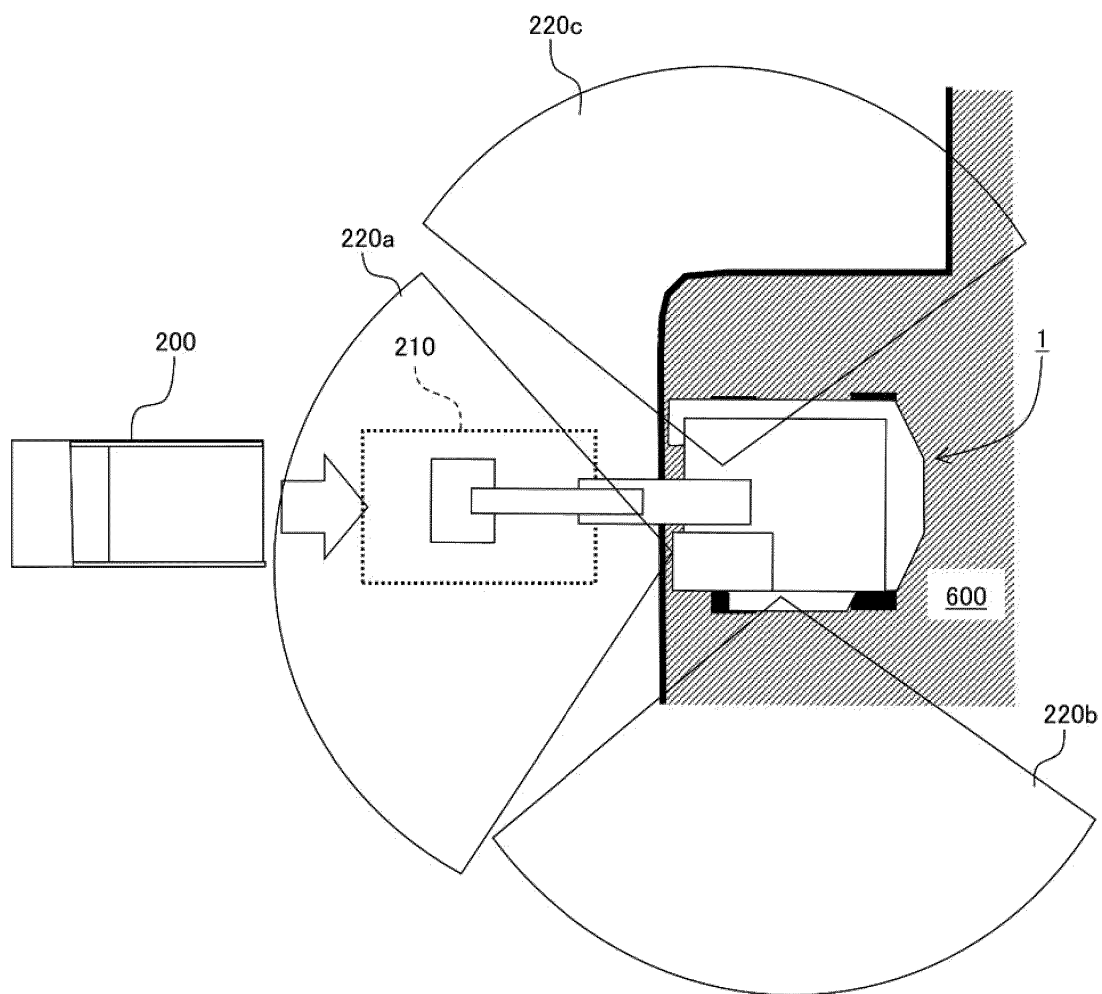


FIG. 21

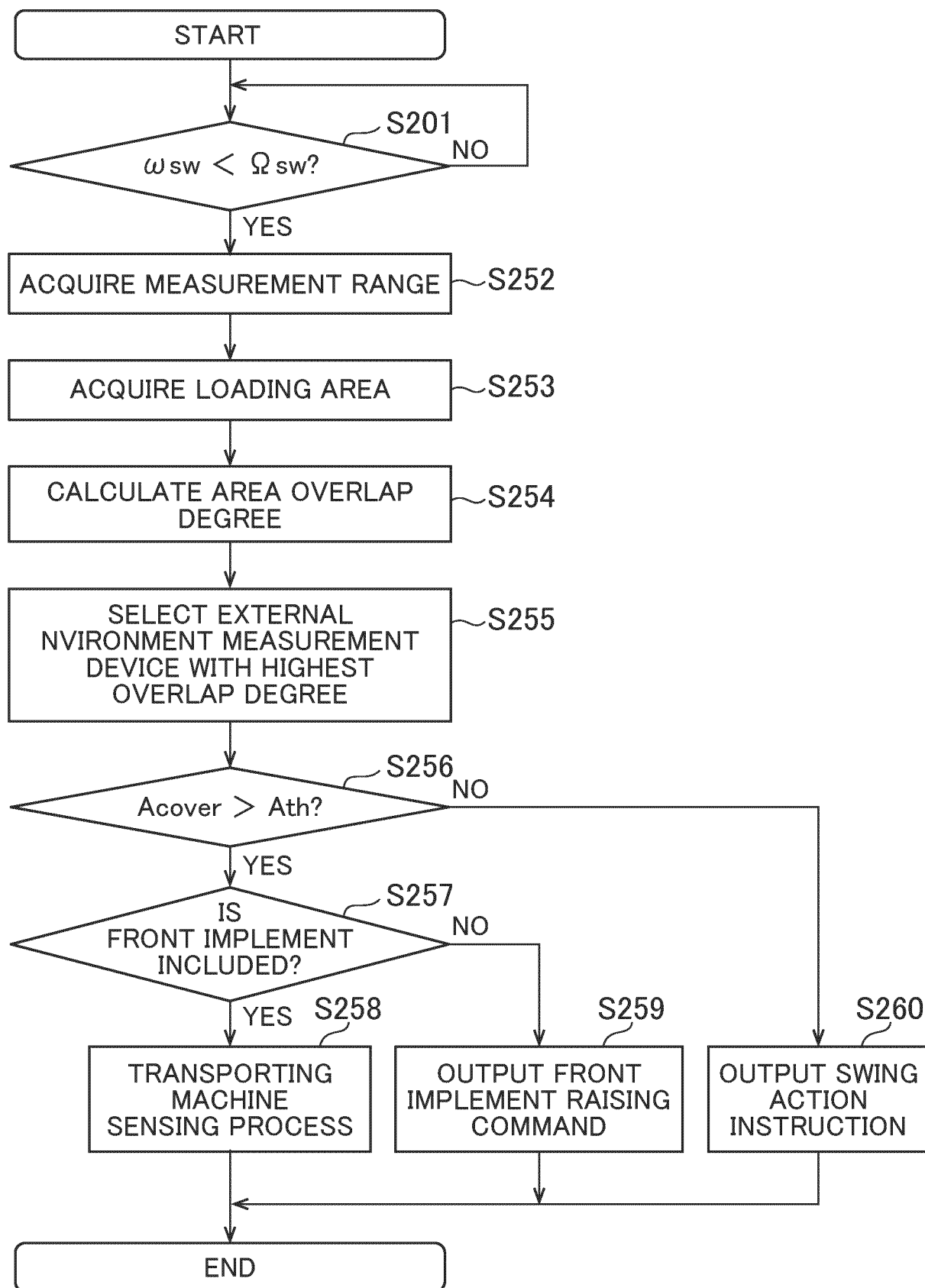
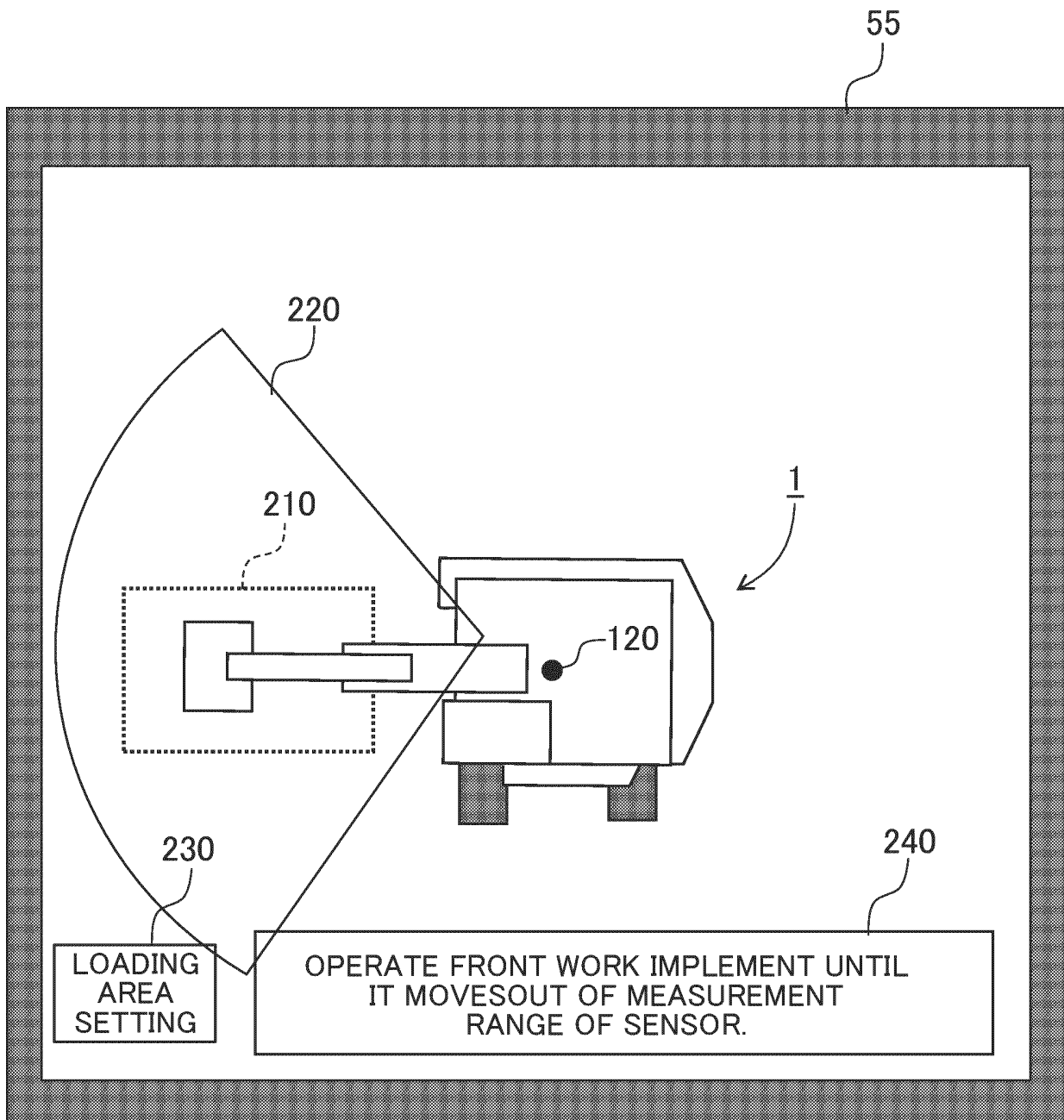


FIG. 22



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/000808

A. CLASSIFICATION OF SUBJECT MATTER

E02F 9/20(2006.01)i; *E02F 9/26*(2006.01)i
 FI: E02F9/20 N; E02F9/26 B; E02F9/20 Q

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02F9/20; E02F9/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2023
 Registered utility model specifications of Japan 1996-2023
 Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2020-060032 A (KOMATSU MFG CO LTD) 16 April 2020 (2020-04-16) entire text, all drawings	1-8
A	CN 111552291 A (JIANGSU XCMG ENGINEERING MACHINERY RESEARCH INSTITUTE CO., LTD.) 18 August 2020 (2020-08-18) entire text, all drawings	1-8
A	JP 2021-156080 A (SUMITOMO HEAVY INDUSTRIES) 07 October 2021 (2021-10-07) entire text, all drawings	1-8
A	WO 2013/058247 A1 (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 25 April 2013 (2013-04-25) entire text, all drawings	1-8
A	JP 2017-199395 A (KOMATSU MFG CO LTD) 02 November 2017 (2017-11-02) entire text, all drawings	1-8
A	JP 2014-006577 A (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 16 January 2014 (2014-01-16) entire text, all drawings	1-8

☒ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

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“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

06 March 2023

Date of mailing of the international search report

20 March 2023

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915
 Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/000808

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017/0073935 A1 (CATERPILLAR INC.) 16 March 2017 (2017-03-16) entire text, all drawings	1-8
A	WO 2015/087430 A1 (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 18 June 2015 (2015-06-18) entire text, all drawings	1-8
A	WO 2015/087382 A1 (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 18 June 2015 (2015-06-18) entire text, all drawings	1-8
A	JP 2020-033825 A (KOMATSU MFG CO LTD) 05 March 2020 (2020-03-05) entire text, all drawings	1-8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/000808

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 9
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

The specification and drawings do not disclose the matters specified in the invention in claim 9 at all, and the matters are matters for which it is not possible to predict the amendment that allows for a meaningful search and examination.
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2023/000808

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2020-060032 A	16 April 2020	US 2021/0165414 A1 WO 2020/075458 A1 DE 112019003683 T5 CN 112384661 A	
CN 111552291 A	18 August 2020	(Family: none)	
JP 2021-156080 A	07 October 2021	(Family: none)	
WO 2013/058247 A1	25 April 2013	US 2014/0261152 A1 DE 112012004057 T5 AU 2012327156 A1	
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WO 2015/087382 A1	18 June 2015	(Family: none)	
JP 2020-033825 A	05 March 2020	US 2021/0246625 A1 WO 2020/044842 A1 DE 112019003165 T5 CN 112424430 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2020033825 A [0005]