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(54) **SHOVEL AND SHOVEL CONTROL DEVICE**

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(57) **ABSTRACT**

A shovel includes a lower traveling body, an upper turning body turnably mounted on the lower traveling body, an attachment attached to the upper turning body, and an attitude detection device (a boom angle sensor, an arm angle sensor, a bucket angle sensor, a machine attitude sensor, and a turning angle sensor), and a controller configured to calculate a target angle related to a working angle formed by a plane or a line determined based on a shape of a bucket included in the attachment and a target surface. The controller changes the target angle in accordance with the attitude of the attachment and information relating to the target surface.

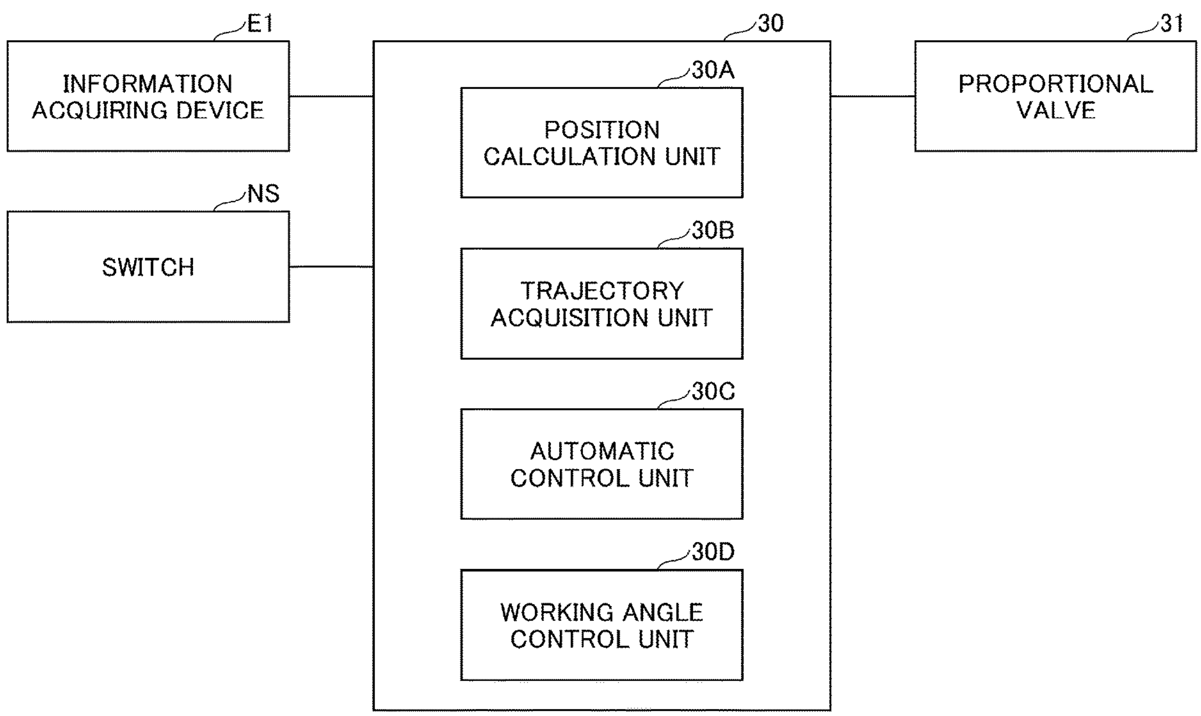
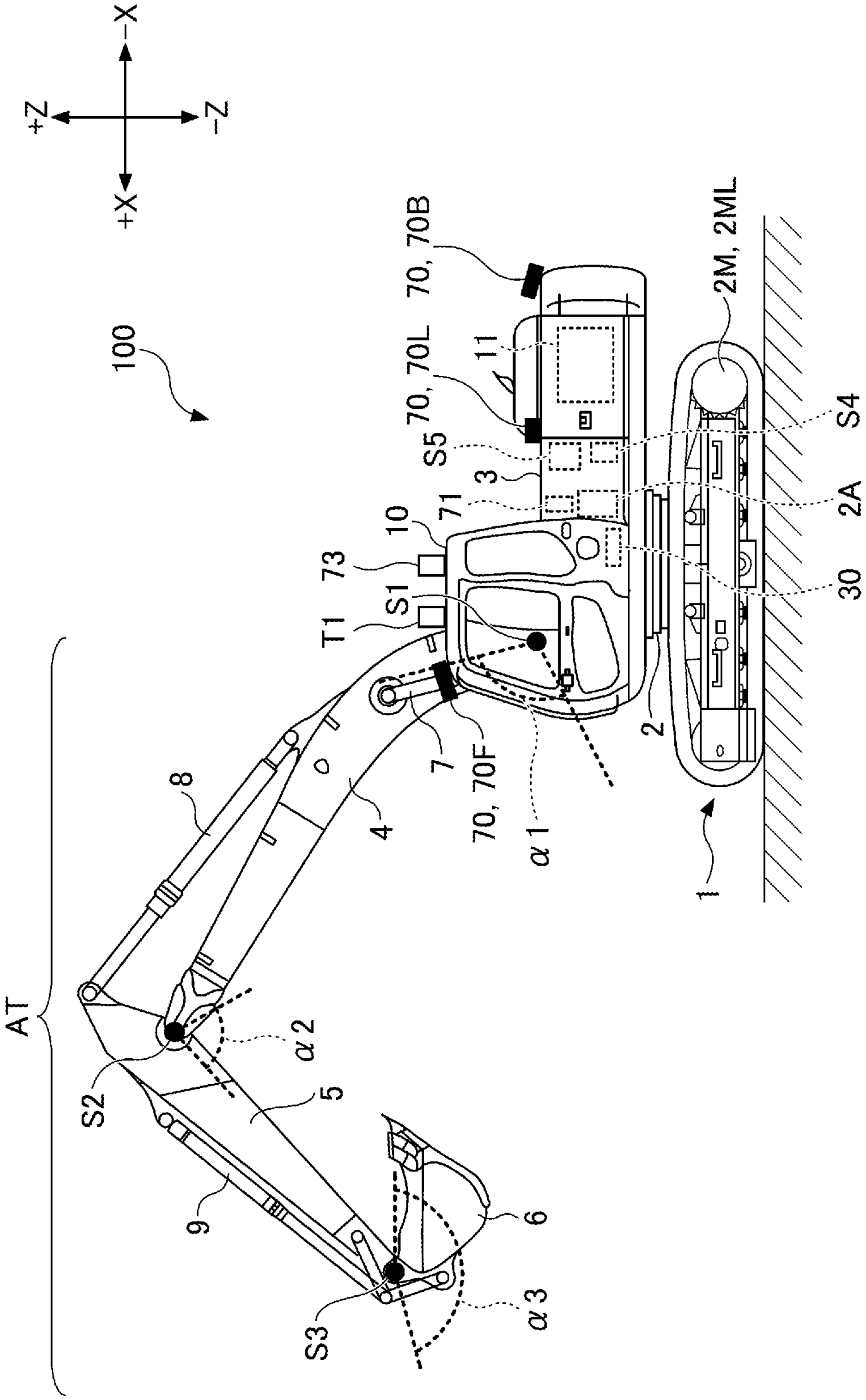
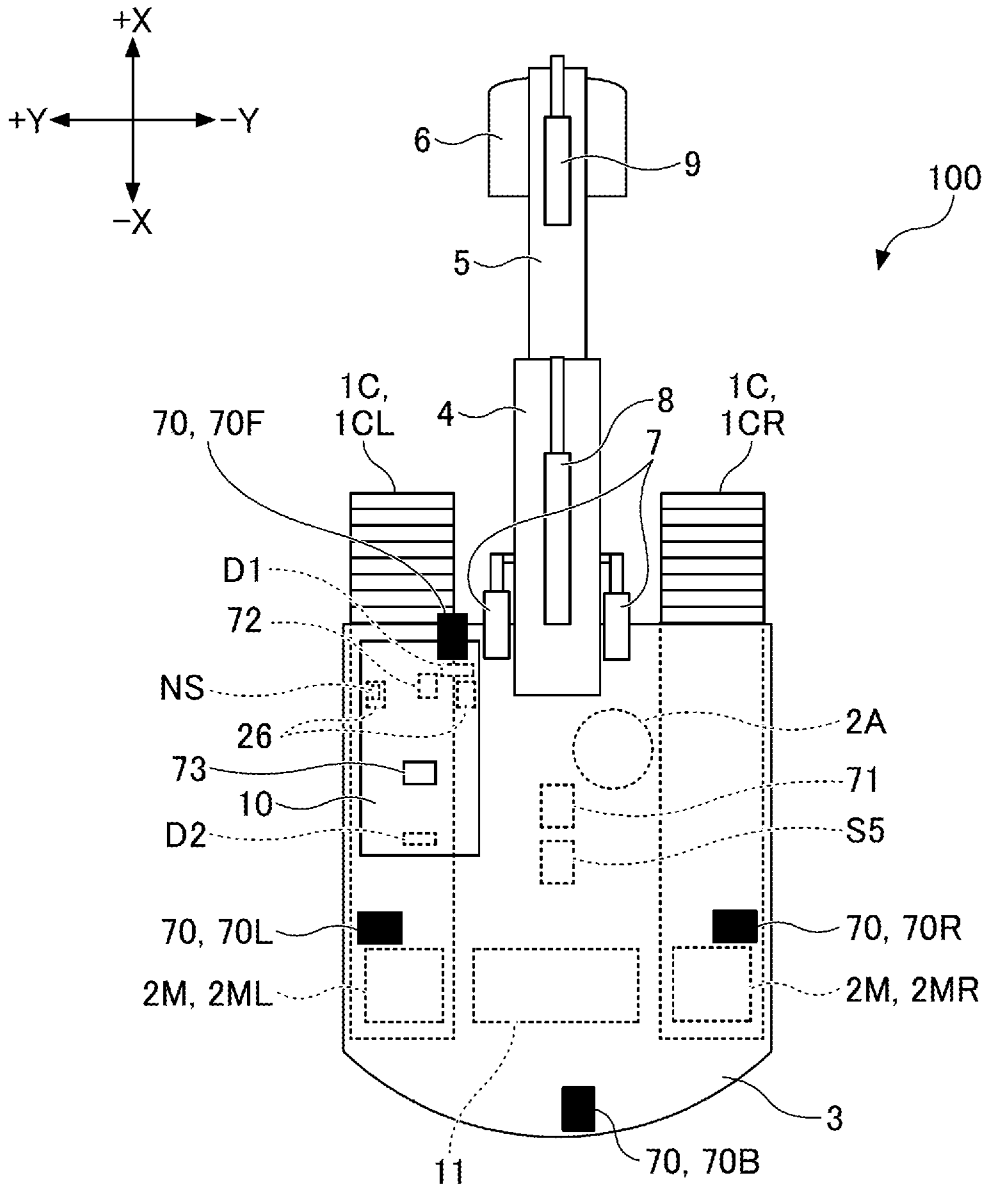


FIG.1



+Z
-Z
+X
-X
100
AT
1
2
2A
2M, 2ML
3
4
5
6
7
8
9
10
11
30
70, 70B
70, 70L
70, 70F
71
73
S1
S2
S3
S4
S5
T1
α1
α2
α3

FIG.2



+X
+Y
-Y
-X
6
9
100
5
4
8
7
1C,
1CL
1C,
1CR
70, 70F
D1
72
NS
26
2A
73
71
10
S5
D2
70, 70L
70, 70R
2M, 2ML
2M, 2MR
3
11
70, 70B

FIG.3

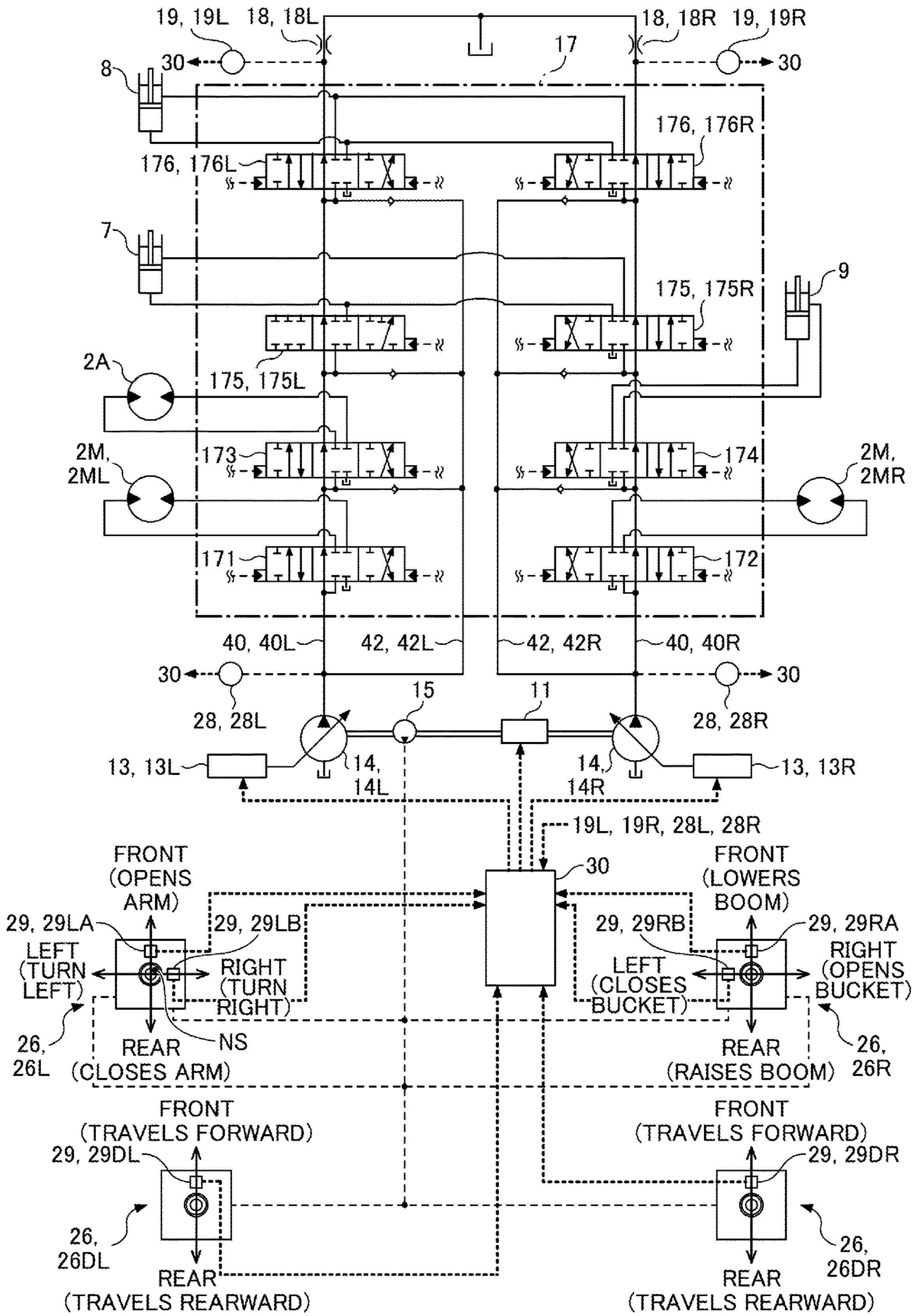
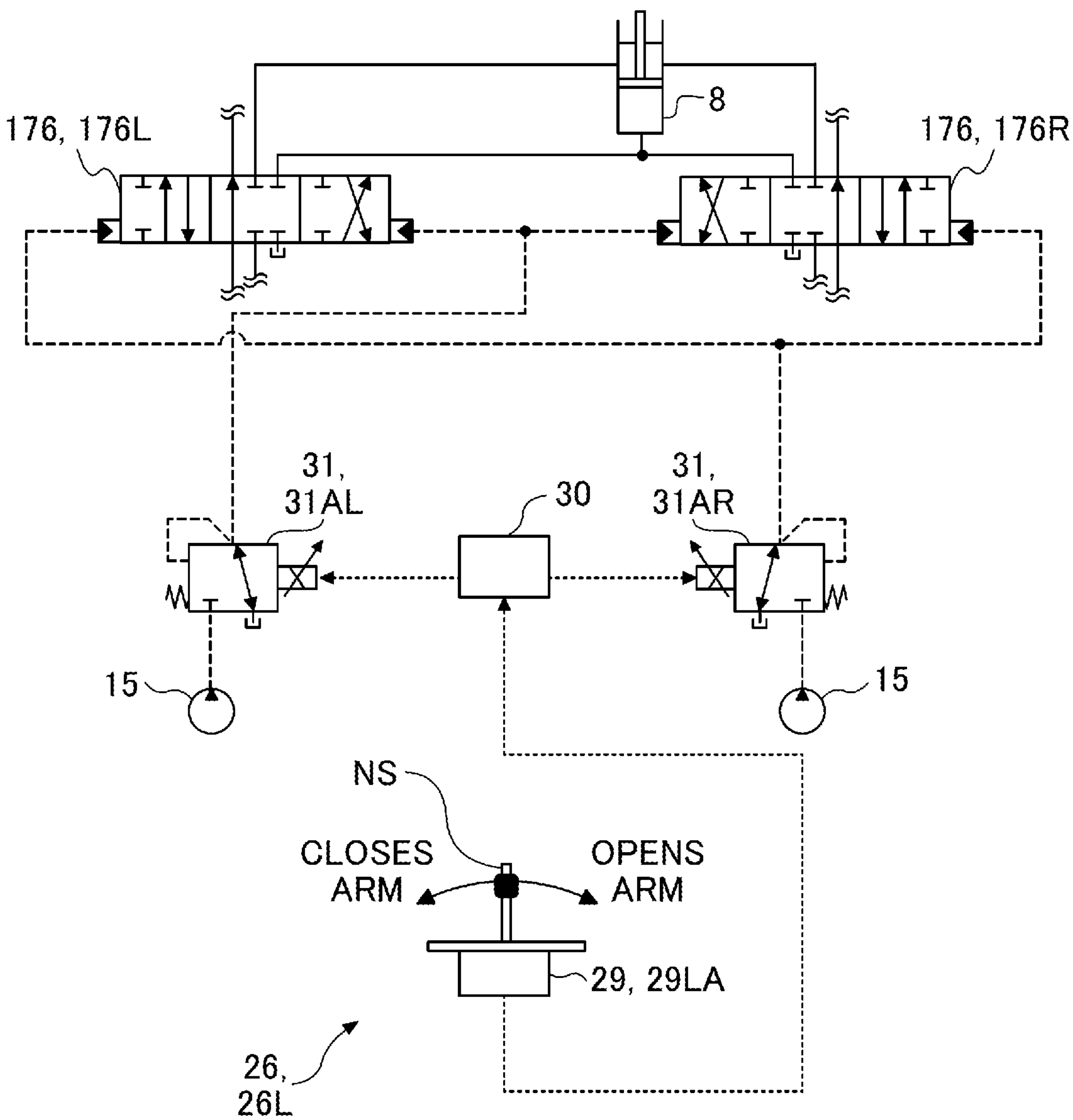
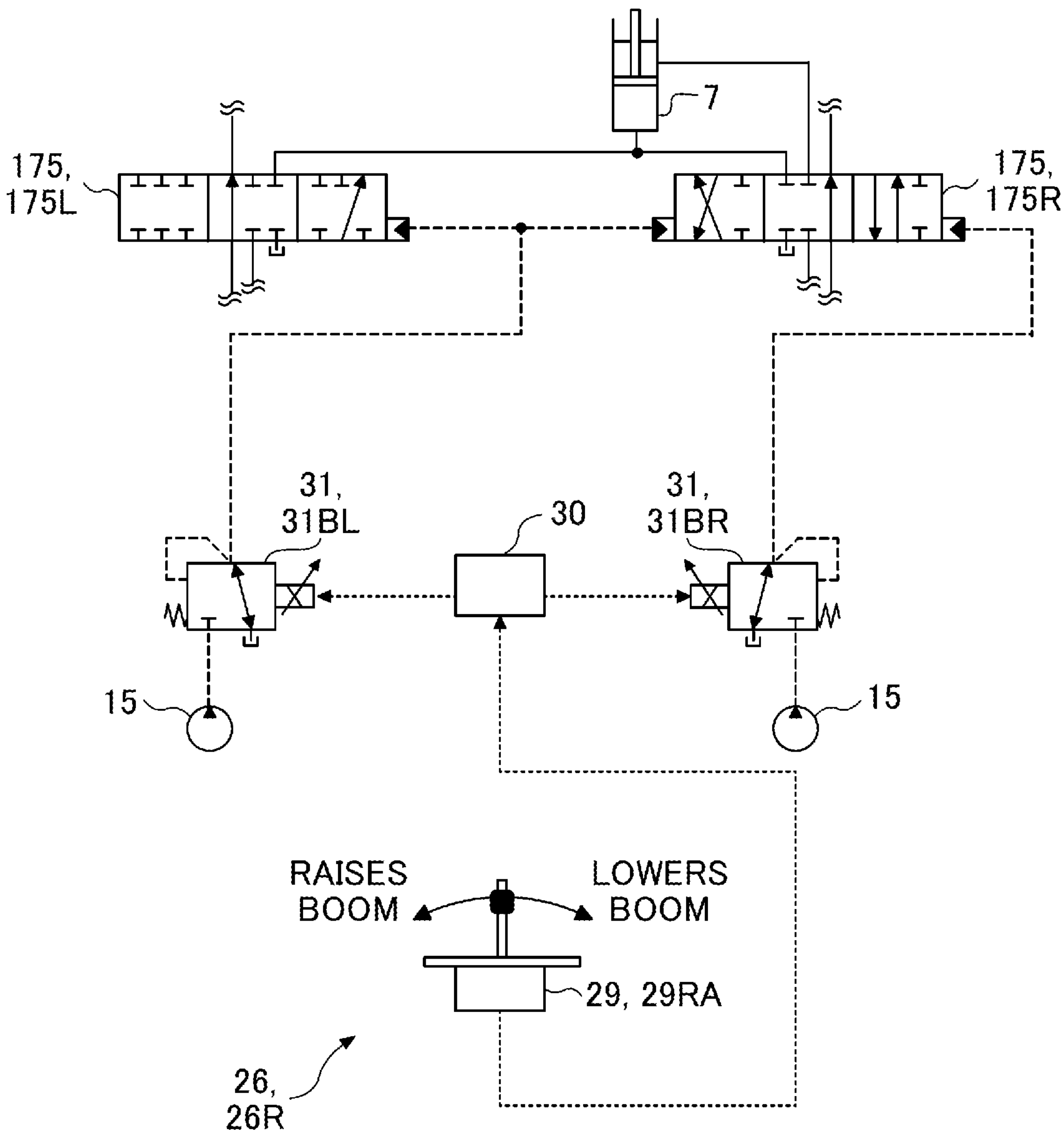

19, 19L
18, 18L
18, 18R
19, 19R
30
17
8
176, 176R
176, 176L
7
9
175, 175R
2A
175, 175L
2M,
2ML
173
174
2M,
2MR
171
172
40, 40L
42, 42L
42, 42R
40, 40R
28, 28L
15
11
28, 28R
13, 13L
14,
14L
14,
14R
13, 13R
19L, 19R, 28L, 28R
FRONT
(OPENS
ARM)
FRONT
(LOWERS
BOOM)
29, 29LA
29, 29LB
29, 29RB
29, 29RA
LEFT
(TURN
LEFT)
RIGHT
(TURN
RIGHT)
LEFT
(CLOSES
BUCKET)
RIGHT
(OPENS
BUCKET)
26,
26L
NS
REAR
(CLOSES ARM)
REAR
(RAISES BOOM)
26,
26R
FRONT
(TRAVELS FORWARD)
29, 29DL
29, 29DR
26,
26DL
26,
26DR
REAR
(TRAVELS REARWARD)

FIG.4A



8
176, 176L
176, 176R
31,
31AL
30
31,
31AR
15
15
NS
CLOSES
ARM
OPENS
ARM
29, 29LA
26,
26L

FIG.4B



7
175,
175L
175,
175R
31,
31BL
30
31,
31BR
15
15
RAISES
BOOM
LOWERS
BOOM
29, 29RA
26,
26R

FIG.4C

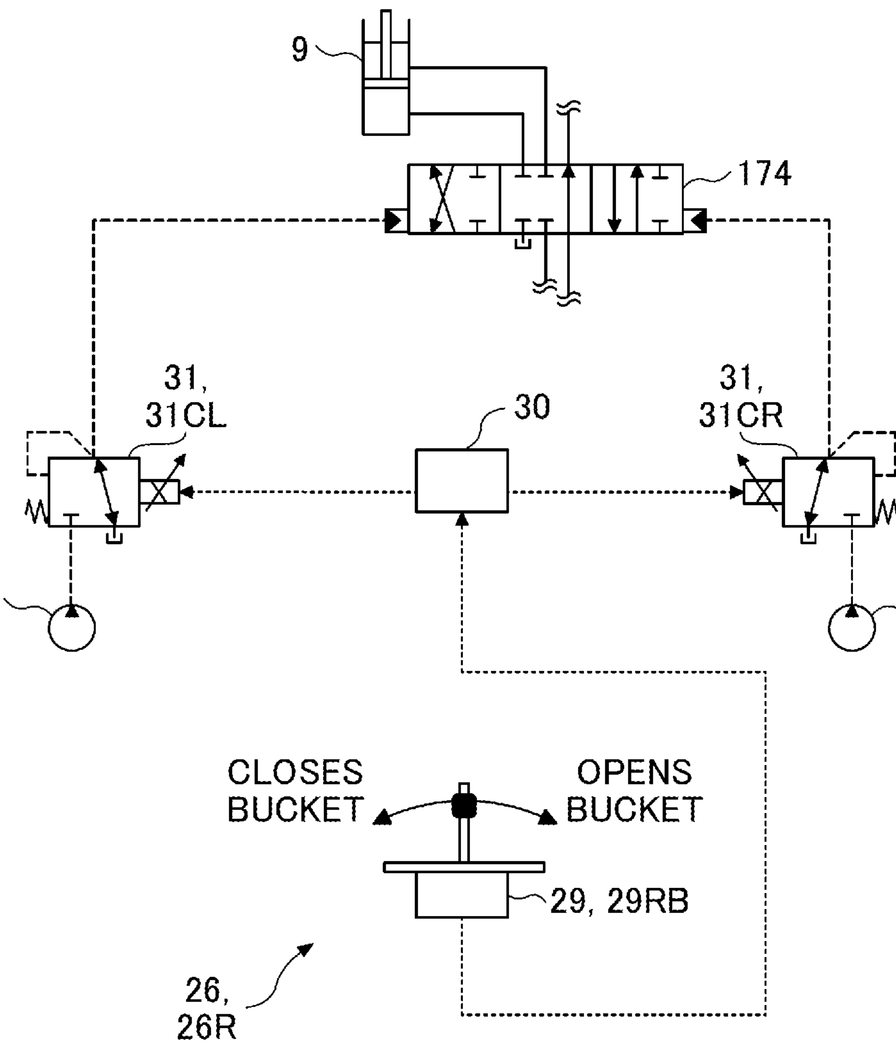

9
174
31,
31CL
30
31,
31CR
15
15
CLOSES
BUCKET
OPENS
BUCKET
29, 29RB
26,
26R

FIG.4D

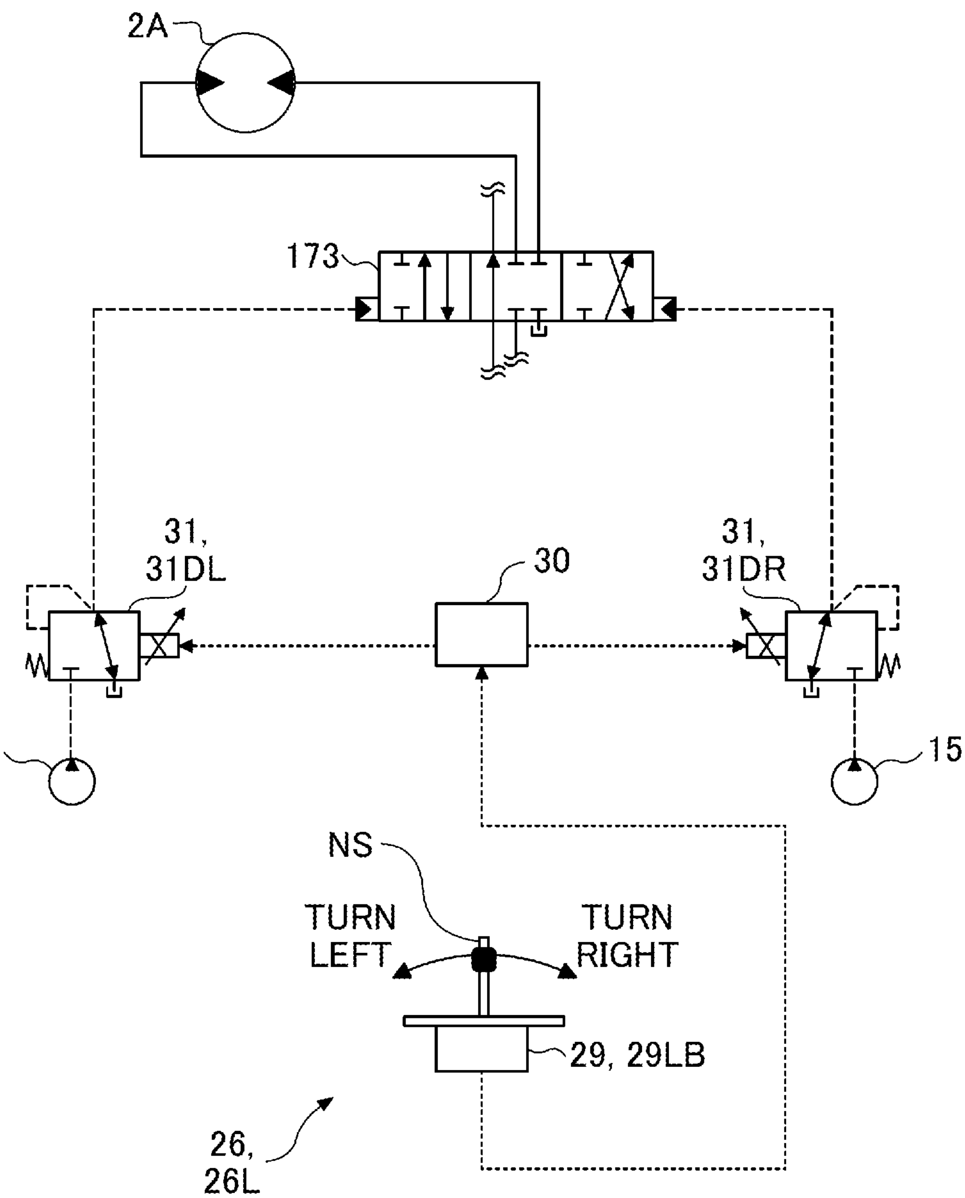

2A
173
31,
31DL
30
31,
31DR
15
15
NS
TURN
LEFT
TURN
RIGHT
29, 29LB
26,
26L

FIG.5

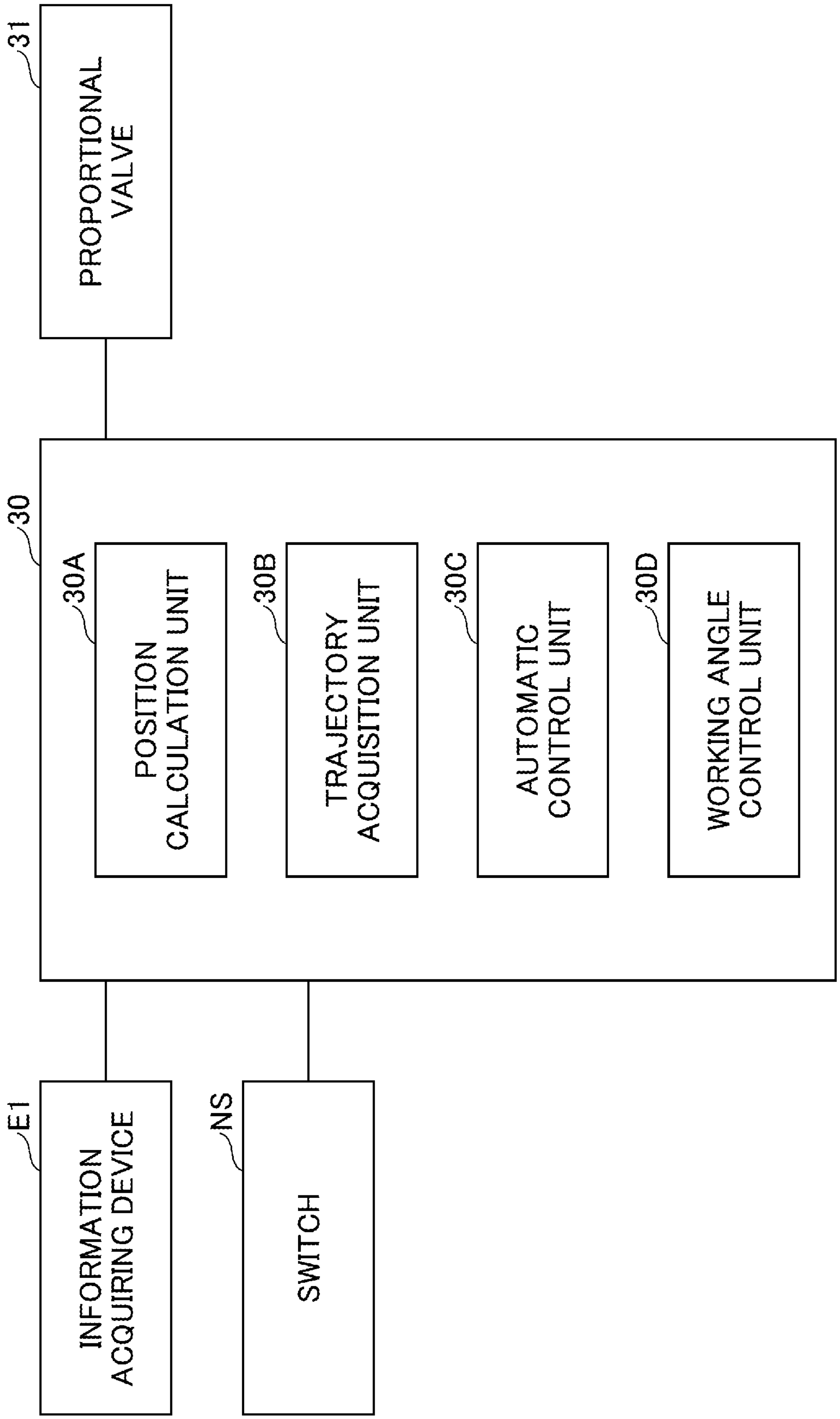

31
PROPORTIONAL VALVE
30
30A
POSITION CALCULATION UNIT
30B
TRAJECTORY ACQUISITION UNIT
30C
AUTOMATIC CONTROL UNIT
30D
WORKING ANGLE CONTROL UNIT
E1
INFORMATION ACQUIRING DEVICE
NS
SWITCH

FIG.6A

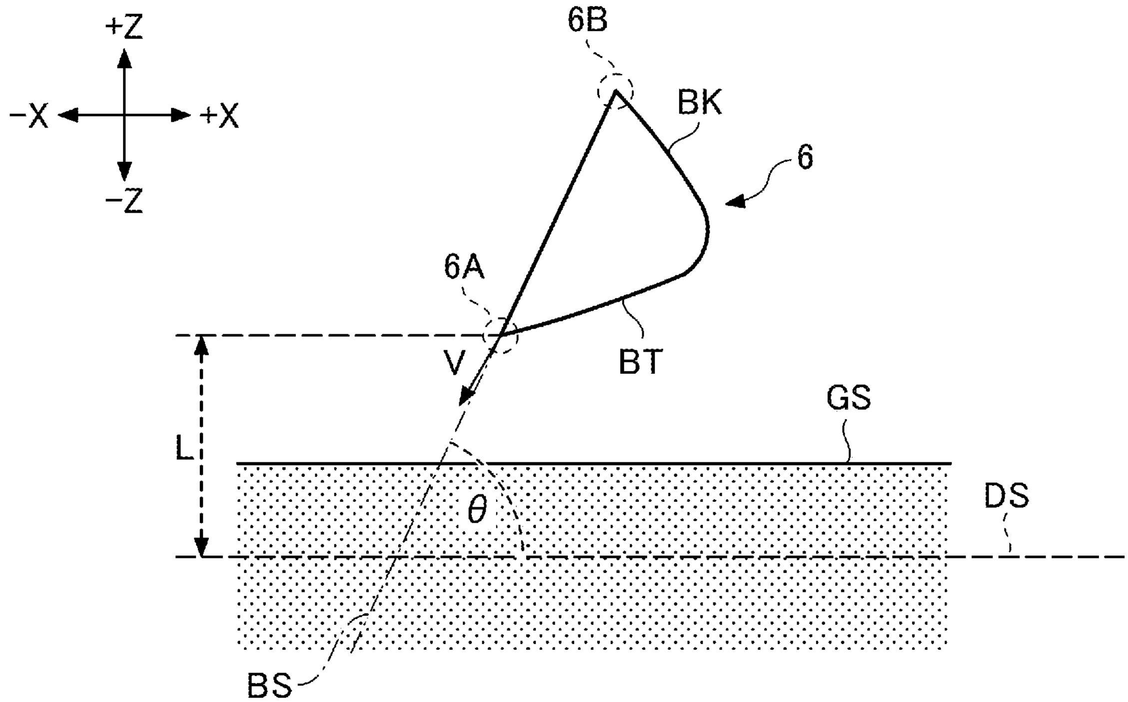


FIG.6B

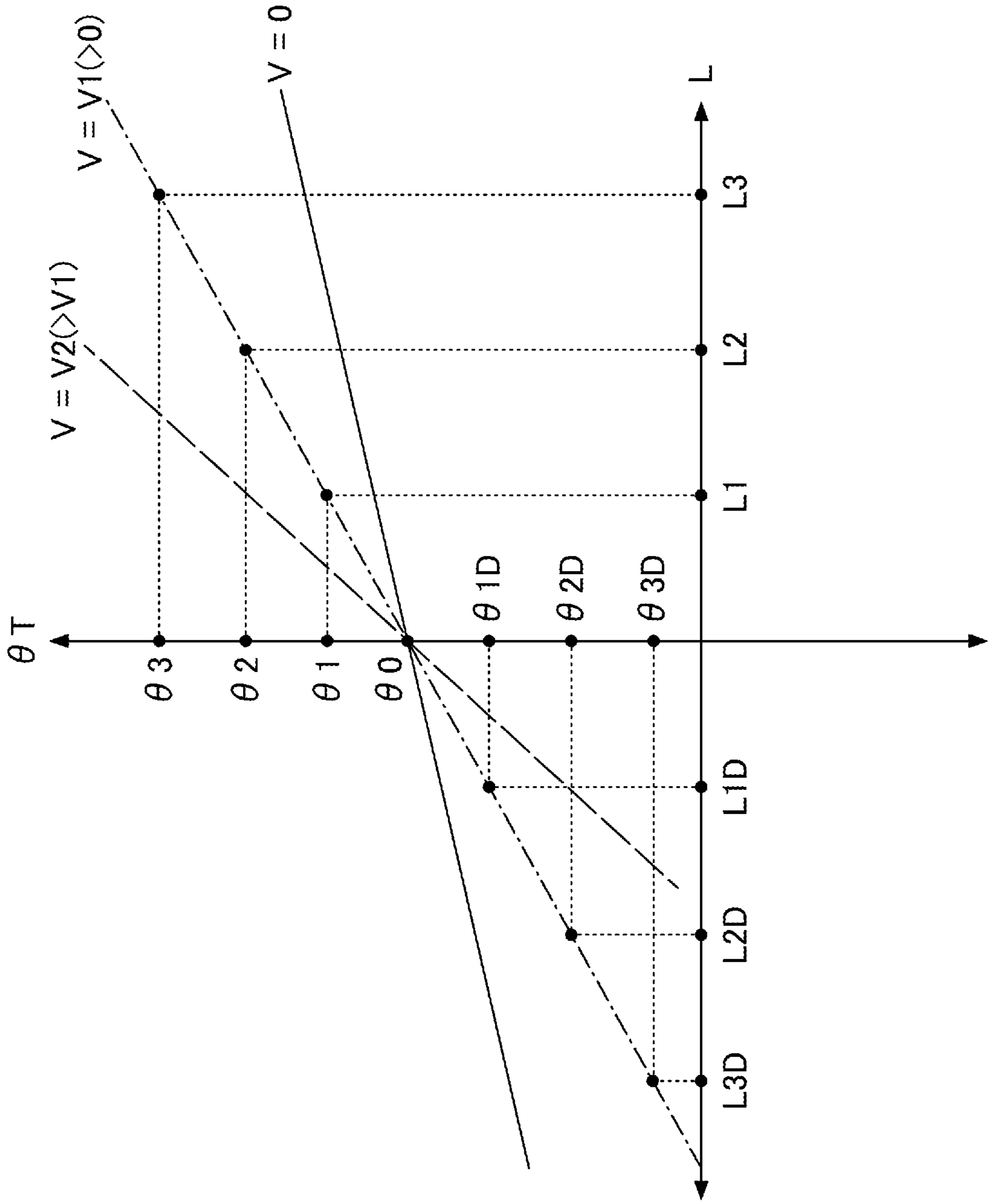


FIG.7A

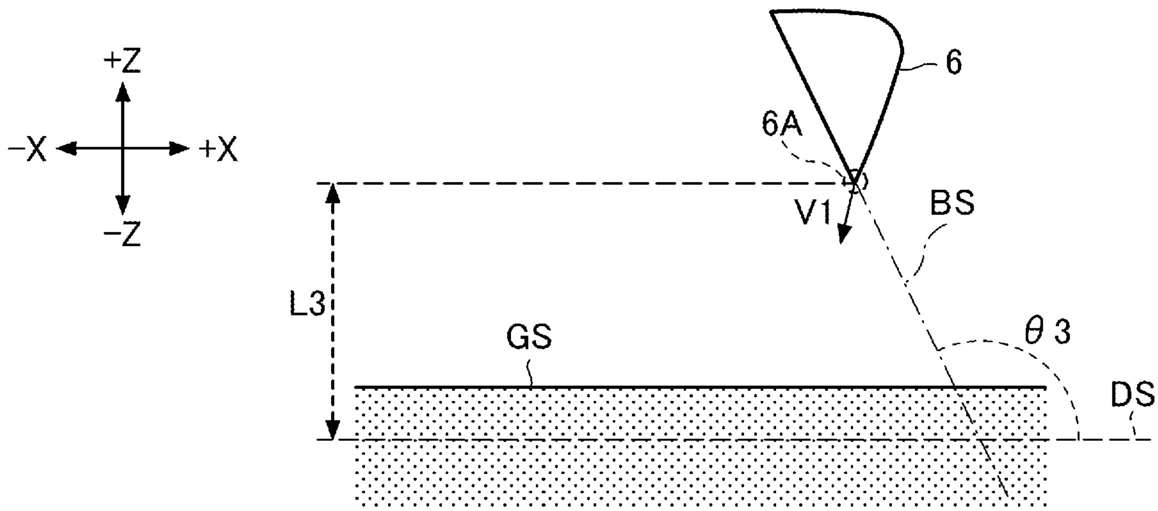


FIG.7B

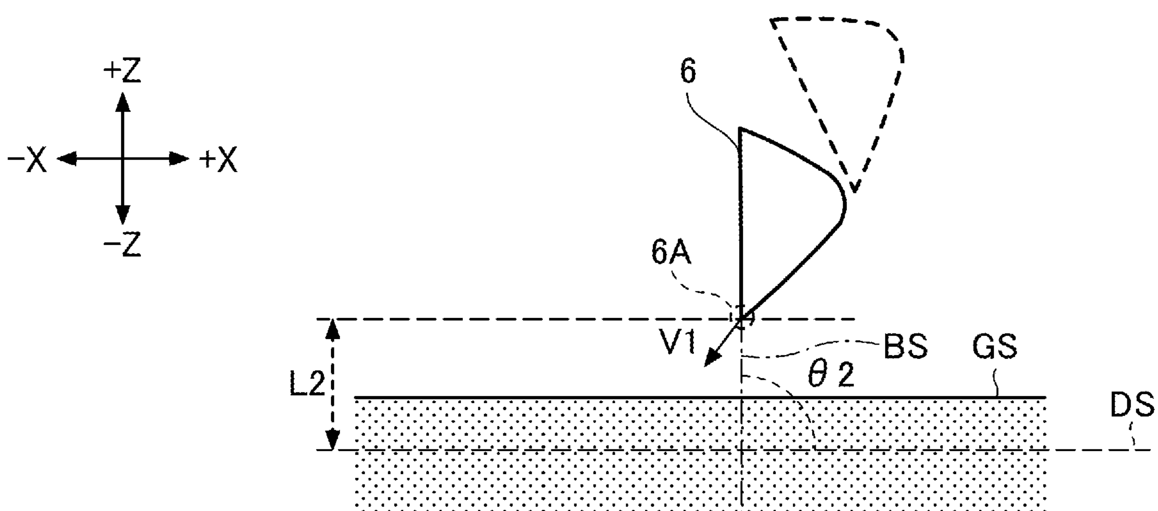


FIG.7C

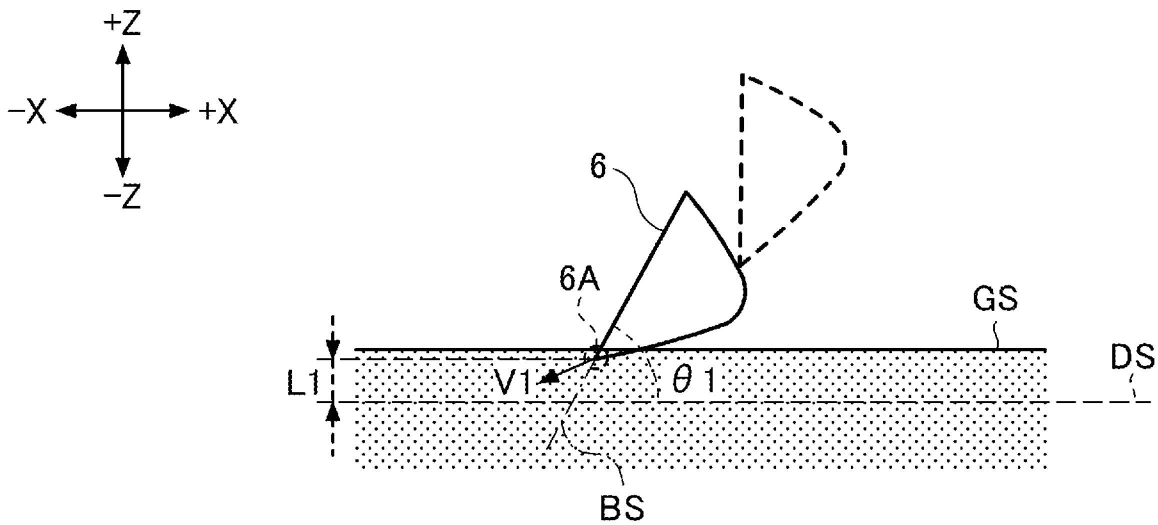


FIG.7D

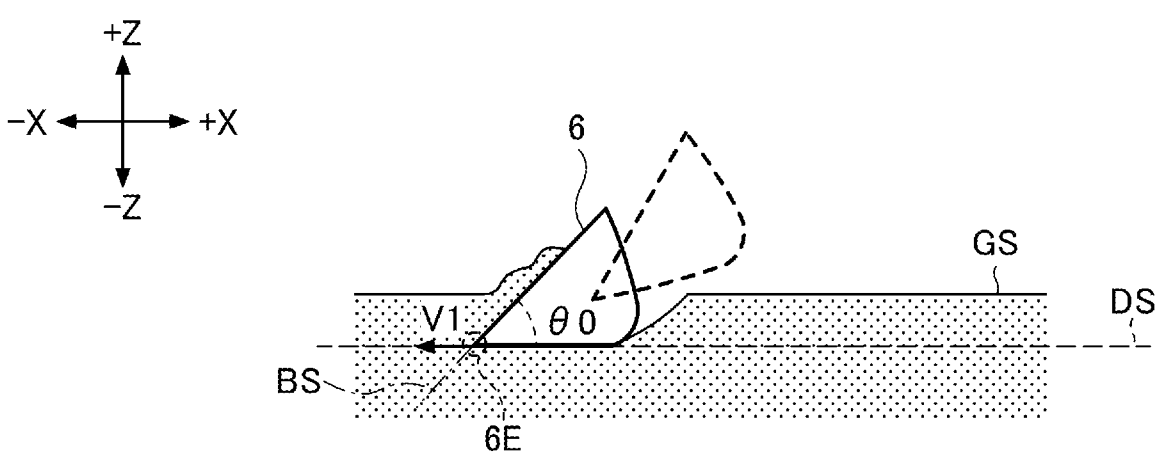


FIG.8A

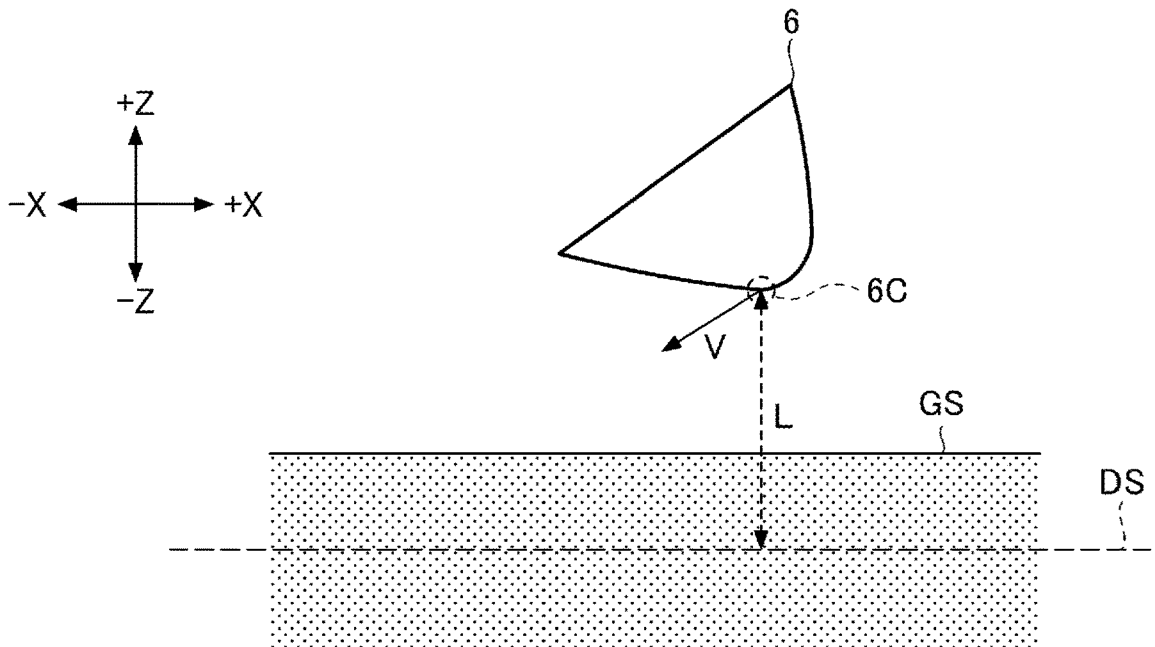


FIG.8B

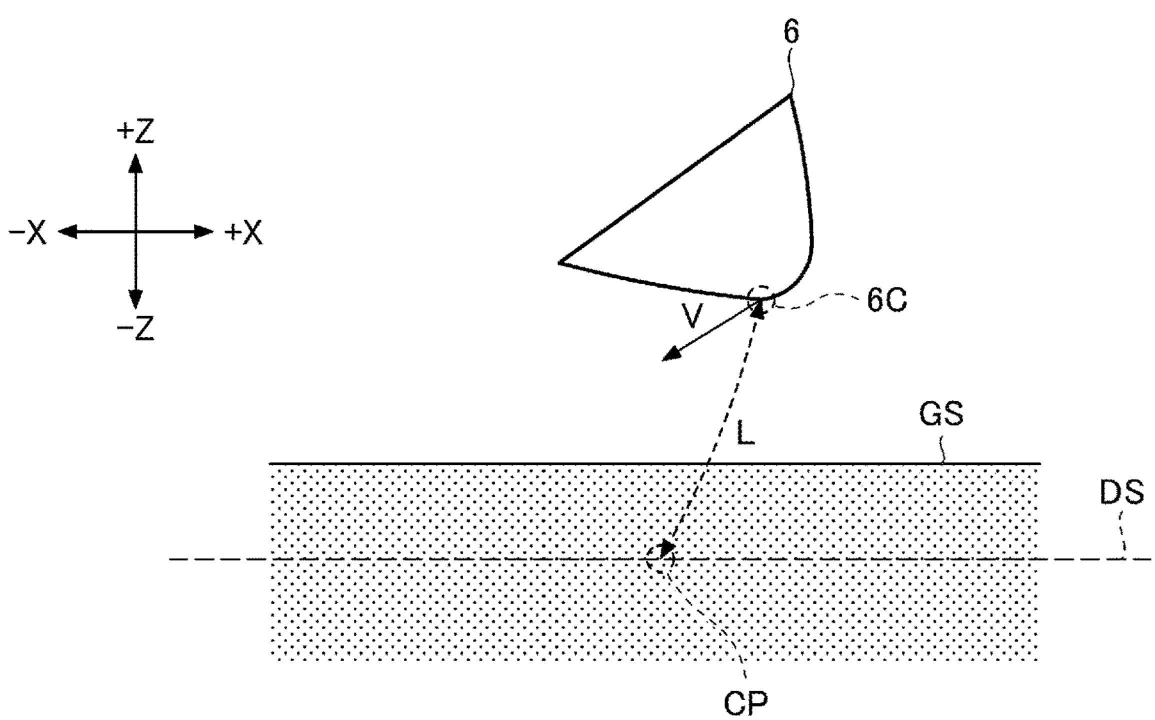


FIG.9A

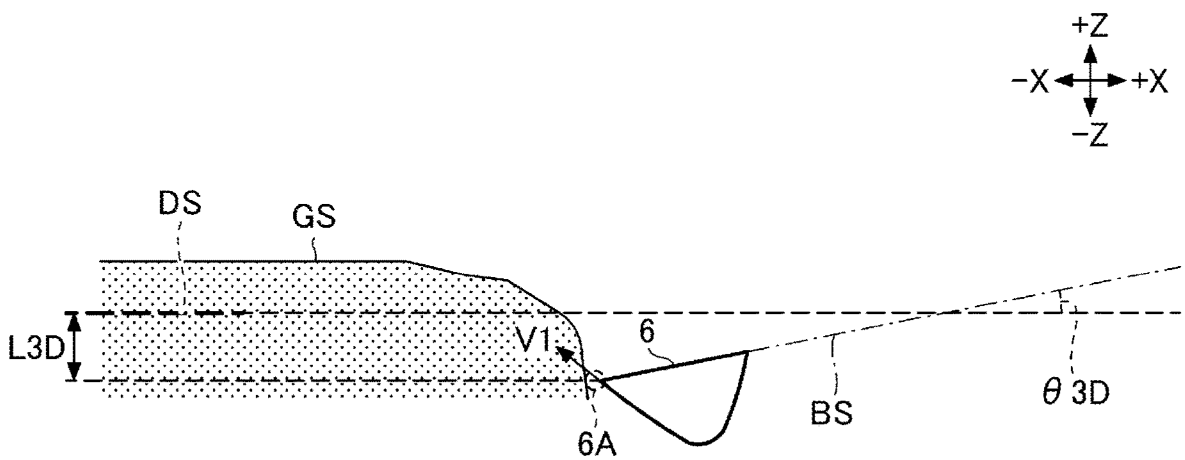


FIG.9B

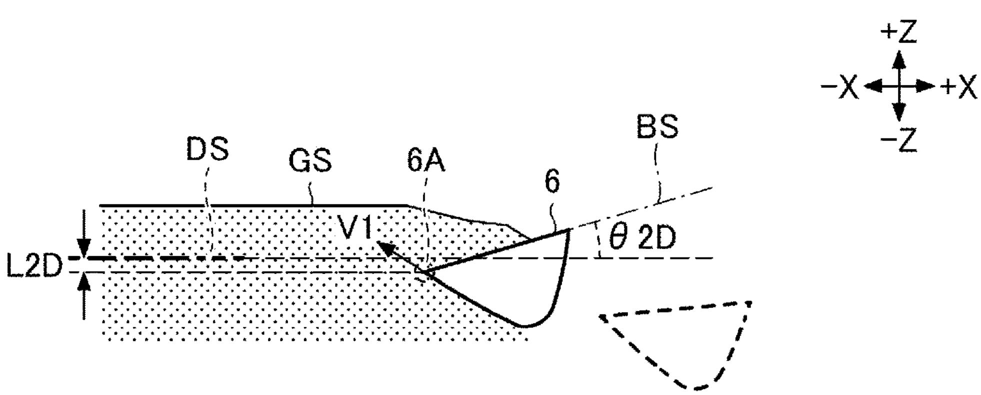


FIG.9C

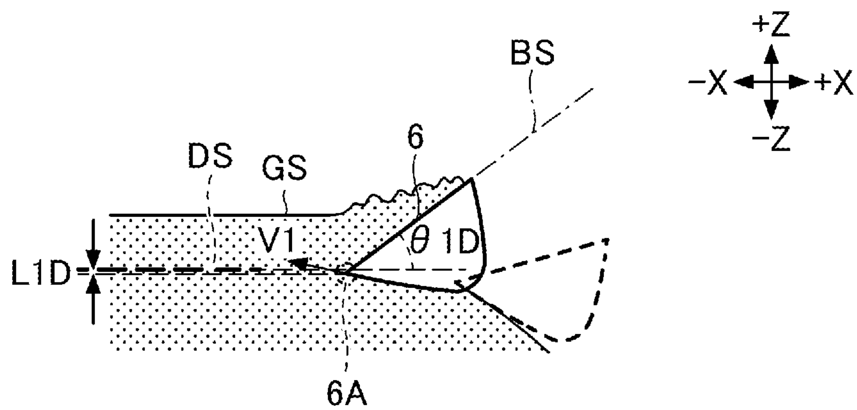


FIG.9D

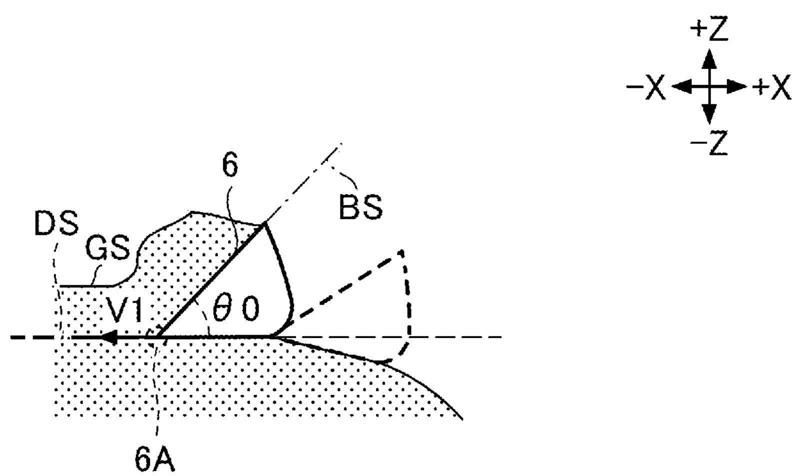


FIG.10

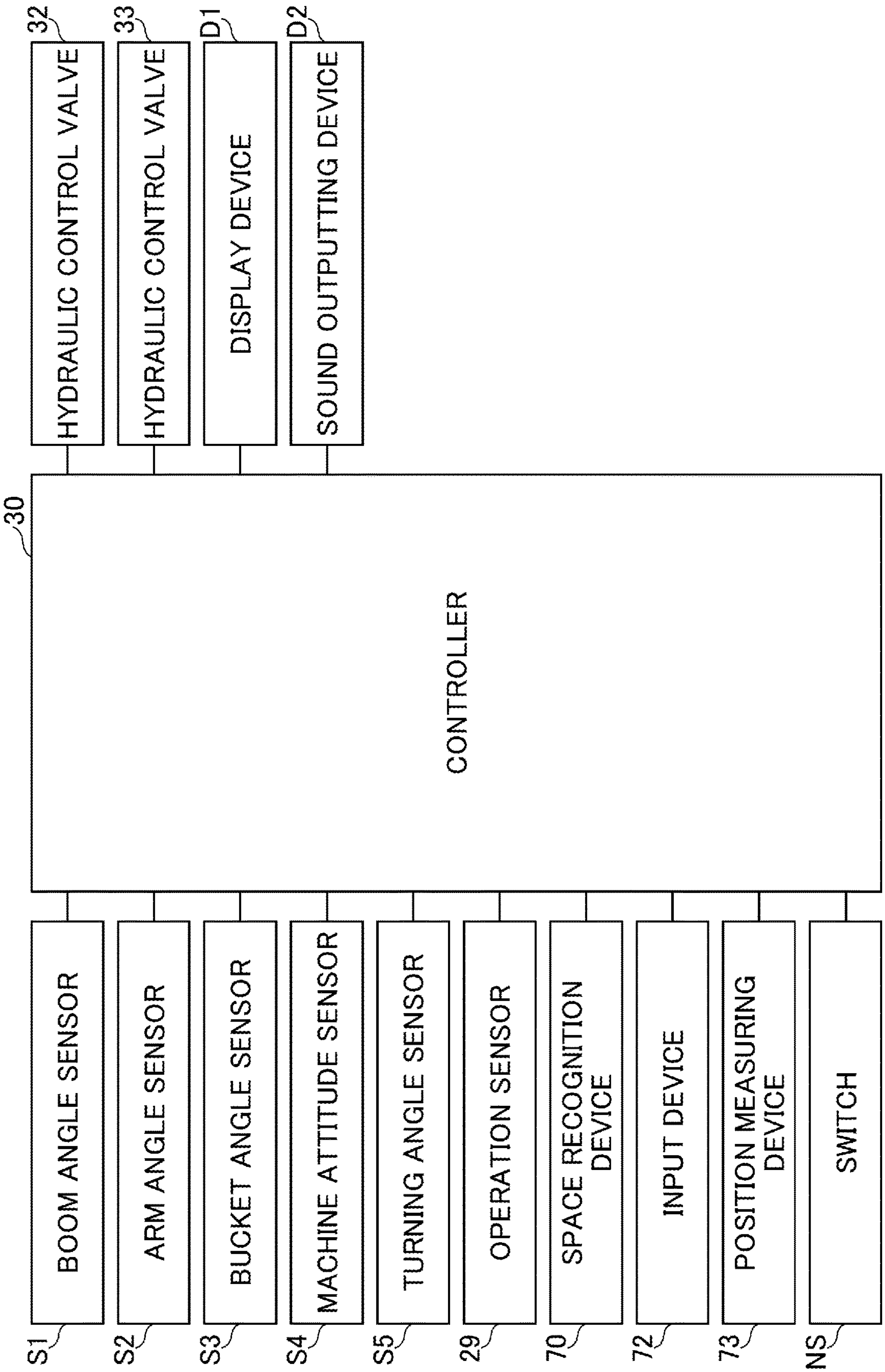

32
HYDRAULIC CONTROL VALVE
33
HYDRAULIC CONTROL VALVE
D1
DISPLAY DEVICE
D2
SOUND OUTPUTTING DEVICE
30
CONTROLLER
S1
BOOM ANGLE SENSOR
S2
ARM ANGLE SENSOR
S3
BUCKET ANGLE SENSOR
S4
MACHINE ATTITUDE SENSOR
S5
TURNING ANGLE SENSOR
29
OPERATION SENSOR
70
SPACE RECOGNITION DEVICE
72
INPUT DEVICE
73
POSITION MEASURING DEVICE
NS
SWITCH

FIG.11

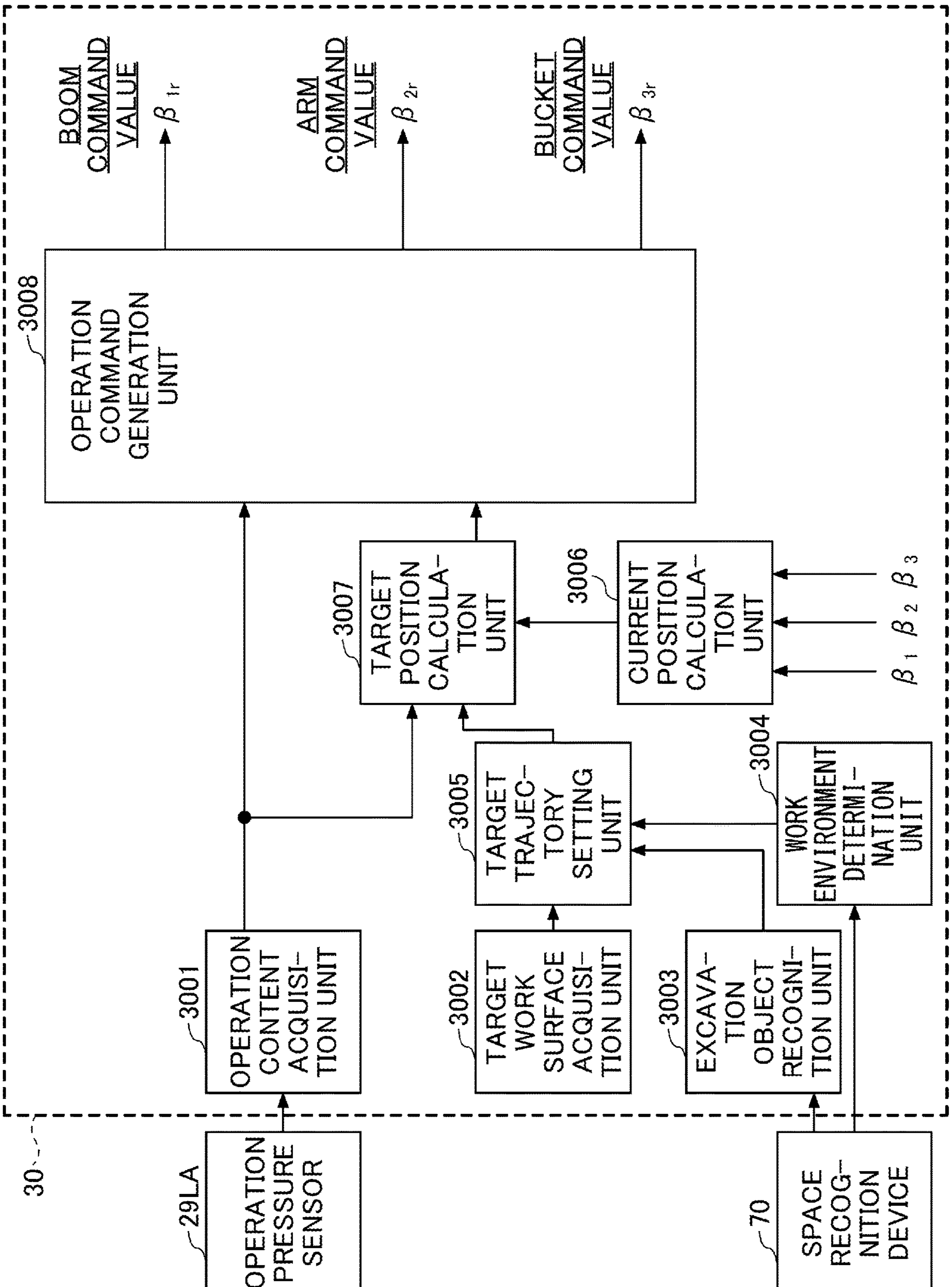

30
29LA
OPERATION PRESSURE SENSOR
70
SPACE RECOGNITION DEVICE
3001
OPERATION CONTENT ACQUISITION UNIT
3002
TARGET WORK SURFACE ACQUISITION UNIT
3003
EXCAVATION OBJECT RECOGNITION UNIT
3004
WORK ENVIRONMENT DETERMINATION UNIT
3005
TARGET TRAJECTORY SETTING UNIT
3006
CURRENT POSITION CALCULATION UNIT
β1 β2 β3
3007
TARGET POSITION CALCULATION UNIT
3008
OPERATION COMMAND GENERATION UNIT
BOOM COMMAND VALUE
β1r
ARM COMMAND VALUE
β2r
BUCKET COMMAND VALUE
β3r

FIG.12

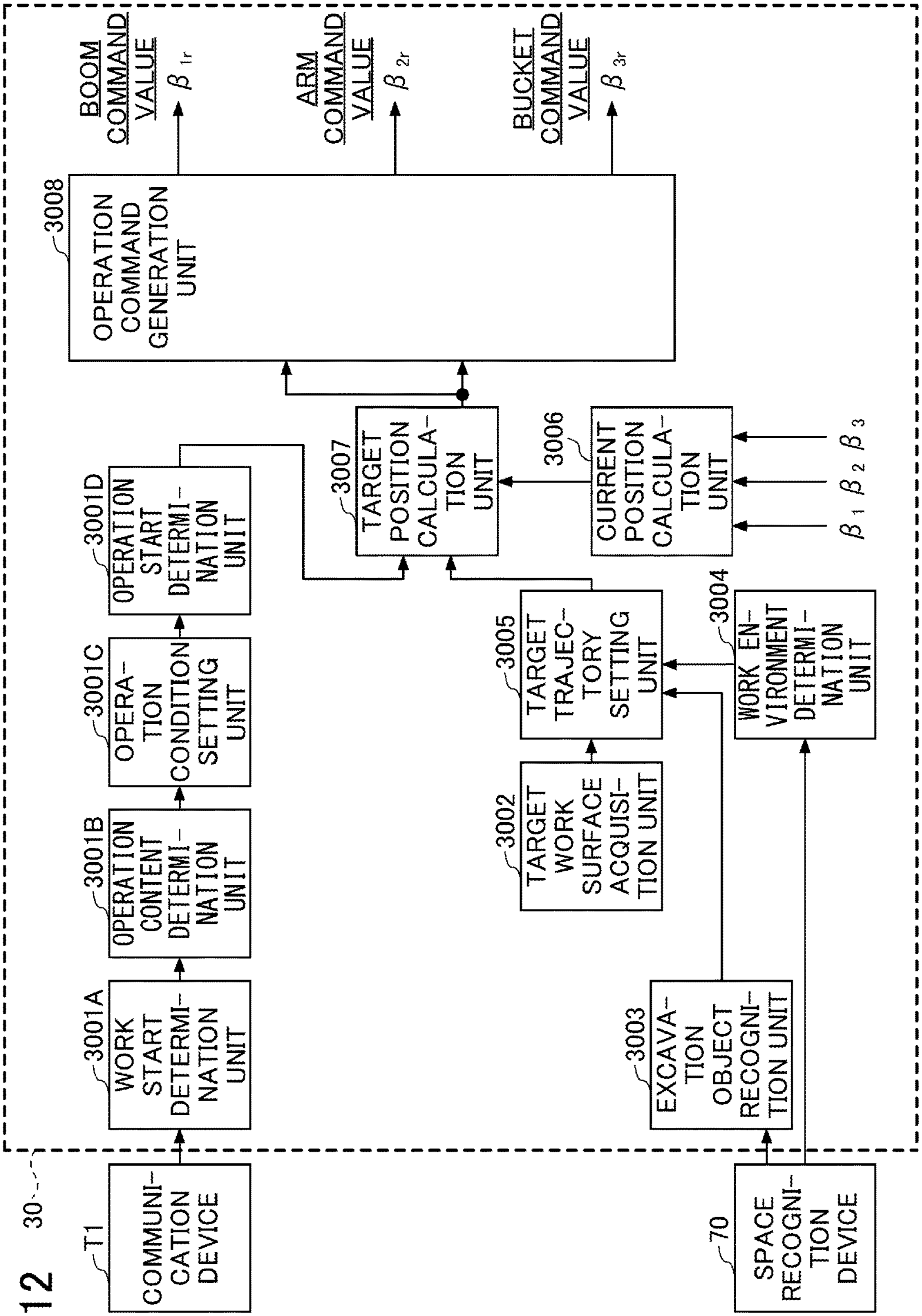

30
T1
COMMUNICATION DEVICE
70
SPACE RECOGNITION DEVICE
3001A
WORK START DETERMINATION UNIT
3001B
OPERATION CONTENT DETERMINATION UNIT
3001C
OPERATION CONDITION SETTING UNIT
3001D
OPERATION START DETERMINATION UNIT
3002
TARGET WORK SURFACE ACQUISITION UNIT
3003
EXCAVATION OBJECT RECOGNITION UNIT
3004
WORK ENVIRONMENT DETERMINATION UNIT
3005
TARGET TRAJECTORY SETTING UNIT
3006
CURRENT POSITION CALCULATION UNIT
3007
TARGET POSITION CALCULATION UNIT
3008
OPERATION COMMAND GENERATION UNIT
β_1 β_2 β_3
BOOM COMMAND VALUE
β_{1r}
ARM COMMAND VALUE
β_{2r}
BUCKET COMMAND VALUE
β_{3r}

FIG.13

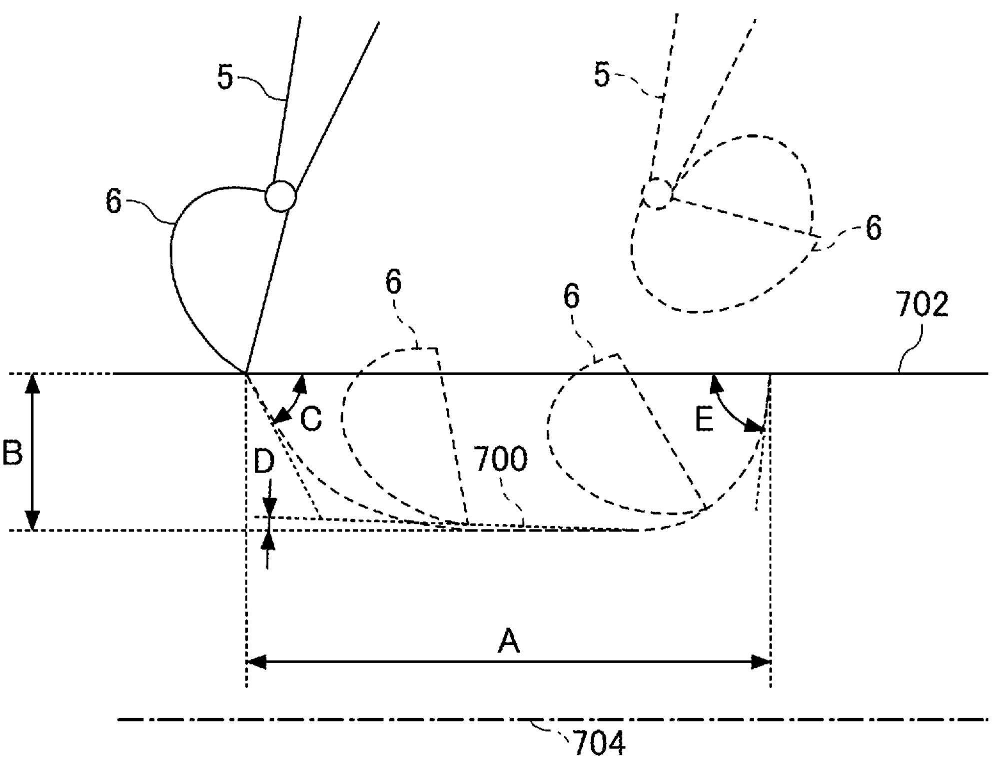


FIG.14

800

			WORK SITE			
			No. 1	No. 2	No. 3	‥
PARAMETER	A	EXCAVATION LENGTH	PA1	PA2	PA3	‥
	B	EXCAVATION DEPTH	PB1	PB2	PB3	‥
	C	PENETRATION ANGLE	PC1	PC2	PC3	‥
	D	HORIZONTAL PULLING ANGLE	PD1	PD2	PD3	‥
	E	SCOOPING ANGLE	PE1	PE2	PE3	‥

SHOVEL AND SHOVEL CONTROL DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation application filed under 35 U.S.C. 111(a) claiming benefit under 35 U.S.C. 120 and 365(c) of PCT International Application No. PCT/JP2022/015207, filed on Mar. 28, 2022 and designating the U.S., which claims priority to Japanese Patent Application No. 2021-057821, filed on Mar. 30, 2021 and Japanese Patent Application No. 2021-057895, filed on Mar. 30, 2021. The entire contents of the foregoing applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present disclosure relates to a shovel as an excavator and a control device for the shovel.

2. Description of the Related Art

DESCRIPTION OF THE RELATED ART

[0003] Conventionally, hydraulic shovels that maintain an angle of a bucket with respect to a target surface (design surface) at a constant angle during excavation work are known.

SUMMARY OF THE INVENTION

[0004] However, if the angle of the bucket with respect to the target surface is maintained at a constant angle, at a stage where a large amount of earth and sand remains on the design surface, it becomes difficult for the claw tip of the bucket to stick into the ground, and there is a possibility that smooth excavation work is hindered.

[0005] Therefore, it is desirable to provide a shovel capable of realizing smoother work.

[0006] A shovel according to an embodiment of the present includes a lower traveling body, an upper turning body turnably mounted on the lower traveling body, an attachment attached to the upper turning body, an attitude detection device configured to detect an attitude of the attachment, and a control device configured to calculate a target angle related to a work angle formed by a plane or a line determined based on a shape of a bucket included in the attachment and a target surface.

[0007] By the above-described configurations, a shovel capable of realizing smoother work is provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a side view of a shovel according to an embodiment of the present disclosure;

[0009] FIG. **2** is a top view of the shovel of FIG. **1**;

[0010] FIG. **3** is a diagram illustrating a configuration example of a hydraulic system mounted on the shovel of FIG. **1**;

[0011] FIG. **4**A is a view of a portion of a hydraulic system for an operation of an arm cylinder;

[0012] FIG. **4**B is a view of a portion of a hydraulic system for a boom cylinder;

[0013] FIG. **4**C is a view of a portion of a hydraulic system for a bucket cylinder;

[0014] FIG. **4**D is a view of a portion of a hydraulic system for a traveling hydraulic motor.

[0015] FIG. **5** is a diagram illustrating a configuration example of a controller;

[0016] FIG. **6**A is a side view of a bucket;

[0017] FIG. **6**B is a graph illustrating a relationship between a target angle of a work angle, an operation speed, and a separation distance;

[0018] FIG. **7**A is a side view of the bucket in a position higher than the design surface;

[0019] FIG. **7**B is a side view of the bucket in a position higher than the design surface;

[0020] FIG. **7**C is a side view of the bucket in a position higher than the design surface;

[0021] FIG. **7**D is a side view of the bucket in a position higher than the design surface;

[0022] FIG. **8**A is a side view of the bucket in a position higher than the design surface;

[0023] FIG. **8**B is a side view of the bucket in a position higher than the design surface;

[0024] FIG. **9**A is a side view of the bucket in a position lower than the design surface;

[0025] FIG. **9**B is a side view of the bucket in a position lower than the design surface;

[0026] FIG. **9**C is a side view of the bucket in a position lower than the design surface;

[0027] FIG. **9**D is a side view of the bucket in a position lower than the design surface;

[0028] FIG. **10** is a diagram illustrating an example of a configuration of a control system of the shovel;

[0029] FIG. **11** is a functional block diagram illustrating an example of a functional configuration for a machine control function of the shovel;

[0030] FIG. **12** is a functional block diagram illustrating another example of the functional configuration for the machine control function of the shovel;

[0031] FIG. **13** is a diagram illustrating an example of a parameter for a trajectory of a claw tip of the bucket during excavation; and

[0032] FIG. **14** is a diagram illustrating an example of table information for parameters for each work site.

DETAILED DESCRIPTION OF THE INVENTION

[0033] First, a shovel **100** as an excavator according to an embodiment of the present disclosure will be described with reference to FIGS. **1** and **2**. FIG. **1** is a side view of the shovel **100**, and FIG. **2** is a top view of the shovel **100**.

[0034] In the present embodiment, the lower traveling body **1** of the shovel **100** includes crawlers **1**C. The crawlers **1**C are driven by traveling hydraulic motors **2**M as traveling actuators mounted on the lower traveling body **1**. In particular, the crawlers **1**C include a left crawler **1**CL and a right crawler **1**CR. The left crawler **1**CL is driven by a left traveling hydraulic motor **2**ML, and the right crawler **1**CR is driven by a right traveling hydraulic motor **2**MR.

[0035] An upper turning body **3** is turnably mounted on the lower traveling body **1** via a turning mechanism **2**. The turning mechanism **2** is driven by a turning hydraulic motor **2**A as a turning actuator mounted on the upper turning body **3**. However, the turning actuator may be a turning motor generator as an electric actuator.

[0036] A boom **4** is attached to the upper turning body **3**. An arm **5** is attached to a distal end of the boom **4**, and a bucket 6 as an end attachment is attached to a distal end of the arm 5. The boom 4, the arm 5, and the bucket 6 constitute an excavation attachment which is an example of the attachment AT. The boom 4 is driven by a boom cylinder 7, the arm 5 is driven by an arm cylinder 8, and the bucket 6 is driven by a bucket cylinder 9. The boom cylinder 7, the arm cylinder 8, and the bucket cylinder 9 constitute an attachment actuator. The bucket 6 may be, for example, a slope bucket. Further, the bucket 6 may include a bucket tilt mechanism.

[0037] The boom 4 is supported so as to be vertically rotatable with respect to the upper turning body 3. A boom angle sensor S1 is attached to the boom 4. The boom angle sensor S1 can detect a boom angle α1 which is a rotation angle of the boom 4. The boom angle α1 is, for example, a rising angle from a state in which the boom 4 is most lowered. Therefore, the boom angle α1 becomes maximum when the boom 4 is lifted to the maximum.

[0038] The arm 5 is turnably supported with respect to the boom 4. An arm angle sensor S2 is attached to the arm 5. The arm angle sensor S2 can detect an arm angle α2 which is a rotation angle of the arm 5. The arm angle α2 is, for example, an opening angle from a state where the arm 5 is most closed. Therefore, the arm angle α2 becomes maximum when the arm 5 is opened most.

[0039] The bucket 6 is turnably supported with respect to the arm 5. A bucket angle sensor S3 is attached to the bucket 6. The bucket angle sensor S3 can detect a bucket angle α3 which is a rotation angle of the bucket 6. The bucket angle α3 is an opening angle of the bucket 6 from the most closed state. Therefore, the bucket angle α3 becomes maximum when the bucket 6 is most opened.

[0040] In the embodiment of FIG. 1, each of the boom angle sensor S1, the arm angle sensor S2, and the bucket angle sensor S3 is configured by a combination of an accelerometer sensor and a gyro sensor. However, each of these angle sensors may be configured by only the acceleration sensor. The boom angle sensor S1 may be a stroke sensor attached to the boom cylinder 7, or may be a rotary encoder, a potentiometer, an inertial measurement device, or the like. The same applies to the arm angle sensor S2 and the bucket angle sensor S3.

[0041] The upper turning body 3 is provided with a cabin 10 as a driver's cabin, and is mounted with a power source such as an engine 11. In addition, a space recognition device 70, a direction detection device 71, a position measuring device 73, a machine attitude sensor S4, a turning angle sensor S5, and the like are attached to the upper turning body 3. An operation device 26, a controller 30, an input device 72, a display device D1, a sound outputting device D2, and the like are provided in the cabin 10. In this specification, for the sake of convenience, a side of the upper turning body 3 to which the attachment AT is attached is referred to as a front side, and a side of the upper turning body 3 to which the counterweight is attached is referred to as a rear side.

[0042] The space recognition device 70 is configured to recognize an object present in a three-dimensional space around the shovel 100. Further, the space recognition device 70 may be configured to calculate a distance from the space recognition device 70 or the shovel 100 to the recognized object. The space recognition device 70 includes, for example, an ultrasonic sensor, a millimeter wave radar, an imaging device, a LIDAR, a distance image sensor, an infrared sensor, or the like, or any combination thereof. The imaging device is a monocular camera, a stereo camera, or the like, for example. In the present embodiment, the space recognition device 70 includes a front sensor 70F attached to the front end of the upper surface of the cabin 10, a rear sensor 70B attached to the rear end of the upper surface of the upper turning body 3, a left sensor 70L attached to the left end of the upper surface of the upper turning body 3, and a right sensor 70R attached to the right end of the upper surface of the upper turning body 3. An upper sensor that recognizes an object present in a space above the upper turning body 3 may be attached to the shovel 100.

[0043] The space recognition device 70 may be configured to be able to detect a predetermined object in a predetermined region set around the shovel 100. That is, the space recognition device 70 may be configured to be able to identify at least one of a type, a position, a shape, and the like of an object. For example, the space recognition device 70 may be configured to be able to distinguish between a person and an object other than a person. Furthermore, the space recognition device 70 may be configured to be able to specify the type of terrain around the shovel 100. The type of terrain is, for example, a ground surface, a hole, an inclined surface, a river, or the like. Furthermore, the space recognition device 70 may be configured to be able to specify the type of obstacle. The type of the obstacle is, for example, an electric wire, a utility pole, a person, an animal, a vehicle, work equipment, a construction machine, a building, a fence, or the like. Furthermore, the space recognition device 70 may be configured to be able to specify the type, size, or the like of a dump truck as a vehicle. Further, the space recognition device 70 may be configured to detect a person by recognizing a helmet, a safety vest, work clothes, or the like, or by recognizing a predetermined mark or the like on the helmet, the safety vest, the work clothes, or the like. Further, the space recognition device 70 may be configured to recognize a state of a road surface. Specifically, the space recognition device 70 may be configured to specify, for example, a type of an object present on a road surface. The types of objects present on the road surface are, for example, cigarettes, cans, PET bottles, stones, and the like. The above-described function of the space recognition device 70 may be realized by the controller 30 that receives the output of the space recognition device 70.

[0044] The direction detection device 71 is configured to detect information on a relative relationship between the direction of the upper turning body 3 and the direction of the lower traveling body 1. The direction detection device 71 may be configured by, for example, a combination of a geomagnetic sensor attached to the lower traveling body 1 and a geomagnetic sensor attached to the upper turning body 3. Alternatively, the direction detection device 71 may be configured by a combination of a GNSS receiver attached to the lower traveling body 1 and a GNSS receiver attached to the upper turning body 3. The direction detection device 71 may be a rotary encoder, a rotary position sensor, or the like, or any combination thereof. In a configuration in which the upper turning body 3 is driven to turning by the turning motor generator, the direction detection device 71 may be configured by a resolver. The direction detection device 71 may be attached to, for example, a center joint provided in association with the turning mechanism 2 that realizes the relative rotation between the lower traveling body 1 and the upper turning body 3.

[0045] The direction detection device **71** may be configured by a camera attached to the upper turning body **3**. In this case, the direction detection device **71** performs known image processing on an image (input image) captured by the camera attached to the upper turning body **3** to detect an image of the lower traveling body **1** included in the input image. The direction detection device **71** detects the image of the lower traveling body **1** using a known image recognition technique, thereby specifying the longitudinal direction of the lower traveling body **1**. Then, an angle formed between the direction of the longitudinal axis of the upper turning body **3** and the longitudinal direction of the lower traveling body **1** is derived. The direction of the longitudinal axis of the upper turning body **3** is derived from the mounting position of the camera. In particular, since the crawler **1**C protrudes from the upper turning body **3**, the direction detection device **71** can specify the longitudinal direction of the lower traveling body **1** by detecting the image of the crawler **1**C. In this case, the direction detection device **71** may be integrated into the controller **30**. The camera may be the space recognition device **70**.

[0046] The input device **72** is configured to allow an operator of the shovel to input information to the controller **30**. In the present embodiment, the input device **72** is a switch panel provided close to the display unit of the display device D**1**. However, the input device **72** may be a touch panel disposed on the display unit of the display device D**1**, or may be a voice input device such as a microphone disposed in the cabin **10**. Further, the input device **72** may be a communication device that acquires information from the outside.

[0047] The position measuring device **73** is configured to measure a current position of the upper turning body **3**. In the present embodiment, the position measuring device **73** is a GNSS receiver, detects the position of the upper turning body **3**, and outputs the detected value to the controller **30**. The position measuring device **73** may be a GNSS compass. In this case, the position measuring device **73** can detect the position and the direction of the upper turning body **3**. Therefore, the position measuring device **73** also functions as the direction detection device **71**.

[0048] The machine attitude sensor S**4** detects an inclination of the upper turning body **3** with respect to a predetermined plane. In the present embodiment, the machine attitude sensor S**4** is an accelerometer that detects an inclination angle about a longitudinal axis and an inclination angle about a lateral axis of the upper turning body **3** with respect to a horizontal plane. For example, the longitudinal axis and the lateral axis of the upper turning body **3** are orthogonal to each other and pass through a shovel center point which is a point on the pivot axis of the shovel **100**.

[0049] The turning angle sensor S**5** detects a turning angle of the upper turning body **3**. In the present embodiment, it is a gyro sensor. It may be a resolver, a rotary encoder, or the like, or any combination thereof. The turning angle sensor S**5** may detect a turning speed or a turning angular speed. The turning speed may be calculated from the turning angular speed.

[0050] Hereinafter, at least one of the boom angle sensor S**1**, the arm angle sensor S**2**, the bucket angle sensor S**3**, the machine attitude sensor S**4**, and the turning angle sensor S**5** is also referred to as an attitude detection device. The attitude of the attachment AT is detected based on, for example, the outputs of the boom angle sensor S**1**, the arm angle sensor S**2**, and the bucket angle sensor S**3**.

[0051] The display D**1** is a device that displays information. In the present embodiment, the display device D**1** is a liquid crystal display installed in the cabin **10**. However, the display device D**1** may be a display of a mobile device such as a smartphone.

[0052] The sound outputting device D**2** is a device that outputs sound. The sound outputting device D**2** includes at least one of devices that outputs sound to an operator in the cabin **10** and a device that outputs sound to an operator outside the cabin **10**. The sound outputting device D**2** may be a speaker of a mobile terminal.

[0053] The operation device **26** is a device used by an operator to operate the actuator. The operation device **26** includes, for example, an operation lever and an operation pedal. The actuator includes at least one of a hydraulic actuator and an electric actuator.

[0054] The controller **30** is a control device for controlling the shovel **100**. In the present embodiment, the controller **30** is configured by a computer including a CPU, a volatile storage device, a non-volatile storage device, and the like. Then, the controller **30** reads a program corresponding to each function from the non-volatile storage device, loads the program into the volatile storage device, and causes the CPU to execute a corresponding process. The functions include, for example, a machine guidance function that guides the operator's manual operation of the shovel **100** and a machine control function that supports the operator's manual operation of the shovel **100** or causes the shovel **100** to operate automatically or autonomously. The controller **30** may include a contact avoidance function of automatically or autonomously operating or stopping the shovel **100** in order to avoid contact between the shovel **100** and an object present in a monitoring range around the shovel **100**. Monitoring of objects around the shovel **100** is performed not only within the monitoring range but also outside the monitoring range.

[0055] Next, a configuration example of a hydraulic system mounted on the shovel **100** will be described with reference to FIG. **3**. FIG. **3** is a diagram illustrating a configuration example of a hydraulic system mounted on the shovel **100**. FIG. **3** illustrates the mechanical drive train, hydraulic line, pilot line, and electrical control system in double, solid, dashed, and dotted lines, respectively.

[0056] The hydraulic system of the shovel **100** mainly includes an engine **11**, regulators **13**, main pumps **14**, a pilot pump **15**, a control valve unit **17**, operation devices **26**, discharge pressure sensors **28**, operation sensors **29**, a controller **30**, and the like.

[0057] In FIG. **3**, the hydraulic system is configured such that hydraulic oil can be circulated from the main pump **14** driven by the engine **11** to the hydraulic oil tank via the center bypass oil passage **40** or the parallel oil passage **42**.

[0058] The engine **11** is a drive source of the shovel **100**. In the present embodiment, the engine **11** is, for example, a diesel engine that operates to maintain a predetermined rotational speed. An output shaft of the engine **11** is coupled to respective input shafts of the main pump **14** and the pilot pump **15**.

[0059] The main pump **14** is configured to supply hydraulic oil to the control valve unit **17** via hydraulic oil lines. In the present embodiment, the main pumps **14** are swash plate type variable displacement hydraulic pumps.

[0060] The regulators **13** are configured to be able to control the discharge amount of the main pumps **14**. In the present embodiment, the regulators **13** control the discharge amount of the main pumps **14** by adjusting the swash plate tilt angle of the main pumps **14** in response to a control command from the controller **30**.

[0061] The pilot pump **15** is an example of a pilot pressure generating device, and is configured to supply hydraulic oil to the hydraulic control device via pilot lines. In the present embodiment, the pilot pump **15** is a fixed displacement hydraulic pump. However, the pilot pressure generating device may be realized by the main pumps **14**. That is, the main pumps **14** may have a function of supplying hydraulic oil to various hydraulic control devices via the pilot lines in addition to a function of supplying hydraulic oil to the control valve unit **17** via the hydraulic oil lines. In this case, the pilot pump **15** may be omitted.

[0062] The control valve unit **17** is a hydraulic control device that controls a hydraulic system in the shovel **100**. In the present embodiment, the control valve unit **17** includes the control valves **171** to **176**. The control valve **175** includes a control valve **175**L and a control valve **175**R, and the control valve **176** includes a control valve **176**L and a control valve **176**R. The control valve unit **17** is configured to selectively supply the hydraulic oil discharged by the main pumps **14** to one or a plurality of hydraulic actuators through the control valves **171** to **176**. The control valves **171** to **176** control, for example, the flow rate of the hydraulic oil flowing from the main pump **14** to the hydraulic actuator and the flow rate of the hydraulic oil flowing from the hydraulic actuator to the hydraulic oil tank. The hydraulic actuators include a boom cylinder **7**, an arm cylinder **8**, a bucket cylinder **9**, a left traveling hydraulic motor **2**ML, a right traveling hydraulic motor **2**MR, and a turning hydraulic motor **2**A.

[0063] The operation devices **26** are configured so that an operator can operate the actuators. In the present embodiment, the operation device **26** includes a hydraulic actuator operation device configured to allow an operator to operate a hydraulic actuator. Specifically, the hydraulic actuator operation device is configured such that the hydraulic oil discharged by the pilot pump **15** can be supplied to the pilot ports of the corresponding control valves in the control valve unit **17** via the pilot lines. The pressure (pilot pressure) of the hydraulic oil supplied to each of the pilot ports is a pressure corresponding to the operation direction and the operation amount of the operation device **26** corresponding to each of the hydraulic actuators.

[0064] The discharge pressure sensors **28** are configured to be able to detect the discharge pressure of the main pump **14**. In the present embodiment, the discharge pressure sensors **28** output the detected value to the controller **30**.

[0065] The operation sensors **29** are configured to be able to detect contents of an operation of the operation device **26** by the operator. In the present embodiment, the operation sensors **29** electrically detect an operation direction and an operation amount of the operation device **26** corresponding to each of the actuators, and outputs the detected values to the controller **30**.

[0066] The main pumps **14** include a left main pump **14**L and a right main pump **14**R. The left main pump **14**L circulates hydraulic oil to a hydraulic oil tank via a left center bypass oil passage **40**L or a left parallel oil passage **42**L, and a right main pump **14**R circulates the working oil to the hydraulic oil tank via a right center bypass oil passage **40**R or a right parallel oil passage **42**R.

[0067] The left center bypass oil passage **40**L is a hydraulic oil line passing through the control valves **171**, **173**, **175**L, and **176**L disposed in the control valve unit **17**. The right center bypass oil passage **40**R is a hydraulic oil line passing through the control valves **172**, **174**, **175**R, and **176**R disposed in the control valve unit **17**.

[0068] The control valve **171** is a spool valve that switches the flow of the hydraulic oil in order to supply the hydraulic oil discharged by the left main pump **14**L to the left traveling hydraulic motor **2**ML and discharge the hydraulic oil discharged by the left traveling hydraulic motor **2**ML to the hydraulic oil tank.

[0069] The control valve **172** is a spool valve that switches the flow of the hydraulic oil in order to supply the hydraulic oil discharged by the right main pump **14**R to the right traveling hydraulic motor **2**MR and discharge the hydraulic oil discharged by the right traveling hydraulic motor **2**MR to the hydraulic oil tank.

[0070] The control valve **173** is a spool valve that switches the flow of the hydraulic oil in order to supply the hydraulic oil discharged by the left main pump **14**L to the turning hydraulic motor **2**A and discharge the hydraulic fluid discharged by the turning hydraulic motor **2**A to the hydraulic oil tank.

[0071] The control valve **174** is a spool valve that switches the flow of the hydraulic fluid in order to supply the hydraulic oil discharged by the right main pump **14**R to the bucket cylinder **9** and discharge the hydraulic fluid in the bucket cylinder **9** to the hydraulic oil tank.

[0072] The control valve **175**L is a spool valve that switches the flow of the hydraulic oil in order to supply the hydraulic oil discharged by the left main pump **14**L to the boom cylinder **7**. The control valve **175**R is a spool valve that switches the flow of the hydraulic oil in order to supply the hydraulic fluid discharged by the right main pump **14**R to the boom cylinder **7** and discharge the hydraulic oil in the boom cylinder **7** to the hydraulic oil tank.

[0073] The control valve **176**L is a spool valve that switches the flow of the hydraulic oil in order to supply the hydraulic oil discharged by the left main pump **14**L to the arm cylinder **8** and discharge the hydraulic oil in the arm cylinder **8** to the hydraulic oil tank.

[0074] The control valve **176**R is a spool value that switches the flow of the hydraulic fluid in order to supply the hydraulic oil discharged by the right main pump **14**R to the arm cylinder **8** and discharge the hydraulic oil in the arm cylinder **8** to the hydraulic oil tank.

[0075] The left parallel oil passage **42**L is a working oil line parallel to the left center bypass oil passage **40**L. When the flow of the hydraulic fluid passing through the left center bypass oil passage **42**L is limited or blocked by any one of the control valves **171**, **173**, and **175**L, the left parallel oil passage **40**L can supply the hydraulic oil to the control valve further downstream. The right parallel oil passage **42**R is a working oil line parallel to the right center bypass oil passage **40**R. When the flow of the hydraulic fluid passing through the right center bypass oil passage **40**R is limited or blocked by any one of the control valves **172**, **174**, and **175**R, the right parallel oil passage **42**R can supply the hydraulic oil to the control valve further downstream.

[0076] The regulators **13** include a left regulator **13**L and a right regulator **13**R. The left regulator **13**L controls the discharge amount of the left main pump **14**L by adjusting the swash plate tilt angle of the left main pump **14**L in accordance with the discharge pressure of the left main pump **14**L. For example, the left regulator **13**L reduces the discharge amount by adjusting the swash plate tilt angle of the left main pump **14**L in accordance with an increase in the discharge pressure of the left main pump **14**L. The same applies to the right regulator **13**R. This is to prevent the absorption power (absorption horsepower) of the main pump **14** represented by the product of the discharge pressure and the discharge amount from exceeding the output power (output horsepower) of the engine **11**.

[0077] The operation devices **26** include a left operation lever **26**L, a right operation lever **26**R, and a traveling lever **26**D. The traveling lever **26**D includes a left traveling lever **26**DL and a right traveling lever **26**DR.

[0078] The left operation lever **26**L is used for the turning operation and the operation of the arm **5**. When the left operation lever **26**L is operated in the front-rear direction, the control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valves **176** by using the hydraulic fluid discharged by the pilot pump **15**. When the left operation lever **26**L is operated in the left-right direction, the control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valve **173** by using the hydraulic oil discharged from the pilot pump **15**.

[0079] To be more specific, when the left operation lever **26**L is operated in the arm closing direction, the operating oil is introduced into the right pilot port of the control valve **176**L and the operating oil is introduced into the left pilot port of the control valve **176**R. When the left operation lever **26**L is operated in the arm opening direction, the operating oil is introduced into the left pilot port of the control valve **176**L and the operating oil is introduced into the right pilot port of the control valve **176**R. When the left operation lever **26**L is operated in the left turning direction, the hydraulic oil is introduced into the left pilot port of the control valve **173**, and when the left operation lever **26**L is operated in the right turning direction, the hydraulic oil is introduced into the right pilot port of the control valve **173**.

[0080] The right operation lever **26**R is used to operate the boom **4** and the bucket **6**. When the right operation lever **26**R is operated in the front-rear direction, the control pressure corresponding to the lever operation amount is introduced into the pilot ports of the control valves **175** using the hydraulic oil discharged by the pilot pump **15**. When the right operation lever **26**R is operated in the left-right direction, the control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valve **174** by using the hydraulic oil discharged from the pilot pump **15**.

[0081] To be specific, when the right operation lever **26**R is operated in the boom lowering direction, the hydraulic oil is introduced into the left pilot port of the control valve **175**R. When the right operation lever **26**R is operated in the boom raising direction, the hydraulic oil is introduced into the right pilot port of the control valve **175**L and the hydraulic oil is introduced into the left pilot port of the control valve **175**R. Further, when the right operation lever **26**R is operated in the bucket closing direction, the hydraulic oil is introduced into the right pilot port of the control valve **174**, and when the right operation lever **26**R is operated in the bucket opening direction, the hydraulic oil is introduced into the left pilot port of the control valve **174**.

[0082] The traveling lever **26**D is used to operate the crawler **1**C. Specifically, the left traveling lever **26**DL is used to operate the left crawler **1**CL. The traveling lever **26**D may be configured to be interlocked with the left traveling pedal. When the left traveling lever **26**DL is operated in the front-rear direction, the control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valve **171** using the hydraulic oil discharged by the pilot pump **15**. The right traveling lever **26**DR is used to operate the right crawler **1**CR. The right traveling lever **26**DR may be configured to be interlocked with the right traveling pedal. When the right traveling lever **26**DR is operated in the front-rear direction, the control pressure corresponding to the lever operation amount is introduced into the pilot port of the control valve **172** using the hydraulic oil discharged by the pilot pump **15**.

[0083] The discharge pressure sensors **28** include a left discharge pressure sensor **28**L and a right discharge pressure sensor **28**R. The left discharge pressure sensor **28**L detects the discharge pressure of the left main pump **14**L and outputs the detected value to the controller **30**. The same applies to the right discharge pressure sensor **28**R.

[0084] The operation sensors **29** include operation sensors **29**LA, **29**LB, **29**RA, **29**RB, **29**DL, and **29**DR. The operation sensor **29**LA electrically detects the content of an operation performed by an operator on the left operation lever **26**L in the front-rear direction and outputs the detected value to the controller **30**. The content of the operation is, for example, a lever operation direction, a lever operation amount (lever operation angle), or the like.

[0085] Similarly, the operation sensor **29**LB electrically detects the content of an operation performed by the operator on the left operation lever **26**L in the left-right direction, and outputs the detected value to the controller **30**. The operation sensor **29**RA electrically detects the content of an operation performed by the operator on the right operation lever **26**R in the front-rear direction, and outputs the detected value to the controller **30**. The operation sensor **29**RB electrically detects the content of an operation performed by the operator on the right operation lever **26**R in the left-right direction, and outputs the detected value to the controller **30**. The operation sensor **29**DL electrically detects the content of an operation performed by the operator on the left traveling lever **26**DL in the front-rear direction, and outputs the detected value to the controller **30**. The operation sensor **29**DR electrically detects the content of an operation performed by the operator on the right traveling lever **26**DR in the front-rear direction, and outputs the detected value to the controller **30**.

[0086] The controller **30** receives the output of the operation sensor **29**, outputs a control command to the regulator **13** as necessary, and changes the discharge amount of the main pump **14**. Further, the controller **30** receives an output of a control pressure sensor **19** provided upstream of the throttle **18**, outputs a control command to the regulator **13** as necessary, and changes the discharge amount of the main pump **14**. The throttle **18** includes a left throttle **18**L and a right throttle **18**R, and the control pressure sensor **19** includes a left control pressure sensor **19**L and a right control pressure sensor **19**R.

[0087] In the left center bypass oil passage **40**L, the left throttle **18**L is disposed between the most downstream control valve **176**L and the hydraulic oil tank. Therefore, the flow of the hydraulic oil discharged by the left main pump **14**L is limited by the left throttle **18**L. The left throttle **18**L generates a control pressure for controlling the left regulator **13**L. The left control pressure sensor **19**L is a sensor for detecting the control pressure, and outputs the detected value to the controller **30**. The controller **30** controls the discharge amount of the left main pump **14**L by adjusting the swash plate tilt angle of the left main pump **14**L in accordance with the control pressure. The controller **30** decreases the discharge amount of the left main pump **14**L as the control pressure increases, and increases the discharge amount of the left main pump **14**L as the control pressure decreases. The discharge amount of the right main pump **14**R is also controlled in the same manner.

[0088] To be more specific, as illustrated in FIG. **3**, in the case of a standby state in which none of the hydraulic actuators in the shovel **100** is operated, the hydraulic fluid discharged from the left main pump **14**L passes through the left center bypass oil passage **40**L and reaches the left throttle **18**L. The flow of the working oil discharged by the left main pump **14**L increases the control pressure generated upstream of the left throttle **18**L. As a result, the controller **30** reduces the discharge amount of the left main pump **14**L to the allowable minimum discharge amount, and suppresses the pressure loss (pumping loss) when the discharged working oil passes through the left center bypass oil passage **40**L. On the other hand, when any of the hydraulic actuators is operated, the working oil discharged by the left main pump **14**L flows into the hydraulic actuators to be operated via the control valves corresponding to the hydraulic actuators to be operated. Then, the flow of the working oil discharged by the left main pump **14**L reduces or eliminates the amount of the working oil reaching the left throttle **18**L, thereby reducing the control pressure generated upstream of the left throttle **18**L. As a result, the controller **30** increases the discharge amount of the left main pump **14**L to circulate a sufficient amount of working oil to the hydraulic actuators to be operated, thereby ensuring the driving of the hydraulic actuators to be operated. The controller **30** controls the discharge amount of the right main pump **14**R in the same manner.

[0089] With the above-described configuration, the hydraulic system of FIG. **3** can suppress wasteful energy consumption in the main pump **14** in the standby state. The wasteful energy consumption includes a pumping loss generated in the center bypass oil passage **40** by the hydraulic oil discharged by the main pump **14**. In addition, in the hydraulic system of FIG. **3**, when the hydraulic actuator is operated, a necessary and sufficient amount of hydraulic oil can be reliably supplied from the main pump **14** to the hydraulic actuators to be operated.

[0090] Next, a configuration in which the controller **30** operates the actuators by the machine control function will be described with reference to FIGS. **4**A to **4**D. FIGS. **4**A to **4**D are diagrams in which a part of the hydraulic system is extracted. To be specific, FIG. **4**A is a diagram in which a hydraulic system portion related to the operation of the arm cylinder **8** is extracted, and FIG. **4**B is a diagram in which a hydraulic system portion related to the operation of the boom cylinder **7** is extracted. FIG. **4**C is a diagram in which a hydraulic system portion related to the operation of the bucket cylinder **9** is extracted, and FIG. **4**D is a diagram in which a hydraulic system portion related to the operation of the turning hydraulic motor **2**A is extracted.

[0091] As illustrated in FIGS. **4**A to **4**D, the hydraulic system includes proportional valves **31**. The proportional valves **31** include proportional valves **31**AL to **31**DL and **31**AR to **31**DR.

[0092] The proportional valves **31** function as control valves for machine control. The proportional valves **31** are disposed in oil passages connecting the pilot pump **15** and pilot ports of corresponding control valves in the control valve unit **17**, and are configured to be able to change a flow passage area of the oil passages. In the present embodiment, the proportional valves **31** operate in response to a control command output from the controller **30**. Therefore, the controller **30** can supply the hydraulic oil discharged by the pilot pump **15** to the pilot port of the corresponding control valve in the control valve unit **17** via the proportional valves **31** regardless of the operation of the operation device **26** by the operator. Then, the controller **30** can apply the pilot pressure generated by the proportional valves **31** to the pilot port of the corresponding control valves.

[0093] With this configuration, even when a specific operation device **26** is not operated, the controller **30** can operate the hydraulic actuator corresponding to the specific operation device **26**. In addition, even when a specific operation device **26** is operated, the controller **30** can forcibly stop the operation of the hydraulic actuator corresponding to the specific operation device **26**.

[0094] For example, as illustrated in FIG. **4**A, the left operation lever **26**L is used to operate the arm **5**. To be specific, the left operation lever **26**L uses the hydraulic oil discharged by the pilot pump **15** to apply the pilot pressure corresponding to the operation in the front-rear direction to the pilot port of the control valve **176**. To be more specific, when the left operation lever **26**L is operated in the arm closing direction (rearward direction), the left operation lever **26**L causes the pilot pressure corresponding to the operation amount to act on the right pilot port of the control valve **176**L and the left pilot port of the control valve **176**R. When the left control lever **26**L is operated in the arm opening direction (forward direction), pilot pressure corresponding to the operation amount is applied to the left pilot port of control valve **176**L and the right pilot port of control valve **176**R.

[0095] A switch NS is provided on the left operation lever **26**L. In the present embodiment, the switch NS is a push button switch provided at the tip of the left operation lever **26**L. An operator can operate the left operation lever **26**L while pressing the switch NS. The switch NS may be provided on the right operation lever **26**R or may be provided at another position in the cabin **10**.

[0096] The operation sensor **29**LA detects the content of an operation performed by the operator on the left operation lever **26**L in the front-rear direction and outputs the detected value to the controller **30**.

[0097] The proportional valve **31**AL operates in response to a control command (current command) output from the controller **30**. The proportional valve **31**AL adjusts the pilot pressure of the hydraulic oil introduced from the pilot pump **15** to the right pilot port of the control valve **176**L and the left pilot port of the control valve **176**R via the proportional valve **31**AL. The proportional valve **31**AR operates in response to a current command output from the controller **30**. The proportional valve **31**AR adjusts the pilot pressure of the hydraulic oil introduced from the pilot pump **15** to the left pilot port of the control valve **176**L and the right pilot port of the control valve **176**R via the proportional valve **31**AR. The proportional valve **31**AL can adjust the pilot pressure so that the control valves **176**L and **176**R can be stopped at arbitrary positions. In the similar manner, the proportional valve **31**AR can adjust the pilot pressure so that the control valves **176**L and **176**R can be stopped at arbitrary positions.

[0098] With this configuration, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **176**L and the left pilot port of the control valve **176**R via the proportional valve **31**AL in response to the arm closing operation by the operator. In addition, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **176**L and the left pilot port of the control valve **176**R via the proportional valve **31**AL regardless of the arm closing operation by the operator. That is, the controller **30** can close the arm in response to the arm closing operation by the operator or independently of the arm closing operation by the operator.

[0099] In addition, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the left pilot port of the control valve **176**L and the right pilot port of the control valve **176**R via the proportional valve **31**AR in response to the arm opening operation by the operator. Further, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the left pilot port of the control valve **176**L and the right pilot port of the control valve **176**R via the proportional valve **31**AR regardless of the arm opening operation by the operator. That is, the controller **30** can open the arm **5** in response to the arm opening operation by the operator or independently of the arm opening operation by the operator.

[0100] With this configuration, even when the operator performs the arm closing operation, the controller **30** can forcibly stop the closing operation of the arm **5** by reducing the pilot pressure acting on the pilot port on the closing side of the control valve **176** (the left pilot port of the control valve **176**L and the right pilot port of the control valve **176**R) as necessary. The same applies to a case where the opening operation of the arm **5** is forcibly stopped when the operator performs the arm opening operation.

[0101] Alternatively, even when the operator performs the arm closing operation, the controller **30** may forcibly stop the closing operation of the arm **5** by controlling the proportional valves **31**AR as necessary to increase the pilot pressures acting on the pilot ports (the right pilot port of the control valve **176**L and the left pilot port of the control valve **176**R) on the opening side of the control valve **176** on the opposite side of the pilot port on the closing side of the control valve **176** and forcibly returning the control valve **176** to the neutral position. The same applies to a case where the opening operation of the arm **5** is forcibly stopped when the operator performs the arm opening operation.

[0102] Although description with reference to the following FIGS. **4**B to **4**D is omitted, the same applies to a case where the operation of the boom **4** is forcibly stopped when the operator performs the boom raising operation or the boom lowering operation, a case where the operation of the bucket **6** is forcibly stopped when the operator performs the bucket closing operation or the bucket opening operation, and a case where the turning operation of the upper turning body **3** is forcibly stopped when the operator performs the turning operation. The same applies to a case where the traveling operation of the lower traveling body **1** is forcibly stopped when the traveling operation is performed by the operator.

[0103] As illustrated in FIG. **4**B, the right operation lever **26**R is used to operate the boom **4**. To be more specific, the right operation lever **26**R applies a pilot pressure corresponding to the operation in the front-rear direction to the pilot port of the control valve **175** using the hydraulic oil discharged by the pilot pump **15**. To be more specific, when the right operation lever **26**R is operated in the boom raising direction (rearward direction), the pilot pressure corresponding to the operation amount is applied to the right pilot port of the control valve **175**L and the left pilot port of the control valve **175**R. When the right operation lever **26**R is operated in the boom lowering direction (forward direction), the pilot pressure corresponding to the operation amount is applied to the right pilot port of the control valve **175**R.

[0104] The operation sensor **29**RA detects the content of an operation performed by the operator on the right operation lever **26**R in the front-rear direction, and outputs the detected value to the controller **30**.

[0105] The proportional valve **31**BL operates in response to a control command (current command) output from the controller **30**. The proportional valve **31**BL adjusts the pilot pressure of the hydraulic oil introduced from the pilot pump **15** to the right pilot port of the control valve **175**L and the left pilot port of the control valve **175**R via the proportional valve **31**BL. The proportional valve **31**BR operates in response to a control command (current command) output from the controller **30**. The proportional valve **31**BR adjusts the pilot pressure of the hydraulic oil introduced from the pilot pump **15** to the right pilot port of the control valve **175**R via the proportional valve **31**BR. The proportional valves **31**BL can adjust the pilot pressure so that the control valves **175**L and **175**R can be stopped at arbitrary positions. Furthermore, the proportional valve **31**BR can adjust the pilot pressure so that the control valve **175**R can be stopped at arbitrary positions.

[0106] With this configuration, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **175**L and the left pilot port of the control valve **175**R via the proportional valve **31**BL in response to the boom raising operation by the operator. Further, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **175**L and the left pilot port of the control valve **175**R via the proportional valve **31**LB regardless of the boom raising operation by the operator. That is, the controller **30** can raise the boom **4** in response to the boom raising operation by the operator or independently of the boom raising operation by the operator.

[0107] Further, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **175**R via the proportional valve **31**BR in response to the boom lowering operation by the operator. Further, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **175**R via the proportional valve **31**BR regardless of the boom lowering operation by the operator. That is, the controller **30** can lower the boom **4** in response to the boom lowering operation by the operator or independently of the boom lowering operation by the operator.

[0108] As illustrated in FIG. **4**C, the right operation lever **26**R is also used to operate the bucket **6**. To be specific, the right operation lever **26**R uses the hydraulic oil discharged by the pilot pump **15** to apply the pilot pressure corresponding to the operation in the left-right direction to the pilot port of the control valve **174**. To be more specific, when right operation lever **26**R is operated in the bucket closing direction (left direction), the right operation lever **26**R applies a pilot pressure corresponding to the operation amount to the left pilot port of control valve **174**. In addition, when the right operation lever **26**R is operated in the bucket opening direction (right direction), the pilot pressure corresponding to the operation amount is applied to the right pilot port of the control valve **174**.

[0109] The operation sensor **29**RB detects the content of an operation performed by the operator on the right operation lever **26**R in the left-right direction, and outputs the detected value to the controller **30**.

[0110] The proportional valve **31**CL operates in response to a control command (current command) output from the controller **30**. Then, the pilot pressure of the hydraulic oil introduced from the pilot pump **15** to the left pilot port of the control valve **174** via the proportional valve **31**CL is adjusted. The proportional valve **31**CR operates in response to a control command (current command) output from the controller **30**. Then, the pilot pressure of the hydraulic oil introduced from the pilot pump **15** to the right pilot port of the control valve **174** via the proportional valve **31**CR is adjusted. The proportional valve **31**CL can adjust the pilot pressure so that the control valve **174** can be stopped at an arbitrary position. Similarly, the proportional valve **31**CR can adjust the pilot pressure so that the control valve **174** can be stopped at an arbitrary position.

[0111] With this configuration, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the left pilot port of the control valve **174** via the proportional valve **31**CL in response to the bucket closing operation by the operator. In addition, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the left pilot port of the control valve **174** via the proportional valve **31**CL regardless of the bucket closing operation by the operator. That is, the controller **30** can close the bucket **6** in response to the bucket closing operation by the operator or independently of the bucket closing operation by the operator.

[0112] Further, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **174** via the proportional valve **31**CR in response to the bucket opening operation by the operator. Further, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **174** via the proportional valve **31**CR regardless of the bucket opening operation by the operator. That is, the controller **30** can open the bucket **6** in response to the bucket opening operation by the operator or independently of the bucket opening operation by the operator.

[0113] As illustrated in FIG. **4**D, the left operation lever **26**L is also used to operate the turning mechanism **2**. To be specific, the left operation lever **26**L uses the hydraulic oil discharged by the pilot pump to apply the pilot pressure corresponding to the operation in the left-right direction to the pilot port of the control valve **173**. To be more specific, when the left operation lever **26**L is operated in the left turning direction (left direction), the left operation lever **26**L causes the pilot pressure corresponding to the operation amount to act on the left pilot port of the control valve **173**. When the left operation lever **26**L is operated in the right turning direction (right direction), the pilot pressure corresponding to the operation amount is applied to the right pilot port of the control valve **173**.

[0114] The operation sensor **29**LB detects the content of an operation performed by the operator on the left operation lever **26**L in the left-right direction and outputs the detected value to the controller **30**.

[0115] The proportional valve **31**DL operates in response to a control command (current command) output from the controller **30**. The proportional valve **31**DL adjusts the pilot pressure of the hydraulic oil introduced from the pilot pump **15** to the left pilot port of the control valve **173** via the proportional valve **31**DL. The proportional valve **31**DR operates in response to a current command output from the controller **30**. The proportional valve **31**DR adjusts the pilot pressure of the hydraulic oil introduced from the pilot pump **15** to the right pilot port of the control valve **173** via the proportional valve **31**DR. The proportional valves **31**DL can adjust the pilot pressure so that the control valve **173** can be stopped at an arbitrary position. Similarly, the proportional valve **31**DR can adjust the pilot pressure so that the control valve **173** can be stopped at an arbitrary position.

[0116] With this configuration, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the left pilot port of the control valve **173** via the proportional valve **31**DL in response to the leftward turning operation by the operator. In addition, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the left pilot port of the control valve **173** via the proportional valve **31**DL regardless of the leftward turning operation by the operator. That is, the controller **30** can turn the turning mechanism **2** to the left in response to the left turning operation by the operator or independently of the left turning operation by the operator.

[0117] In addition, the controller **30** can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **173** via the proportional valve **31**DR in response to the operator's right turning operation. In addition, the controller can supply the hydraulic oil discharged from the pilot pump **15** to the right pilot port of the control valve **173** via the proportional valve **31**DR regardless of the operator's right turning operation. That is, the controller **30** can turn the turning mechanism **2** to the right in response to the right turning operation by the operator or independently of the right turning operation by the operator.

[0118] The shovel **100** may have a configuration for automatically moving the lower traveling body **1** forward and backward. In this case, the hydraulic system portion related to the operation of the left traveling hydraulic motor **2**ML and the hydraulic system portion related to the operation of the right traveling hydraulic motor **2**MR may be configured in the same manner as the hydraulic system portion related to the operation of the boom cylinder **7** and the like.

[0119] In addition, the shovel **100** may include a configuration for automatically operating the bucket tilt mechanism. In this case, the hydraulic system portion related to the bucket tilt cylinder constituting the bucket tilt mechanism may be configured in the same manner as the hydraulic system portion related to the operation of the boom cylinder **7** or the like.

[0120] Although the electric operation lever has been described as the form of the operation device **26**, a hydraulic operation lever may be employed instead of the electric operation lever. In this case, the lever operation amount of the hydraulic operation lever may be detected in the form of pressure by a pressure sensor and input to the controller **30**. Further, an electromagnetic valve may be disposed between the operation device **26** as the hydraulic operation lever and the pilot port of each control valve. The electromagnetic valve is configured to operate in response to an electrical signal from the controller **30**. With this configuration, when a manual operation using the operation device **26** as a hydraulic operation lever is performed, the operation device **26** can move each control valve by increasing or decreasing the pilot pressure according to the lever operation amount. Further, each control valve may be constituted by an electromagnetic spool valve. In this case, the electromagnetic spool valve operates in response to an electric signal from the controller **30** corresponding to the lever operation amount of the electric operation lever.

[0121] Next, the function of the controller **30** will be described with reference to FIG. **5**. FIG. **5** is a functional block diagram of the controller **30**. In the example of FIG. **5**, the controller **30** is configured to receive a signal output by at least one of the information acquiring device E**1**, the switch NS, and the like, execute various calculations, and output a control command to the proportional valves **31** and the like.

[0122] The information acquiring device E**1** detects information on the shovel **100**. In the present embodiment, the information acquiring device E**1** includes at least one of a boom angle sensor S**1**, an arm angle sensor S**2**, a bucket angle sensor S**3**, a machine attitude sensor S**4**, a turning angle sensor S**5**, a boom rod pressure sensor, a boom bottom pressure sensor, an arm rod pressure sensor, an arm bottom pressure sensor, a bucket rod pressure sensor, a bucket bottom pressure sensor, a boom cylinder stroke sensor, an arm cylinder stroke sensor, a bucket cylinder stroke sensor, a discharge pressure sensor **28**, an operation sensor **29**, a space recognition device **70**, a direction detection device **71**, an information input device **72**, a position measuring device **73**, and a communication device T**1**. The information acquiring device E**1** acquires, for example, at least one of a boom angle, arm angle, bucket angle, machine body inclination angle, turning angular velocity, boom rod pressure, boom bottom pressure, arm rod pressure, arm bottom pressure, bucket rod pressure, bucket bottom pressure, boom stroke amount, arm stroke amount, bucket stroke amount, discharge pressure of the main pump **14**, operation amount of the operation device **26**, information on an object existing in a three dimensional space around the shovel **100**, information on a relative relationship between the direction of the upper turning body **3** and the direction of the lower traveling body **1**, information input to the controller **30**, and information on a current position as information on the shovel **100**. The information acquiring device E**1** may acquire information from another machine (a construction machine, a flying object for acquiring site information, or the like).

[0123] The controller **30** includes a position calculation unit **30**A, a trajectory acquisition unit **30**B, and an automatic control unit **30**C as functional elements. Each functional element may be configured by hardware or may be configured by software. Although the position calculation unit **30**A, the trajectory acquisition unit **30**B, the automatic control unit **30**C, and a working angle control unit **30**D are illustrated as being distinguished from each other for ease of description, they need not be physically distinguished from each other, and may be entirely or partially configured by common software components or hardware components.

[0124] The position calculation unit **30**A is configured to calculate the position of the measurement target. In the present embodiment, the position calculation unit **30**A calculates a coordinate point of a predetermined portion of the attachment AT in the reference coordinate system. The predetermined portion is, for example, a claw tip of the bucket **6**. Specifically, the claw tip of the bucket **6** is the tip of the claw at the center among the plurality of claws attached to the tip of the bucket **6**. However, the claw tip of the bucket **6** may be the tip of the claw at the left end among the plurality of claws attached to the tip of the bucket **6**, or may be the tip of the claw at the right end among the plurality of claws attached to the tip of the bucket **6**. The origin of the reference coordinate system is, for example, an intersection point between the pivot axis and the ground contact surface of the shovel **100**. The reference coordinate system is, for example, an XYZ orthogonal coordinate system, and has an X-axis parallel to the longitudinal axis of the shovel **100**, a Y-axis parallel to the lateral axis of the shovel **100**, and a Z-axis parallel to the pivot axis of the shovel **100**. The position calculation unit **30**A calculates, for example, the coordinate point of the claw tip of the bucket **6** from the rotation angle of each of the boom **4**, the arm **5**, and the bucket **6**. The position calculation unit **30**A may calculate not only the coordinate point of the tip of the claw at the center but also the coordinate point of the tip of the claw at the left end and the coordinate point of the tip of the claw at the right end. In this case, the position calculation unit **30**A may use the output of the machine attitude sensor S**4**. Further, the predetermined portion may be one point on the bottom surface of the bucket **6** or one point on the opening surface of the bucket **6**.

[0125] The trajectory acquisition unit **30**B is configured to obtain a target trajectory which is a trajectory followed by a predetermined portion of the attachment AT when the shovel **100** is automatically operated. In the present embodiment, the trajectory acquisition unit **30**B acquires a target trajectory used when the automatic control unit **30**C automatically operates the shovel **100**. To be specific, the trajectory acquisition unit **30**B derives the target trajectory based on a design surface stored in the non-volatile storage device. The trajectory acquisition unit **30**B may derive the target trajectory based on information related to the topography around the shovel **100** recognized by the space recognition device **70**. Alternatively, the trajectory acquisition unit **30**B may derive information on the past trajectory of the claw tip of the bucket **6** from the past output of the attitude detecting device stored in the volatile storage device, and derive the target trajectory based on the information. Alternatively, the trajectory acquisition unit **30**B may derive the target trajectory based on the current position of the predetermined portion of the attachment AT and the design surface.

[0126] The automatic controller **30**C is configured to be able to automatically operate the shovel **100**. In the present embodiment, when a predetermined start condition is satisfied, a predetermined portion of the attachment AT is moved along the target trajectory acquired by the trajectory acquisition unit **30**B. Specifically, when the operation device **26** is operated in a state where the switch NS is pressed, the shovel **100** is automatically operated so that the predetermined portion moves along the target trajectory.

[0127] In the present embodiment, the automatic control unit **30**C is configured to support manual operation of the shovel **100** by the operator by automatically operating the actuators. For example, when the operator manually performs the arm closing operation while pressing the switch NS, the automatic control unit **30**C may automatically extend and contract at least one of the boom cylinder **7**, the arm cylinder **8**, and the bucket cylinder **9** so that the target trajectory and the position of the claw tip of the bucket **6** coincide with each other. In this case, for example, only by operating the left operation lever **26**L in the arm closing direction, the operator can close the arm **5** while causing the claw tip of the bucket **6** to coincide with the target trajectory.

[0128] In the present embodiment, the automatic control unit **30**C can automatically operate the actuators by giving control commands (current commands) to the proportional valves **31** and individually adjusting the pilot pressures acting on the control valves corresponding to the actuators. For example, at least one of the boom cylinder **7** and the bucket cylinder **9** can be operated regardless of whether or not the right operation lever **26**R is tilted.

[0129] The working angle control unit **30**D is configured to be able to control the working angle θ. The working angle θ is an angle formed by a plane or a line determined based on the shape of the bucket **6** and a design surface. In the present embodiment, the working angle control unit **30**D is configured to execute control for causing the working angle θ to follow the target angle **6**T (for example, causing the working angle θ to coincide with the target angle θT, as described below).

[0130] Here, the working angle θ will be described with reference to FIG. **6**A and FIG. **6**B. FIGS. **6**A and **6**B are diagrams illustrating a relationship between the working angle θ, the operation speed V, and the separation distance L. To be specific, FIG. **6**A is a side view of the bucket **6** when the bucket **6** is viewed from the −Y direction on the Y axis, and FIG. **6**B is a graph illustrating a relationship between the target angle **6**T of the work angle θ, the operation speed V, and the separation distance L.

[0131] The working angle θ is an angle formed by a plane or a line determined based on the shape of the bucket **6** and the design surface DS. In the example illustrated in FIG. **6**A, the design surface DS is located below the ground surface GS. The working angle θ is an angle formed between a virtual surface BS including the opening surface of the bucket **6** and the design surface DS. However, the working angle θ may be an angle formed between a virtual plane including the bottom surface BT of the bucket **6** and the design surface DS, or may be an angle formed between the virtual plane including the back surface BK of the bucket **6** and the design surface DS. In the example illustrated in FIG. **6**A, the bucket **6** is at a position higher than the ground surface to be worked, and the design surface DS is covered with earth and sand and is not yet exposed.

[0132] The operation speed V is a moving speed at the control reference point. The control reference point is a point serving as a reference when executing control of the working angle θ, and corresponds to, for example, a point at a predetermined portion of the attachment AT. In the example illustrated in FIGS. **6**A and **6**B, the predetermined portion of the attachment AT is the claw tip **6**A of the bucket **6**. To be more specific, the claw tip **6**A is the tip of the claw located at the center among the plurality of claws attached to the tip of the bucket **6**. In the examples illustrated in FIGS. **6**A and **6**B, the operator of the shovel **100** performs the arm closing operation. Therefore, the bucket **6** moves downward and in a direction approaching the upper turning body **3**. That is, the operation speed V of the claw tip **6**A is represented by a vector having components in the −X direction on the X axis and the −Z direction on the Z axis.

[0133] The separation distance L is a distance between the control reference point and the design surface DS. In the examples illustrated in FIGS. **6**A and **6**B, the separation distance L is the vertical distance between the claw tip **6**A of the bucket **6** and the design surface DS. However, the separation distance L may be a distance (path) along the trajectory of the claw tip **6**A when the claw tip **6**A approaches the design surface DS.

[0134] The working angle control unit **30**D calculates the working angle θ, the operation speed V, and the separation distance L based on the output of the information acquiring device E**1**. To be specific, the working angle control unit **30**D calculates the coordinate point of the claw tip **6**A of the bucket **6** based on the output of the information acquiring device E**1**. Then, the working angle control unit **30**D calculates an operation speed V (a moving distance per unit time) which is a moving speed of the claw tip **6**A based on the coordinate point of the claw tip **6**A at the first time point and the coordinate point of the claw tip **6**A at the second time point. The working angle control unit **30**D calculates the coordinate point of the bucket pin **6**B based on the output of the information acquiring device E**1**. The bucket pin **6**B is a pin for coupling the arm **5** and the bucket **6**. The working angle control unit **30**D calculates the separation distance L based on the coordinate point of the claw tip **6**A and the design surface DS stored in the non-volatile storage device.

[0135] In the examples illustrated in FIGS. **6**A and **6**B, the working angle control unit **30**D is configured to derive the target angle θT of the working angle θ based on the current operation speed V and the current separation distance L. To be specific, the working angle control unit **30**D refers to the database that stores a correspondence relationship between the target angle θT, the operation speed V, and the separation distance L as illustrated in FIG. **6**B, and derives the target angle θT corresponding to the current operation speed V and the current separation distance L.

[0136] The graph illustrated in FIG. **6**B is a graph in which the vertical axis represents the target angle θT and the horizontal axis represents the separation distance L. In addition, in the graph illustrated in FIG. **6**B, the correspondence relationship between the separation distance L and the target angle θT at each of the three stages of the operation speed V is illustrated by a solid line, a one dot chain line, and a broken line. The graph illustrated in FIG. **6**B indicates that when the bucket **6** is at a position higher than the design surface DS (when the separation distance L is a positive value), the target angle θT increases as the absolute value of the separation distance L increases, and the target angle θT increases as the absolute value of the operation speed V increases. Further, the graph illustrated in FIG. **6**B indicates that when the bucket **6** is at a position lower than the design surface DS (when the separation distance L is a negative value), the target angle θT decreases as the absolute value of the separation distance L increases, and the target angle θT decreases as the absolute value of the operation speed V increases. That is, the graph illustrated in FIG. **6**B indicates that the bucket **6** is opened as the bucket **6** is separated upward from the design surface DS, and the bucket **6** is closed as the bucket **6** is separated downward from the design surface DS. The graph illustrated in FIG. **6**B indicates that when the separation distance L is 0, that is, when the claw tip **6**A of the bucket **6** and the design surface DS are in contact with each other, the target angle θT becomes the value θ**0** regardless of the magnitude of the operation speed V. In the example illustrated in FIG. **6**B, the operation speed V is represented in three stages for the sake of clarity, but in actuality, the operation speed V is represented in more stages.

[0137] Here, an example of a process in which the working angle control unit **30**D sets (changes) the target angle θT will be described with reference to FIG. **6**B and FIGS. **7**A to **7**D. FIGS. **7**A to **7**D are side views of the bucket **6** when work such as finishing excavation work or horizontal pulling work is performed, and indicate the transition of the position of the bucket **6**. In addition, in the examples illustrated in FIGS. **7**A to **7**D, the design surface DS is positioned below the ground surface GS.

[0138] To be more specific, FIG. **7**A indicates the position of the bucket **6** at the time t**1**, FIG. **7**B indicates the position of the bucket **6** at the time t**2** after the time t**1**, FIG. **7**C indicates the position of the bucket **6** at the time t**3** after the time t**2**, and FIG. **7**D indicates the position of the bucket **6** at the time t**4** after the time t**3**. In addition, the figure of the bucket **6** represented by the dotted line in FIG. **7**B indicates the position of the bucket **6** at a past time (time t**1**). The same applies to FIGS. **7**C and **7**D.

[0139] At time t**1**, the bucket **6** is located at the position illustrated in FIG. **7**A, and the working angle control unit **30**D derives the value θ**3** of the target angle θT related to the working angle θ based on the current value V**1** of the operation speed V, the current value L**3** of the separation distance L, and the database storing the correspondence illustrated in FIG. **6**B. Then, the working angle control unit **30**D executes control to make the working angle θ coincide with the value θ**3** of the target angle θT. To be specific, the working angle control unit **30**D outputs a control command to at least one of the proportional valves **31**CL and **31**CR to open and close the bucket **6**, thereby causing the working angle θ to coincide with the value θ**3** of the target angle θT. The working angle control unit **30**D may cause the working angle θ to coincide with the value θ**3** of the target angle θT by executing at least one of raising and lowering the boom **4**, opening and closing the arm **5**, and opening and closing the bucket **6**. The working angle control unit **30**D may cause the working angle θ to coincide with the value θ**3** of the target angle θT without opening and closing the bucket **6**.

[0140] At time t**2**, the bucket **6** is at the position illustrated in FIG. **7**B, and the working angle control unit **30**D derives the value θ**2** of the target angle θT related to the working angle θ based on the current value V**1** of the operation speed V, the current value L**2** of the separation distance L, and the database storing the correspondence illustrated in FIG. **6**B. Then, the working angle control unit **30**D executes control to make the working angle θ coincide with the value θ**2** of the target angle θT.

[0141] At time t**3**, the bucket **6** is at the position illustrated in FIG. **7**C, and the working angle control unit **30**D derives the value θ**1** of the target angle θT related to the working angle θ based on the current value V**1** of the operation speed V, the current value L**1** of the separation distance L, and the database storing the correspondence illustrated in FIG. **6**B. Then, the working angle control unit **30**D executes control to make the working angle θ coincide with the value θ**1** of the target angle θT.

[0142] Similarly, at time t**4**, the bucket **6** is at the position illustrated in FIG. **7**D, and the working angle control unit **30**D derives the value θ**0** of the target angle θT related to the working angle θ based on the current value V**1** of the operation speed V, the current value **0** of the separation distance L, and the database storing the correspondence illustrated in FIG. **6**B. Then, the working angle control unit **30**D executes control to make the working angle θ coincide with the value θ**0** of the target angle θT. In the present embodiment, when the working angle θ is the value θ**0**, as illustrated in FIG. **7**D, the bottom surface of the bucket **6** and the design surface DS coincide with each other (are parallel to each other). Therefore, the operator can expose the design surface DS by pulling the bucket **6** toward the upper turning body **3** side while keeping the attitude (the attitude at the time t**4**) as it is. However, the value θ**0** may be an arbitrary value that is preset or dynamically set by the operator or the like of the shovel **100**. In addition, there is an allowable range of about several tens of millimeters in coincidence between the bottom surface of the bucket **6** and the design surface DS. When the bottom surface of the bucket **6** is positioned within a predetermined allowable width with respect to the design surface DS, the controller **30** determines that the bottom surface of the bucket **6** coincides with the design surface DS.

[0143] In the correspondence relationship illustrated in FIG. **6**B, the operation speed V is the moving speed of the claw tip **6**A of the bucket **6**, that is, the norm (magnitude) of the moving speed of the claw tip **6**A, but the operation speed V may be the norm (magnitude) of the horizontal components of the moving speed of the claw tip **6**A or may be the norm (magnitude) of the vertical components of the moving speed of the claw tip **6**A.

[0144] In addition, although the correspondence relationship illustrated in FIG. **6**B is set such that the target angle θT linearly increases in accordance with an increase in the separation distance L, the correspondence relationship may be set such that the target angle θT non-linearly increases.

[0145] In addition, although the correspondence relationship illustrated in FIG. **6**B is set such that the ratio of the increase in the target angle θT to the increase in the separation distance L increases linearly in accordance with the increase in the operation speed V, the ratio may be set such that the ratio increases nonlinearly.

[0146] In addition, although the correspondence relationship illustrated in FIG. **6**B is stored in the non-volatile storage device as a database, the correspondence relationship may be represented using a mathematical expression. For example, the target angle θT related to the working angle θ may be expressed as a function having the separation distance L and the operation speed V as arguments.

[0147] Further, in the above-described embodiment, the claw tip **6**A of the bucket **6** is adopted as the control reference point, but a portion other than the claw tip **6**A of the bucket **6** may be adopted as the control reference point. In the embodiment described above, the vertical distance between the control reference point (the claw tip **6**A of the bucket 6) and the design surface DS is adopted as the separation distance L. However, a distance other than the vertical distance may be adopted as the separation distance L.

[0148] Here, another example of the control reference point and the separation distance L will be described with reference to FIGS. 8A and 8B. FIGS. 8A and 8B are side views of the bucket 6 at a position higher than the design surface DS. To be specific, FIG. 8A illustrates another example of the control reference point, and FIG. 8B illustrates another example of the separation distance L. In the examples illustrated in FIGS. 8A and 8B, the design surface DS is located below the ground surface GS.

[0149] In the example illustrated in FIG. 8A, a point (nearest neighbor point 6C) closest to the design surface DS among a plurality of points on the outer surface of the bucket 6 is adopted as the control reference point. The separation distance L is a vertical distance between the nearest neighbor point 6C and the design surface DS. At the time point illustrated in FIG. 8A, the nearest neighbor point 6C is a point corresponding to the rear end of the bottom surface BT of the bucket 6, but the point on the attachment AT (bucket 6) corresponding to the nearest neighbor point 6C differs depending on the attitude of the bucket 6 at each time. However, the controller 30 may continuously set the point on the attachment AT (bucket 6) that has become the nearest neighbor point 6C at a predetermined time point as the nearest neighbor point 6C even after the point is no longer the actual closest point.

[0150] In the example illustrated in FIG. 8B, as in the case of FIG. 8A, the nearest neighbor point 6C located at the rear end of the bottom surface BT of the bucket 6 is adopted as the control reference point. The distance between the nearest neighbor point 6C and the intersection point CP is adopted as the separation distance L. In the example illustrated in FIG. 8B, the intersection point CP is an intersection point between the design surface DS and a circumferential line of a circle centered on the boom foot pin and passing through the control reference point (nearest neighbor point 6C).

[0151] Next, another example of the process in which the working angle control unit 30D sets (changes) the target angle θT will be described with reference to FIGS. 9A to 9D. FIGS. 9A to 9D are side views of the bucket 6 when work such as finishing excavation work or horizontal pulling work is performed, and indicate the transition of the position of the bucket 6. In the examples illustrated in FIGS. 9A to 9D, the design surface DS is located below the ground surface GS.

[0152] To be more specific, FIG. 9A indicates the position of the bucket 6 at the time t1, FIG. 9B indicates the position of the bucket 6 at the time t2 after the time t1, FIG. 9C indicates the position of the bucket 6 at the time t3 after the time t2, and FIG. 9D indicates the position of the bucket 6 at the time t4 after the time t3. In addition, the figure of the bucket 6 represented by the dotted line in FIG. 9B indicates the position of the bucket 6 at a past time (time t1). The same applies to FIGS. 9C and 9D.

[0153] The examples illustrated in FIGS. 9A to 9D differ from the examples illustrated in FIGS. 7A to 7D in that the control reference point (the claw tip 6A of the bucket 6) is located at a position lower than the virtual plane including the design surface DS. Therefore, the value L3D, the value L2D, and the value L1D of the separation distance L in FIGS. 9A to 9C are negative values. In the examples illustrated in FIGS. 7A to 7D, the control reference point (the claw tip 6A of the bucket 6) is located at a position higher than the virtual plane including the design surface DS. Therefore, the value L3, the value L2, and the value L1 of the separation distance L in FIGS. 7A to 7C are positive values.

[0154] At the time t1, the bucket 6 is at the position illustrated in FIG. 9A, and the working angle control unit 30D derives the value θ3D of the target angle θT related to the working angle θ based on the current value V1 of the operation speed V, the current value L3D of the separation distance L, and the database storing the correspondence illustrated in FIG. 6B. Then, the working angle control unit 30D executes control to make the working angle θ coincide with the value θ3D of the target angle θT. To be specific, the working angle control unit 30D outputs a control command to at least one of the proportional valves 31CL and 31CR to open and close the bucket 6, thereby causing the working angle θ to coincide with the value θ3D of the target angle θT. The working angle control unit 30D may cause the working angle θ to coincide with the value θ3 of the target angle θT by executing at least one of raising and lowering the boom 4, opening and closing the arm 5, and opening and closing the bucket 6.

[0155] At the time t2, the bucket 6 is at the position illustrated in FIG. 9B, and the working angle control unit 30D derives the value θ2D of the target angle θT related to work angle θ based on the current value V1 of the operation speed V, the current value L2D of the separation distance L, and the database storing the correspondence illustrated in FIG. 6B. Then, the working angle control unit 30D executes control to make the working angle θ coincide with the value θ2D of the target angle θT.

[0156] At the time t3, the bucket 6 is at the position illustrated in FIG. 9C, and the working angle control unit 30D derives the value θ1D of the target angle θT related to the work angle θ based on the current value V1 of the operation speed V, the current value L1D of the separation distance L, and the database storing the correspondence illustrated in FIG. 6B. Then, the working angle control unit 30D executes control to make the working angle θ coincide with the value θ1D of the target angle θT.

[0157] Similarly, at the time t4, the bucket 6 is at the position illustrated in FIG. 9D, and the working angle control unit 30D derives the value θ0 of the target angle θT related to the working angle θ based on the current value V1 of the operation speed V, the current value 0 of the separation distance L, and the database storing the correspondence illustrated in FIG. 6B. Then, the working angle control unit 30D executes control to make the working angle θ coincide with the value θ0 of the target angle θT. In the present embodiment, when the working angle θ is the value θ0, as illustrated in FIG. 9D, the bottom surface of the bucket 6 and the design surface DS coincide with each other (are parallel to each other). Therefore, the operator can expose the design surface DS by pulling the bucket 6 toward the upper turning body 3 while keeping the bucket 6 in the same attitude. However, the value θ0 may be an arbitrary value that is preset or dynamically set by an operator or the like of the shovel 100.

[0158] As described above, the shovel 100 according to the embodiment of the present disclosure includes the lower traveling body 1, the upper turning structure 3 turnably mounted on the lower traveling body 1, the excavation attachment which is an example of the attachment AT attached to the upper turning structure **3**, the attitude detection device (the boom angle sensor S**1**, the arm angle sensor S**2**, the bucket angle sensor S**3**, the machine attitude sensor S**4**, and the turning angle sensor S**5**) which detects the attitude of the attachment AT, and the controller **30** as a control device for calculating the target angle θT related to the working angle θ formed by a plane or a line determined based on the shape of the bucket **6** included in the attachment AT (for example, the virtual plane BS containing the opening plane of the bucket **6** in FIG. **6**A) and the designed surface DS. The controller **30** is configured to change the target angle θT according to the attitude of the attachment AT and the information about the design surface DS. The information about the design surface DS is, for example, information about the position of the design surface DS.

[0159] According to this configuration, since the working angle θ of the attachment AT can be automatically adjusted, a smoother work can be realized. For example, with this configuration, even in a case where a horizontal pulling operation is performed in which the bucket **6** is pulled horizontally toward the machine side along a horizontally extending target trajectory (design surface DS), when the bucket **6** is brought closer to the target trajectory (design surface DS) in the vertical direction, the attitude of the claw tip **6**A of the bucket **6** can be set to an attitude in which the bucket **6** is easily stuck into the ground. Therefore, in this configuration, even when earth and sand remain on the design surface DS, the claw tip **6**A of the bucket **6** can be caused to penetrate into the earth and sand at an appropriate penetration angle. In this configuration, the direction of the claw tip **6**A is gradually brought closer to the horizontal direction after the claw tip **6**A is penetrated into the earth and sand, and when the claw tip **6**A and the design surface DS coincide with each other, the claw tip **6**A can be directed to the horizontal direction. That is, this configuration can control the attitude of the attachment AT such that the angle formed between the bottom surface of the bucket **6** and the design surface DS decreases as the bucket **6** approaches the design surface DS, and can further control the attitude of the attachment AT such that the bottom surface of the bucket **6** and the design surface DS become parallel to each other when the claw tip **6**A and the design surface DS coincide with each other. In this way, with this configuration, it is possible to prevent the function of turning the claw tip **6**A of the bucket **6** horizontally for the horizontal pulling work from becoming an obstacle when excavating the earth and sand remaining on the design surface DS.

[0160] The controller **30** may be configured to change the target angle θT in accordance with the distance (separation distance L) between the bucket **6** and the design surface DS. Further, the controller **30** may be configured to change the target angle θT according to the operation speed V of the bucket **6**. The controller **30** may be configured to change the target angle θT regardless of the operation speed V of the bucket **6**.

[0161] Further, the controller **30** may be configured to execute control for causing the working angle θ to track the target angle θT. For example, the controller **30** may be configured to control the attachment AT such that the bucket **6** located at a position higher than the design surface DS is closed as the bucket **6** approaches the design surface DS, as illustrated in FIGS. **7**A to **7**D. Specifically, the controller **30** may automatically extend the bucket cylinder **9** so that the bucket **6** is closed as the bucket **6** at a position higher than the design surface DS approaches the design surface DS. Alternatively, the controller **30** may automatically close the arm **5** so that the bucket **6** is closed as the bucket **6** at a position higher than the design surface DS approaches the design surface DS. Alternatively, the controller **30** may automatically close each of the arm **5** and the bucket **6** so that the bucket **6** is closed as the bucket **6** at a position higher than the design surface DS approaches the design surface DS.

[0162] The controller **30** may control the attachment AT such that the bucket **6** is opened as the bucket **6** located at a position lower than the design surface DS approaches the design surface DS, as illustrated in FIGS. **9**A to **9**D. For example, the controller **30** may automatically contract the bucket cylinder **9** so that the bucket **6** is opened as the bucket **6** at a position lower than the design surface DS approaches the design surface DS. Alternatively, the controller **30** may automatically open the arm **5** so that the bucket **6** is opened as the bucket **6** at a position lower than the design surface DS approaches the design surface DS. Alternatively, the controller **30** may automatically open each of the arm **5** and the bucket **6** so that the bucket **6** is opened as the bucket **6** at a position lower than the design surface DS approaches the design surface DS. This configuration brings about an effect that the claw tip **6**A can be smoothly returned to the target trajectory (design surface DS) when the claw tip **6**A is dug excessively from the design surface DS, that is, when the claw tip **6**A deviates downward from the target trajectory (design surface DS), for example. Further, this configuration brings about an effect that further over-digging can be prevented.

[0163] Next, another embodiment will be described with reference to the drawings.

[0164] For example, there is known a technique of changing an angle of a bucket in accordance with a work environment (hardness of ground to be excavated).

[0165] However, in the conventional technique, the angle of the bucket is only automatically changed. Therefore, for example, when a machine control (MC) function causes an attachment to perform an excavation operation in a fully automatic or semi-automatic manner, it is necessary to set a target trajectory of a bucket in accordance with a work environment.

[0166] Therefore, it is desirable to provide a technique capable of easily setting a target trajectory of a bucket during excavation by a shovel.

[0167] The shovel **100** according to another embodiment described below can easily set the target trajectory of the bucket **6** during excavation.

Overview of Shovel

[0168] First, an overview of a shovel **100** according to another embodiment will be described with reference to FIGS. **1** and **2**.

[0169] FIGS. **1** and **2** are a top view and a side view, respectively, of the shovel **100** according to another embodiment.

[0170] As illustrated in FIGS. **1** and **2**, the shovel **100** according to another embodiment includes a lower traveling body **1**, an upper turning body **3** mounted on the lower traveling body **1** so as to be turnable via a turning mechanism **2**, an attachment AT for performing various kinds of work, and a cabin **10**. Hereinafter, the front side of the shovel **100** (upper turning body **3**) corresponds to a direction in which the attachment to the upper turning body **3** extends when the shovel **100** is viewed in a plan view (top view) from directly above along the pivot axis of the upper turning body **3**. The left side and the right side of the shovel **100** (the upper turning body **3**) correspond to the left side and the right side as viewed from an operator seated on the cockpit in the cabin **10**, respectively.

[0171] As will be described later, the cabin **10** may be omitted when the shovel **100** is operated by remote control or fully automatic operation.

[0172] The lower traveling body **1** includes, for example, a pair of left and right crawlers **1**C. In particular, the crawler **1**C includes a left crawler **1**CL and a right crawler **1**CR. In the lower traveling body **1**, the left crawler **1**CL and the right crawler **1**CR are hydraulically driven by a left traveling hydraulic motor **2**ML and a right traveling hydraulic motor **2**MR (see FIG. **3**), respectively, so that the shovel **100** travels.

[0173] The upper turning structure **3** turns with respect to the lower traveling body **1** by the turning mechanism **2** being hydraulically driven by the turning hydraulic motor **2**A.

[0174] The attachment AT (an example of a work attachment) includes a boom **4**, an arm **5**, and a bucket **6**.

[0175] The boom **4** is attached to the center of the front portion of the upper turning body **3** so as to be able to rise and fall, the arm **5** is attached to the distal end of the boom **4** so as to be able to rotate up and down, and the bucket **6** is attached to the distal end of the arm **5** so as to be able to rotate up and down.

[0176] The bucket **6** is an example of an end attachment. The bucket **6** is used for, for example, excavation work or the like. In addition, instead of the bucket **6**, another end attachment may be attached to the distal end of the arm **5** depending on the work content or the like. The other end attachments may be other types of buckets such as, for example, large buckets, slope buckets, dredging buckets, or the like. In addition, the other end attachment may be an end attachment of a type other than a bucket, such as an agitator, a breaker, or a grapple.

[0177] The boom **4**, the arm **5**, and the bucket **6** are hydraulically driven by a boom cylinder **7**, an arm cylinder **8**, and a bucket cylinder **9** as hydraulic actuators, respectively.

[0178] It should be noted that the shovel **100** may be configured such that some of the driven elements such as the lower traveling body **1**, the upper turning body **3**, the boom **4**, the arm **5**, and the bucket **6** are electrically driven. That is, the shovel **100** may be a hybrid shovel, an electric shovel, or the like in which a part of driven elements is driven by an electric actuator.

[0179] The cabin **10** is a cockpit in which an operator rides, and is mounted on the front left side of the upper turning body **3**.

[0180] As will be described later, the cabin **10** may be omitted when the shovel **100** is operated by remote control or fully automatic operation.

[0181] The shovel **100** may be equipped with, for example, a communication device T**1**, and may be capable of communicating with an external device via a predetermined communication line.

[0182] The communication line includes, for example, a wide area network (WAN). The wide area network may include, for example, a mobile communication network terminated by a base station. The wide area network may include, for example, a satellite communication network that uses a communication satellite above the shovel **100**. The wide area network may include, for example, the Internet. In addition, the communication line may include, for example, a local area network (LAN) of a facility or the like in which the external device is installed. The local network may be a wireless line, a wired line, or a line including both of them. The communication line may include, for example, a short-range communication line based on a predetermined wireless communication scheme such as WiFi or Bluetooth (registered trademark).

[0183] The external device is, for example, a management device that manages (monitors) a working state, an operation state, and the like of the shovel **100**. Accordingly, the shovel **100** can transmit (upload) various types of information to the management device and receive various types of signals (for example, information signals and control signals) and the like from the management device.

[0184] The management device is, for example, a cloud server or an on-premise server installed in a remote place different from the work site of the shovel **100**. In addition, the management device may be, for example, an edge server installed inside the work site of the shovel **100** (for example, an administrative office of the work site or the like) or at a place relatively close to the work site (for example, communication facilities such as nearby base stations). Further, the management device may be a terminal device for management used in a work site.

[0185] The external device may be, for example, a terminal device (user terminal) used by a user of the shovel **100**. The user of the shovel **100** includes, for example, an operator, a serviceman, a manager, an owner, and the like of the shovel **100**. As a result, the shovel **100** can transmit various kinds of information to the user terminal and provide the user of the shovel **100** with information on the shovel **100**.

[0186] The shovel **100** operates an actuator (for example, a hydraulic actuator) in accordance with an operation of an operator who rides in the cabin **10**, and drives operation elements (hereinafter, “driven elements”) such as the lower traveling body **1**, the upper turning body **3**, the boom **4**, the arm **5**, the bucket **6**, and the like.

[0187] Further, instead of or in addition to being configured to be operable by the operator of the cabin **10**, the shovel **100** may be configured to be remotely operable from the outside of the shovel **100**. When the shovel **100** is remotely operated, the inside of the cabin **10** may be in an unmanned state. Hereinafter, description will be made on the assumption that the operation of the operator includes at least one of an operation on the operation device **26** by the operator of the cabin **10** and a remote operation by an external operator.

[0188] The remote operation includes, for example, an aspect in which the shovel **100** is operated by an input from a user (operator) regarding an actuator of the shovel **100** performed by a predetermined external device (for example, the above-described management device). In this case, for example, the shovel **100** may transmit image information (hereinafter, “peripheral image”) of the periphery of the shovel **100** based on an output of a space recognition device **70** (imaging device) described later to the external device, and the image information may be displayed on a display device (hereinafter, “display device for remote operation”) provided in the external device. Various information images (information screens) displayed on the display device D**1** in the cabin **10** of the shovel **100** may also be displayed on the remote control display device of the external device. Accordingly, the operator of the external device can remotely operate the shovel **100** while checking display contents such as a peripheral image representing a state of the periphery of the shovel **100** and various information images displayed on the remote operation display device, for example. Then, the shovel **100** may operate the actuator in accordance with a remote operation signal indicating the content of the remote operation received from the external device and drive the driven elements such as the lower traveling body **1**, the upper turning body **3**, the boom **4**, the arm **5**, the bucket **6**, and the like.

[0189] The remote operation may include, for example, an aspect in which the shovel **100** is operated by a voice input, a gesture input, or the like from the outside to the shovel **100** by a person (for example, an operator) around the shovel **100**. Specifically, the shovel **100** recognizes a voice uttered by a nearby worker or the like, a gesture performed by the worker or the like, through a voice input device (for example, a microphone), an imaging device, or the like mounted on the shovel **100** (reference machine). Then, the shovel **100** may operate the actuator in accordance with the content of the recognized voice, gesture, or the like to drive the driven elements such as the lower traveling body **1**, the upper turning body **3**, the boom **4**, the arm **5**, the bucket **6**, and the like.

[0190] In addition, the shovel **100** may automatically operate the actuator regardless of the content of the operation by the operator. Thus, the shovel **100** realizes a function of automatically operating at least a part of the driven elements such as the lower traveling body **1**, the upper turning body **3**, the boom **4**, the arm **5**, the bucket **6**, and the like that is, a so-called "automatic operation function" or "machine control function".

[0191] The automatic operation function may include a function of automatically operating a driven element (actuator) other than the driven element (actuator) to be operated in response to an operator's operation or remote operation on the operation device **26**, that is, a so-called "semi-automatic operation function" or "operation-assisted machine control function". In addition, the automatic operation function may include a function of automatically operating at least a part of a plurality of driven elements (hydraulic actuators) on the assumption that there is no operation or remote operation of the operation device **26** by the operator, that is, a so-called "fully automatic operation function" or "fully automatic machine control function". When the fully automated driving function is enabled in the shovel **100**, the inside of the cabin **10** may be in an unmanned state. In addition, the semi-autonomous driving function, the fully autonomous driving function, or the like may include an aspect in which the operation content of a driven element (actuator) that is a target of autonomous driving is automatically determined in accordance with a rule defined in advance. In addition, the semi-autonomous driving function, the fully autonomous driving function, or the like may include an aspect (so-called "autonomous driving function") in which the shovel **100** autonomously performs various determinations and the operation content of a driven element (hydraulic actuator), which is a target of autonomous driving, is autonomously determined according to the determination result.

Configuration of Shovel

[0192] Next, the configuration of the shovel **100** will be described with reference to FIGS. **3** and **10** in addition to FIGS. **1** and **2**.

[0193] FIG. **3** is a diagram illustrating an example of a configuration of a hydraulic system of the shovel **100** according to another embodiment. FIG. **10** is a diagram illustrating an example of a configuration of a control system of the shovel **100** according to another embodiment.

[0194] The shovel **100** includes components such as a hydraulic drive system related to hydraulic drive of a driven element, an operation system related to operation of the driven element, a user interface system related to exchange of information with a user, a communication system related to communication with the outside, and a control system related to various controls.

Hydraulic Drive System

[0195] As illustrated in FIG. **3**, the hydraulic drive system of the shovel **100** according to another embodiment includes hydraulic actuators that hydraulically drive the respective driven elements such as the lower traveling body **1** (the left crawler **1**CL and the right crawler **1**CR), the upper turning body **3**, the boom **4**, the arm **5**, the bucket **6**, and the like as described above. The hydraulic actuators include a left traveling hydraulic motor **2**ML, a right traveling hydraulic motor **2**MR, a turning hydraulic motor **2**A, a boom cylinder **7**, an arm cylinder **8**, a bucket cylinder **9**, and the like. Further, the hydraulic drive system of the shovel **100** according to another embodiment includes the engine **11**, the regulator **13**, the main pump **14**, and the control valve unit **17**.

[0196] The engine **11** is a prime mover and is a main power source in the hydraulic drive system. The engine **11** is, for example, a diesel engine that uses light oil as fuel. The engine **11** is mounted on, for example, a rear portion of the upper turning body **3**. The engine **11** constantly rotates at a preset target rotation speed under direct or indirect control by a controller **30** described later, and drives the main pump **14** and the pilot pump **15**.

[0197] Instead of or in addition to the engine **11**, another prime mover may be mounted on the shovel **100**. The other prime mover is, for example, an electric motor capable of driving the main pump **14** and the pilot pump **15**.

[0198] The regulator **13** controls (adjusts) the discharge amount of the main pump **14** under the control of the controller **30**. For example, the regulator **13** adjusts an angle of a swash plate of the main pump **14** (hereinafter, referred to as a "tilt angle") in response to a control command from the controller **30**. The regulators **13** include, for example, a left regulator **13**L and a right regulator **13**R corresponding to a left main pump **14**L and a right main pump **14**R described later, respectively.

[0199] The main pump **14** supplies hydraulic oil to the control valve unit **17** through a high-pressure hydraulic line. The main pump **14** is mounted on the rear portion of the upper turning body **3**, for example, similarly to the engine **11**. As described above, the main pump **14** is driven by the engine **11**. The main pump **14** is, for example, a variable displacement hydraulic pump, and as described above, under the control of the controller **30**, the tilting angle of the swash plate is adjusted by the regulator **13** to adjust the stroke length of the piston, thereby controlling the discharge flow rate (discharge pressure). The main pump **14** includes, for example, a left main pump **14**L and a right main pump **14**R.

[0200] The control valve unit **17** is a hydraulic control device that controls the hydraulic actuator in accordance with the content of an operation or a remote operation performed on the operation device **26** by an operator or an operation command related to an automatic operation function output from the controller **30**. The control valve unit **17** is mounted on, for example, a central portion of the upper turning body **3**. As described above, the control valve unit **17** is connected to the main pump **14** via the high-pressure hydraulic line, and selectively supplies the hydraulic oil supplied from the main pump **14** to each of the hydraulic actuators in accordance with an operation of an operator or an operation command output from the controller **30**. Specifically, the control valve unit **17** includes a plurality of control valves (also referred to as "direction switching valves") **171** to **176** that control the flow rate and the flow direction of the hydraulic oil supplied from the main pump **14** to each of the hydraulic actuators.

[0201] As illustrated in FIG. **3**, in the hydraulic drive system, the hydraulic oil is circulated from each of the left main pump **14**L and the right main pump **14**R driven by the engine **11** to the hydraulic oil tank via the left center bypass oil passage **40**L, the right center bypass oil passage **40**R, the left parallel oil passage **42**L, and the right parallel oil passage **42**R.

[0202] The left center bypass oil passage **40**L starts from the left main pump **14**L, sequentially passes through the control valves **171**, **173**, **175**L, and **176**L disposed in the control valve unit **17**, and reaches the hydraulic oil tank.

[0203] The right center bypass oil passage **40**R starts from the right main pump **14**R, sequentially passes through the control valves **172**, **174**, **175**R, and **176**R disposed in the control valve unit **17**, and reaches the hydraulic oil tank.

[0204] The control valve **171** is a spool valve that supplies the hydraulic oil discharged from the left main pump **14**L to the left traveling hydraulic motor **2**ML and discharges the hydraulic oil discharged from the left traveling hydraulic motor **2**ML to the hydraulic oil tank.

[0205] The control valve **172** is a spool valve that supplies the hydraulic oil discharged from the right main pump **14**R to the right traveling hydraulic motor **2**MR and discharges the hydraulic oil discharged from the right traveling hydraulic motor **2**MR to the hydraulic oil tank.

[0206] The control valve **173** is a spool valve that supplies the hydraulic oil discharged from the left main pump **14**L to the turning hydraulic motor **2**A and discharges the hydraulic oil discharged from the turning hydraulic motor **2**A to the hydraulic oil tank.

[0207] The control valve **174** is a spool valve that supplies the hydraulic oil discharged from the right main pump **14**R to the bucket cylinder **9** and discharges the hydraulic oil in the bucket cylinder **9** to the hydraulic oil tank.

[0208] The control valve **175** includes control valves **175**L and **175**R. The control valves **175**L and **175**R are spool valves that supply the hydraulic oil discharged from the left main pump **14**L and the right main pump **14**R to the boom cylinder **7** and discharge the hydraulic oil in the boom cylinder **7** to the hydraulic oil tank.

[0209] The control valve **176** includes control valves **176**L and **176**R. The control valves **176**L and **176**R are spool valves that supply the hydraulic oil discharged from the left main pump **14**L and the right main pump **14**R to the arm cylinder **8** and discharge the hydraulic oil in the arm cylinder **8** to the hydraulic oil tank.

[0210] Each of the control valves **171**, **172**, **173**, **174**, **175**L, **175**R, **176**L, and **176**R adjusts the flow rate of the hydraulic oil supplied to and discharged from the hydraulic actuators or switches the flow direction in accordance with the pilot pressure acting on the pilot port.

[0211] The left parallel oil passage **42**L supplies the hydraulic oil of the left main pump **14**L to the control valves **171**, **173**, **175**L, and **176**L in parallel with the left center bypass oil passage **40**L. To be specific, the left parallel oil passage **42**L is branched from the left center bypass oil passage **40**L on the upstream side of the control valve **171**, and is configured to be able to supply the hydraulic oil of the left main pump **14**L in parallel to each of the control valves **171**, **173**, **175**L, and **176**R. Accordingly, when the flow of the hydraulic oil passing through the left center bypass oil passage **40**L is limited or blocked by any one of the control valves **171**, **173**, and **175**L, the left parallel oil passage **42**L can supply the hydraulic oil to the control valve further downstream.

[0212] The right parallel oil passage **42**R supplies the hydraulic oil of the right main pump **14**R to the control valves **172**, **174**, **175**R, and **176**R in parallel with the right center bypass oil passage **40**R. To be specific, the right parallel oil passage **42**R is branched from the right center bypass oil passage **40**R on the upstream side of the control valve **172**, and is configured to be able to supply the working oil of the right main pump **14**R in parallel to each of the control valves **172**, **174**, **175**R, and **176**R. When the flow of the hydraulic oil passing through the right center bypass oil passage **40**R is limited or blocked by any one of the control valves **172**, **174**, and **175**R, the right parallel oil passage **42**R can supply the hydraulic oil to the control valve further downstream.

[0213] In the left center bypass oil passage **40**L and the right center bypass oil passage **40**R, a left throttle **18**L and a right throttle **18**R are provided between the most downstream control valves **176**L and **176**R and the hydraulic oil tank, respectively. Accordingly, the flow of the hydraulic oil discharged by the left main pump **14**L and the right main pump **14**R is limited by the left throttle **18**L and the right throttle **18**R. The left throttle **18**L and the right throttle **18**R generate control pressures for controlling the left regulator **13**L and the right regulator **13**R.

Operation System

[0214] As illustrated in FIGS. **3** and **10**, the operation system of the shovel **100** according to another embodiment includes the pilot pump **15**, the operation device **26**, the hydraulic control valve **32**, and the hydraulic control valve **33**.

[0215] The pilot pump **15** supplies a pilot pressure to various hydraulic devices via a pilot line **25**. The pilot pump **15** is mounted on, for example, a rear portion of the upper turning body **3** similarly to the engine **11**. The pilot pump **15** is, for example, a fixed displacement hydraulic pump, and is driven by the engine **11** as described above.

[0216] It should be noted that the pilot pump **15** may be omitted. In this case, a relatively low-pressure hydraulic oil obtained by reducing the pressure of a relatively high-pressure hydraulic oil discharged from the main pump **14** by a predetermined pressure reducing valve is supplied to various hydraulic devices as a pilot pressure.

[0217] The operation device **26** is provided in the vicinity of a cockpit of the cabin **10** and is used by an operator to operate various driven elements (the lower traveling body **1**, the upper turning body **3**, the boom **4**, the arm **5**, the bucket **6**, and the like). In other words, the operation device **26** is used by the operator to operate the hydraulic actuators that drive the respective driven elements (that is, the left traveling hydraulic motor **2**ML, the right traveling hydraulic motor **2**MR, the turning hydraulic motor **2**A, the boom cylinder **7**, the arm cylinder **8**, the bucket cylinder **9**, and the like).

[0218] As illustrated in FIG. **3**, the operation device **26** is, for example, a hydraulic pilot type. The operation device **26** is connected to the control valve unit **17** via a shuttle valve (not illustrated) provided in a pilot line on the secondary side of the operation device **26**. Thus, the pilot pressure corresponding to the operation state of each driven element in the operation device **26**, that is, each hydraulic actuator can be input to the control valve unit **17** via the shuttle valve. Therefore, the control valve unit **17** can drive each driven element (hydraulic actuator) in accordance with the operation state of the operation device **26**. The operation device **26** includes a left operation lever **26**L and a right operation lever **26**R for operating the arm **5** (arm cylinder **8**) and the upper turning body **3** (turning hydraulic motor **2**A), and the boom **4** (boom cylinder **7**) and the bucket **6** (bucket cylinder **9**). The operation device **26** includes a traveling lever **26**D for operating the lower traveling body **1**. The traveling lever **26**D includes a left traveling lever **26**DL for operating the left crawler **1**CL and a right traveling lever **26**DR for operating the right crawler **1**CR.

[0219] The left operation lever **26**L is used for a turning operation of the upper turning body **3** and an operation of the arm **5**.

[0220] Operations of the left operation lever **26**L in the forward direction and the rearward direction as viewed from the operator in the cabin **10** (that is, the forward direction and the rearward direction of the upper turning body **3**) correspond to operations of the arm **5** in the opening direction and the closing direction, respectively. When the left operation lever **26**L is operated in the forward direction, the control pressure (pilot pressure) corresponding to the lever operation amount is output to the pilot line on the secondary side corresponding to the arm opening operation, using hydraulic oil discharged from the pilot pump **15**. Further, when the left operation lever **26**L is operated in the backward direction, the pilot pressure corresponding to the lever operation amount is output to the pilot line on the secondary side corresponding to the arm closing operation using the hydraulic oil discharged from the pilot pump **15**. The pilot lines on the secondary side of the left operation lever **26**L corresponding to arm opening and arm closing are connected to pilot ports corresponding to arm opening and arm closing of the control valves **176**L and **176**R via shuttle valves (not illustrated) for arm opening and arm closing, respectively.

[0221] Operations of the left operation lever **26**L in the left direction and the right direction as viewed from the operator in the cabin **10** (that is, the left direction and the right direction of the upper turning body **3**) correspond to operations of the left turning and the right turning of the upper turning body **3**, respectively. When the left operation lever **26**L is operated in the left direction, the left operation lever **26**L uses the hydraulic oil discharged from the pilot pump **15** to output a pilot pressure corresponding to the lever operation amount to the pilot line on the secondary side corresponding to the left turning of the upper turning body **3**. When the left operation lever **26**L is operated in the right direction, the left operation lever **26**L outputs a pilot pressure corresponding to the lever operation amount to the pilot line on the secondary side corresponding to the right turning of the upper turning body **3** by using the hydraulic oil discharged from the pilot pump **15**. The pilot lines on the secondary side of the left operation lever **26**L corresponding to the left turning and the right turning of the upper turning body **3** are connected to pilot ports corresponding to the left turning and the right turning of the control valve **173** via shuttle valves (not illustrated) for left turning and right turning, respectively.

[0222] The right operation lever **26**R is used to operate the boom **4** and the bucket **6**.

[0223] Operations of the right operation lever **26**R in the forward direction and the backward direction correspond to operations of the boom **4** in the lowering direction and the raising direction, respectively. When the right operation lever **26**R is operated in the forward direction, the right operation lever **26**R uses the hydraulic oil discharged from the pilot pump **15** to output the pilot pressure corresponding to the lever operation amount to the pilot line on the secondary side corresponding to the boom lowering operation. When the right operation lever **26**R is operated in the rearward direction, the right operation lever **26**R outputs a pilot pressure corresponding to the lever operation amount to the pilot line on the secondary side corresponding to the boom raising operation by using the hydraulic oil discharged from the pilot pump **15**. The pilot lines on the secondary side of the right operation lever **26**R corresponding to boom raising and boom lowering are connected to pilot ports corresponding to boom raising and boom lowering of the control valves **175**L and **175**R via shuttle valves (not illustrated) for boom raising and boom lowering, respectively.

[0224] Operations of the right operation lever **26**R in the left direction and the right direction correspond to operations of the bucket **6** in the closing direction and the opening direction, respectively. When the right operation lever **26**R is operated in the left direction, the pilot pressure corresponding to the lever operation amount is output to the pilot line on the secondary side corresponding to the bucket closing operation by using the hydraulic oil discharged from the pilot pump **15**. When the right operation lever **26**R is operated in the right direction, the pilot pressure corresponding to the lever operation amount is output to the pilot line on the secondary side corresponding to the bucket opening operation by using the hydraulic oil discharged from the pilot pump **15**. The pilot lines on the secondary side of the right operation lever **26**R corresponding to bucket closing and bucket opening are connected to pilot ports corresponding to bucket closing and bucket opening of the control unit **174** via shuttle valves (not illustrated) for bucket closing and bucket opening, respectively.

[0225] As described above, the left traveling lever **26**DL is used to operate the left crawler **1**CL. The left traveling lever **26**DL may be configured to interlock with a left traveling pedal (not illustrated). The operation of the left traveling lever **26**DL in the forward direction and the rearward direction corresponds to the operation of the left crawler **1**CL in the forward movement and the rearward movement, respectively. When the left traveling lever **26**DL is operated in the forward direction, the left traveling lever **1**CL uses the hydraulic oil discharged from the pilot pump **15** to output a pilot pressure corresponding to the lever operation amount to the pilot line on the secondary side corresponding to the forward movement operation of the left crawler **1**CL. When the left traveling lever **26**DL is operated in the rearward direction, the left traveling lever **26**DL uses the hydraulic oil discharged from the pilot pump **15** to output a pilot pressure corresponding to the lever operation amount to the pilot line on the secondary side corresponding to the rearward movement operation of the left crawler **1**CL. The pilot lines on the secondary side of the left traveling lever **26**DL corresponding to forward travel and backward travel of the left crawler **1**CL are connected to pilot ports corresponding to left forward travel and left backward travel of the control valve **171** via shuttle valves (not illustrated) for left forward travel and left backward travel, respectively.

[0226] As described above, the right traveling lever **26**DR is used to operate the right crawler **1**CR. The right traveling lever **26**DR may be configured to interlock with a right traveling pedal which is not illustrated. Operations of the right traveling lever **26**DR in the forward direction and the rearward direction correspond to operations of the right crawler **1**CR in the forward movement and the rearward movement, respectively. When the right traveling lever **26**DR is operated in the forward direction, the right traveling lever **26**DR uses the hydraulic oil discharged from the pilot pump **15** to output a pilot pressure corresponding to the lever operation amount to the pilot line on the secondary side corresponding to the forward movement operation of the right crawler **1**CR. When the right traveling lever **26**DR is operated in the rearward direction, the right traveling lever **26**DR outputs a pilot pressure corresponding to the lever operation amount to the pilot line on the secondary side corresponding to the rearward movement operation of the right crawler **1**CR by using the hydraulic oil discharged from the pilot pump **15**. The pilot lines on the secondary side of the right traveling lever **26**DR corresponding to forward travel and backward travel of the right crawler **1**CR are connected to pilot ports corresponding to right forward travel and right backward travel of the control valve **171** via shuttle valves (not illustrated) for right forward travel and right backward travel, respectively.

[0227] The hydraulic control valve **32** is provided in a pilot line connecting between the pilot pump **15** and the above-described shuttle valve. The hydraulic control valve **32** outputs a pilot pressure corresponding to a control command (control current) from the controller **30** to the pilot line on the secondary side by using the hydraulic oil discharged from the pilot pump **15**. The hydraulic control valve **32** is, for example, an electromagnetic proportional valve configured to be able to change a flow path area thereof in response to a control command (control current) from the controller **30**. The pilot line on the secondary side of the hydraulic control valve **32** is connected to the control valve unit **17** (pilot ports of the control valves **171** to **176**) through the above-described shuttle valve. A pilot line on the secondary side of the operation device **26** is connected to one inlet port of the shuttle valve, and a pilot line on the secondary side of the hydraulic control valve **32** is connected to the other inlet port. Thus, the controller **30** can cause the pilot pressure of the hydraulic control valve **32** to act on the control valve unit **17** via the shuttle valve by causing the hydraulic control valve **32** to output a pilot pressure greater than the pilot pressure on the secondary side of the operation device **26**. Therefore, the controller **30** can drive the hydraulic actuator regardless of the operation of the operation device **26**.

[0228] The operation device **26** (the left operation lever **26**L, the right operation lever **26**R, the left traveling lever **26**DL, and the right traveling lever **26**DR) may be an electric type that outputs an electric signal (hereinafter, "operation signal") corresponding to an operation content. In this case, the above-described shuttle valve may be omitted, and the output (operation signal) of the operation device **26** may be taken into the controller **30**, for example, and the controller **30** may output a control command corresponding to the operation signal, that is, a control command corresponding to the operation content of the operation device **26** to the hydraulic control valve **32**. The hydraulic control valve **32** may output the pilot pressure corresponding to the control command from the controller **30** by using the hydraulic oil supplied from the pilot pump **15**, and directly apply the pilot pressure to the pilot port of the control valve corresponding to the operation content of the control valve unit **17**. As a result, the controller **30** can control the hydraulic control valve **32** to reflect the operation content of the operation device **26** on the operation of the control valve unit **17**. Therefore, the controller **30** can realize operations of various driven elements in accordance with the operation content of the electric operation device **26**.

[0229] In addition, for example, the controller **30** may realize remote control of the shovel **100** using the hydraulic control valve **32**. Specifically, the controller **30** may output a control command corresponding to the content of the remote operation designated by the remote operation signal received from the external device to the hydraulic control valve **32**. The hydraulic control valve **32** may output the pilot pressure corresponding to the control command from the controller **30** using the hydraulic oil supplied from the pilot pump **15**, and apply the pilot pressure to the pilot port of the control valve of the control valve unit **17** corresponding to the control command. As a result, the controller **30** can control the hydraulic control valve **32** and reflect the content of the remote operation on the operation of the control valve unit **17**. Therefore, the shovel **100** can realize operations of various driven elements in accordance with the content of the remote operation by the hydraulic actuator.

[0230] Further, for example, the controller **30** may control the hydraulic control valve **32** to realize an automatic operation function. Specifically, the controller **30** outputs a control signal corresponding to an operation command related to the automatic operation function to the hydraulic control valve **32** regardless of whether or not the operation device **26** is operated. As a result, the controller **30** causes the hydraulic control valve **32** to supply the pilot pressure corresponding to the operation command related to the automatic operation function to the control valve unit **17**, and can realize the operation of the shovel **100** based on the automatic operation function.

[0231] The hydraulic control valve **32** is provided for each driven element (hydraulic actuator) to be operated by the operation device **26** and for each operating direction of the driven element. That is, two hydraulic control valves **32**

corresponding to two operation directions are provided for each of the plurality of hydraulic actuators. For example, the arm closing and arm opening hydraulic control valves **32** are connected to the other inlet ports of the arm closing and arm opening shuttle valves described above, respectively. Further, for example, the hydraulic control valves **32** for left turning and right turning are connected to the other inlet ports of the hydraulic control valves **32** for left turning and right turning, respectively. Further, for example, the hydraulic control valves **32** for boom raising and boom lowering are connected to the other inlet ports of the hydraulic control valves **32** for boom raising and boom lowering, respectively. For example, the hydraulic control valve **32** for bucket closing and bucket opening is connected to the other inlet port of the shuttle valve for bucket closing and bucket opening described above. Further, for example, the hydraulic control valves **32** for left forward movement and left backward movement are connected to the other inlet ports of the shuttle valves for left forward movement and right backward movement, respectively. Further, for example, the hydraulic control valve **32** for right forward movement and right backward movement is connected to the other inlet port of the hydraulic control valve **32** for right forward movement and right backward movement.

[0232] When the operation device **26** is an electric type, the control valves **171** to **176** of the control valve unit **17** may be electromagnetic solenoid type spool valves. In this case, the hydraulic control valve **32** is omitted, and the output (operation signal) of the operation device **26** is directly input to the electromagnetic solenoid type spool valve.

[0233] The hydraulic control valve **33** is provided in a pilot line connecting the operation device **26** and the above-described shuttle valve. The hydraulic control valve **33** operates in response to a control command input from the controller **30**. The hydraulic control valve **33** is, for example, an electromagnetic proportional valve configured to be able to change a flow path area thereof in response to a control command (control current) from the controller **30**. Thus, when the operation device **26** is operated by the operator, the controller **30** can forcibly reduce the pilot pressure output from the operation device **26**. Therefore, even when the operation device **26** is operated, the controller **30** can forcibly decelerate or stop the operation of the hydraulic actuator corresponding to the operation of the operation device **26**. For example, when the operation device **26** is operated, the controller **30** can reduce the pilot pressure output from the operation device **26** to be lower than the pilot pressure output from the hydraulic pressure control valve **32**. Therefore, by controlling the hydraulic pressure control valve **32** and the hydraulic pressure control valve **33**, the controller **30** can reliably apply a desired pilot pressure to the pilot port of the control valve of the control valve unit **17** regardless of the operation content of the operation device **26**, for example. Therefore, for example, the controller **30** can more appropriately realize the automatic operation function and the remote operation function of the shovel **100** by controlling the hydraulic control valve **33** in addition to the hydraulic control valve **32**.

[0234] When the operation device **26** is of an electric type, the hydraulic control valve **33** may be omitted.

User Interface System

[0235] As illustrated in FIGS. **3** and **10**, the user interface system of the shovel **100** according to another embodiment includes the operation device **26**, the input device **72**, the display device D**1**, the sound outputting device D**2**, and the switch NS.

[0236] The input device **72** is provided in a range close to an operator seated in the cabin **10**, receives various inputs from the operator, and a signal corresponding to the received input is taken into the controller **30**.

[0237] For example, the input device **72** is an operation input device that receives an operation input. The operation input device may include a touch panel mounted on the display device D**1**, a touch pad, a button switch, a lever, a toggle provided around the display device D**1**, and a knob switch and the like provided in the operation device **26** (lever device).

[0238] In addition, for example, the input device **72** may be a voice input device that receives voice input of an operator. The voice input device includes, for example, a microphone.

[0239] In addition, for example, the input device **72** may be a gesture input device that receives a gesture input of an operator. The gesture input device includes, for example, an imaging device (indoor camera) installed in the cabin **10**.

[0240] The display unit D**1** is provided at a location that is easily visible to the seated operator in the cabin **10**, displays various information images, and outputs various information by a visual method. The display device D**1** is, for example, a liquid-crystal display or an organic electroluminescence (EL) display.

[0241] In addition to the display device, a lighting device or the like capable of outputting various kinds of information by a visual method may be provided inside the cabin **10**. The lighting device is, for example, a warning lamp or the like.

[0242] The sound outputting device D**2** outputs various kinds of information by an auditory method. Examples of the sound outputting device D**2** include a buzzer, an alarm, a speaker, and the like.

[0243] It should be noted that an output device capable of outputting various kinds of information by a method other than the visual method and the auditory method, for example, a tactile method such as vibration of the cockpit may be provided inside the cabin **10**.

[0244] The switch NS is, for example, a push-button switch provided at the tip of the left operation lever **26**L. The operator can operate the left operation lever **26**L while pressing the switch NS. For example, when an operation of the arm **5** of the left operation lever **26**L (that is, a tilting operation of the left operation lever **26**L in the front-rear direction) is performed in a state where the switch NS is pressed, the operation-assisted machine control function may be enabled. For example, when the switch NS is pressed in a state where the machine control function is disabled, the machine control function may be enabled, and when the switch NS is pressed in a state where the machine control function is enabled, the machine control function may be disabled. The switch NS may be provided on the right operation lever **26**R, or may be provided at another position in the cabin **10**. A signal corresponding to the operation state of the switch NS is taken into the controller **30**.

Communication System

[0245] As illustrated in FIG. **12**, the communication system of the shovel **100** according to another embodiment includes a communication device T**1**.

[0246] The communication device T**1** is connected to a predetermined communication line and communicates with a device (for example, a management device) provided separately from the shovel **100**. The device provided separately from the shovel **100** may include a portable terminal device brought into the cabin **10** by the user of the shovel **100** in addition to a device provided outside the shovel **100**. The communication device T**1** may include, for example, a mobile communication module conforming to a standard such as 4th Generation (4G) or 5th Generation (5G). The communication device T**1** may also include, for example, a satellite communications module. In addition, the communication device T**1** may include, for example, a WiFi communication module, a Bluetooth communication module, or the like. In addition, the communication device T**1** may include, for example, a communication module or the like capable of performing wired communication with a device or the like connected through a cable connected to a predetermined connector.

Control System

[0247] As illustrated in FIGS. **3** and **10**, the control system of the shovel **100** according to another embodiment includes a controller **30**. Further, the control system of the shovel **100** according to another embodiment includes the control pressure sensor **19**, the discharge pressure sensor **28**, the operation sensor **29**, the space recognition device **70**, and the position measuring device **73**. A control system of the shovel **100** according to another embodiment includes a boom angle sensor S**1**, an arm angle sensor S**2**, a bucket angle sensor S**3**, a machine attitude sensor S**4**, and a turning angle sensor S**5**.

[0248] The controller **30** (an example of a control device) performs various types of control related to the shovel **100**. The functions of the controller **30** may be realized by arbitrary hardware, a combination of arbitrary hardware and software, or the like. For example, the controller **30** is mainly configured by a computer including a central processing unit (CPU), a memory device such as a random access memory (RAM), a non-volatile auxiliary storage device such as a read only memory (ROM), interface devices for various input and output, and the like. For example, the controller realizes various functions by loading a program installed in the auxiliary storage device into the memory device and executing the program on the CPU.

[0249] For example, the controller **30** controls the left main pump **14**L and the right main pump **14**R.

[0250] To be specific, the controller **30** may control the left regulator **13**L and the right regulator **13**R in accordance with the discharge pressures of the left main pump **14**L and the right main pump **14**R detected by the left discharge pressure sensor **28**L and the right discharge pressure sensor **28**R to adjust the discharge amounts of the left main pump **14**L and the right main pump **14**R. For example, the controller **30** may decrease the discharge amount by controlling the left regulator **13**L and adjusting the swash plate tilt angle of the left main pump **14**L in accordance with an increase in the discharge pressure of the left main pump **14**L. The same applies to the right regulators **13**R. As a result, the controller **30** can perform the total horsepower control of the left main pump **14**L and the right main pump **14**R so that the absorption horsepower of the left main pump **14**L and the right main pump **14**R represented by the product of the discharge pressure and the discharge amount does not exceed the power horsepower of the engine **11**.

[0251] Further, the controller **30** may adjust the discharge amounts of the left main pump **14**L and the right main pump **14**R by controlling the left regulator **13**L and the right regulator **13**R in accordance with the control pressures detected by the left control pressure sensor **19**L and the right control pressure sensor **19**R. For example, the controller **30** decreases the discharge amounts of the left main pump **14**L and the right main pump **14**R as the control pressure increases, and increases the discharge amounts of the left main pump **14**L and the right main pump **14**R as the control pressure decreases.

[0252] In a standby state (see FIG. **3**) in which none of the hydraulic actuators in the shovel **100** is operated, the hydraulic oil discharged from the left main pump **14**L and the right main pump **14**R reaches the left throttle **18**L and the right throttle **18**R through the left center bypass oil passage **40**L and the right center bypass oil passage **40**R. The flow of the hydraulic oil discharged from the left main pump **14**L and the right main pump **14**R increases the control pressure generated upstream of the left throttle **18**L and the right throttle **18**R. As a result, the controller **30** reduces the discharge amounts of the left main pump **14**L and the right main pump **14**R to the allowable minimum discharge amount, and suppresses the pumping loss when the discharged hydraulic oil passes through the left center bypass oil passage **40**L and the right center bypass oil passage **40**R.

[0253] On the other hand, when any of the hydraulic actuators is operated, the hydraulic oil discharged from the left main pump **14**L and the right main pump **14**R flows into the hydraulic actuators to be operated via the control valves corresponding to the hydraulic actuators to be operated. The flow of the hydraulic oil discharged from the left main pump **14**L and the right main pump **14**R reduces or eliminates the amount of the hydraulic oil reaching the left throttle **18**L and the right throttle **18**R to reduce the control pressure generated upstream of the left throttle **18**L and the right throttle **18**R. As a result, the controller **30** can increase the discharge amounts of the left main pump **14**L and the right main pump **14**R, circulate a sufficient amount of hydraulic oil to the hydraulic actuators to be operated, and reliably drive the hydraulic actuators to be operated.

[0254] In addition, the controller **30** controls operation of a hydraulic actuator (driven element) of the shovel **100**, for example, with the hydraulic control valve **32** as a control target.

[0255] Specifically, when the operation device **26** is an electric type, the controller **30** may control the hydraulic control valve **32** as a control target and control the operation of the hydraulic actuator (driven element) of the shovel **100** based on the operation of the operation device **26**.

[0256] Further, the controller **30** may control a remote operation of the hydraulic actuator (driven element) of the shovel **100** with the hydraulic control valve **32** as a control target. That is, the operation of the hydraulic actuator (driven element) of the shovel **100** may include a remote operation of the hydraulic actuator from the outside of the shovel **100**.

[0257] In addition, the controller **30** may control the automatic operation function of the shovel **100** with the hydraulic control valve **32** as a control target. That is, the operation of the hydraulic actuator of the shovel **100** may include an operation command of the hydraulic actuator of the shovel **100** output based on the automatic operation function.

[0258] In addition, the controller **30** controls, for example, a periphery monitoring function. In the periphery monitoring function, entry of a monitoring target object into a predetermined range (hereinafter, referred to as a "monitoring range") around the shovel **100** is monitored based on information acquired by the space recognition device **70**. The process of determining the entry of the monitoring target object into the monitoring range may be performed by the space recognition device **70** or may be performed by the outside (for example, the controller **30**) of the space recognition device **70**. Objects to be monitored may include, for example, people, trucks, other construction equipment, utility poles, suspended loads, pylons, buildings, and the like.

[0259] In addition, the controller **30** controls, for example, an object detection notification function. In the object detection notification function, when it is determined that the object to be monitored is present in the monitoring range by the periphery monitoring function, the presence of the object to be monitored with respect to the operator in the cabin **10** and the periphery of the shovel **100** is notified. The controller **30** may realize the object detection notification function using, for example, the display device D**1** or the sound outputting device D**2**.

[0260] In addition, for example, the controller **30** controls an operation restriction function. In the operation restriction function, for example, when it is determined by the periphery monitoring function that an object to be monitored is present in the monitoring targets, the operation of the shovel **100** is restricted.

[0261] For example, when it is determined that a person is present within a predetermined range (monitoring range) from the shovel **100** based on the information acquired by the space recognition device **70** before the actuator operates, the controller **30** may restrict the operation of the actuator to an inoperable state or an operation in a slow speed state even if the operator operates the operation device **26**. Specifically, when it is determined that a person is present within the monitoring range, the controller **30** can disable the actuator by setting the gate lock valve to the locked state. In the case of an electrical operation device **26**, the actuator can be disabled by disabling the signal from the controller **30** to the hydraulic control valve **32**. The same applies to the case where the hydraulic control valve **32** that outputs a pilot pressure corresponding to a control command from the controller **30** and causes the pilot pressure to act on a pilot port of a corresponding control valve in the control valve unit **17** is used in the operation device **26** of another type. When it is desired to operate the actuator at a very low speed, the control signal from the controller **30** to the hydraulic control valve **32** is limited to a content corresponding to a relatively small pilot pressure, so that the operation of the actuator can be brought into a very low speed state. As described above, when it is determined that the detected object to be monitored is present in the monitoring range, the actuator is not driven even when the operation device **26** is operated, or is driven at an operation speed (slow speed) lower than the operation speed corresponding to the operation input to the operation device **26**. Furthermore, when it is determined that a person is present within the monitoring range while the operator is operating the operation device **26**, the operation of the actuator may be stopped or decelerated regardless of the operation by the operator. Specifically, when it is determined that a person is present within the monitoring range, the actuator may be stopped by setting the gate lock valve to the locked state. When a hydraulic control valve **32** that outputs a pilot pressure corresponding to a control command from the controller **30** and applies the pilot pressure to a pilot port of a corresponding control valve in the control valve is used, the actuator can be disabled or limited to operation in a slow speed state by disabling a signal from the controller **30** to the hydraulic control valve **32** or outputting a deceleration command to the hydraulic control valve **32**. When the detected object to be monitored is a truck, the control related to the stop or deceleration of the actuator may not be performed. For example, the actuator may be controlled to avoid the detected truck. In this way, the type of detected object may be recognized and the actuator may be controlled based on that recognition.

[0262] Further, for example, the controller **30** controls a machine guidance function and a machine control function (automatic operation function). Details will be described later.

[0263] A part of the functions of the controller may be realized by another controller (control device). That is, the functions of the controller **30** may be realized by a plurality of controllers in a distributed manner.

[0264] The control pressure sensor **19** includes a left control pressure sensor **19**L and a right control pressure sensor **19**R. The left control pressure sensor **19**L and the right control pressure sensor **19**R detect control pressures of the left throttle **18**L and the right throttle **18**R, respectively, and detection signals corresponding to the detected control pressures are taken into the controller **30**.

[0265] The discharge pressure sensor **28** includes a left discharge pressure sensor **28**L and a right discharge pressure sensor **28**R. The left discharge pressure sensor **28**L and the right discharge pressure sensor **28**R detect the discharge pressures of the left main pump **14**L and the right main pump **14**R, respectively, and detection signals corresponding to the detected discharge pressures are taken into the controller **30**.

[0266] The operation sensor **29** detects a pilot pressure on the secondary side of the hydraulic pilot type operation device **26**, that is, a pilot pressure corresponding to an operation state of each driven element (hydraulic actuator) in the operation device **26**. A detection signal of a pilot pressure corresponding to an operation state of the lower traveling body **1**, the upper turning body **3**, the boom **4**, the arm **5**, the bucket **6**, and the like in the operation device **26** by the operation sensor **29** is taken into the controller **30**. The operation sensor **29** includes operation sensors **29**LA, **29**LB, **29**RA, **29**RB, **29**DL, and **29**DR.

[0267] The operation sensor **29**LA detects an operation content (for example, an operation direction and an operation amount) in the front-rear direction with respect to the left operation lever **26**L by the operator in the form of a hydraulic oil pressure (hereinafter, referred to as an "operation pressure") of the pilot line on the secondary side of the left operation lever **26**L.

[0268] The operation sensor **29**LB detects an operation content (for example, an operation direction and an operation amount) in the left-right direction with respect to the left operation lever **26**L by the operator in the form of an operation pressure of the pilot line on the secondary side of the left operation lever **26**L.

[0269] The operation sensor **29**RA detects an operation content (for example, an operation direction and an operation amount) in the front-rear direction with respect to the right operation lever **26**R by the operator in the form of an operation pressure of the pilot line on the secondary side of the right operation lever **26**R.

[0270] The operation sensor **29**RB detects an operation content (for example, an operation direction and an operation amount) in the left-right direction with respect to the right operation lever **26**R by the operator in the form of an operation pressure of the pilot line on the secondary side of the right operation lever **26**R.

[0271] The operation sensor **29**DL detects an operation content (for example, an operation direction and an operation amount) in the front-rear direction with respect to the left traveling lever **26**DL by the operator in the form of an operation pressure of the pilot line on the secondary side of the left traveling lever **26**DL.

[0272] The operation sensor **29**DR detects an operation content (for example, an operation direction and an operation amount) in the front-rear direction with respect to the right traveling lever **26**DR by the operator in the form of an operation pressure of the pilot line on the secondary side of the right traveling lever **26**DR.

[0273] The operation content of the operation device **26** (the left operation lever **26**L, the right operation lever **26**R, the left traveling lever **26**DL, and the right traveling lever **26**DR) may be detected by sensors other than the operation sensor **29** (for example, potentiometers attached to the right operation lever **26**R, the left traveling lever **26**DL, and the right traveling lever **26**DR). When the operation device **26** is an electric type, the operation sensor **29** is omitted. In this case, the controller **30** can grasp the operation state of each driven element (hydraulic actuator) based on the operation signal taken in from the electric operation device **26**.

[0274] The space recognition device **70** is configured to recognize an object existing in a three dimensional space around the shovel **100** and to measure (calculate) a positional relationship such as a distance from the space recognition device **70** or the shovel **100** to the recognized object. The space recognition device **70** may include, for example, a distance sensor capable of measuring a distance to an object around the shovel **100**, such as an ultrasonic sensor, a millimeter wave radar, an infrared sensor, or light detecting and ranging (LIDAR). The space recognition device **70** may include, for example, an imaging device such as a monocular camera, a stereo camera, a distance image camera, or a depth camera.

[0275] As illustrated in FIGS. **1** and **2**, the space recognition device **70** includes a front sensor **70**F attached to the front end of the upper surface of the cabin **10**, a rear sensor **70**B attached to the rear end of the upper surface of the upper turning body **3**, a left sensor **70**L attached to the left end of the upper surface of the upper turning body **3**, and a right sensor **70**R attached to the right end of the upper surface of the upper turning body **3**. Further, an upper sensor that recognizes an object present in a space above the upper turning body **3** may be attached to the shovel **100**.

[0276] The position measuring device **73** measures a position and a direction of the upper turning body **3**. The position measuring device **73** is, for example, a global navigation satellite system (GNSS) compass and detects the position and the direction of the upper turning body **3**, and a detection signal corresponding to the position and the direction of the upper turning body **3** is taken into the controller **30**. Further, among the functions of the position measuring device **73**, the function of detecting the direction of the upper turning body **3** may be replaced by a direction sensor attached to the upper turning body **3**.

[0277] The boom angle sensor S**1** acquires detection information related to an attitude angle (hereinafter referred to as a "boom angle") of the boom **4** with respect to a predetermined reference (for example, a horizontal plane, a state of one of both ends of a movable angle range of the boom **4**, or the like). The boom angle sensor S**1** may include, for example, a rotary encoder, an accelerometer, an angular velocity sensor, a six-axis sensor, an inertial measurement unit (IMU), or the like. Further, the boom angle sensor S**1** may include a cylinder sensor capable of detecting the extension and contraction position of the boom cylinder **7**.

[0278] The arm angle sensor S**2** acquires detection information related to an attitude angle of the arm **5** (hereinafter referred to as an "arm angle") with respect to a predetermined reference (for example, a straight-line connecting connection points at both ends of the boom **4**, a state of one of both ends of a movable angle range of the arm **5**, or the like). The arm angle sensor S**2** may include, for example, a rotary encoder, an accelerometer, an angular velocity sensor, a six-axis sensor, an IMU, or the like. Further, the arm angle sensor S**2** may include a cylinder sensor capable of detecting the extension and contraction position of the arm cylinder **8**.

[0279] The bucket angle sensor S**3** acquires detection information related to an attitude angle (hereinafter referred to as a "bucket angle") of the bucket **6** with respect to a predetermined reference (for example, a straight-line connecting connection points at both ends of the arm **5**, a state of one of both ends of a movable angle range of the bucket **6**, or the like). The bucket angle sensor S**3** may include, for example, a rotary encoder, an accelerometer, an angular velocity sensor, a six-axis sensor, an IMU, or the like. Further, the bucket angle sensor S**3** may include a cylinder sensor capable of detecting the extension and contraction position of the bucket cylinder **9**.

[0280] The machine attitude sensor S**4** acquires detection information on an attitude state of the machine body including the lower traveling body **1** and the upper turning body **3**. The attitude state of the machine body includes an inclination state of the machine body. The inclination state of the machine body includes, for example, an inclination state in the front-rear direction corresponding to an attitude state around the left-right axis of the upper turning body **3** and an inclination state in the left-right direction corresponding to an attitude state around the front-rear axis of the upper turning body **3**. The attitude state of the machine body includes a turning state of the upper turning body **3** corresponding to an attitude state around the pivot axis of the upper turning body **3**. The machine body attitude sensor S**4** is mounted on, for example, the upper turning body **3**, and acquires (outputs) detection information regarding attitude angles (hereinafter referred to as "front-rear inclination angle" and "left-right inclination angle") about the front-rear axis, the left-right axis, and the turning axes of the upper turning body **3**. As a result, the body attitude sensor S**4** can acquire detection information regarding the orientation of the upper turning body **3** with respect to the ground (turning attitude about the turning shaft). The orientation of the upper turning body **3** means, for example, a direction in which the attachment AT extends in a top view, that is, a front side viewed from the upper turning body **3**. The machine attitude sensor S**4** may include, for example, an accelerometer sensor (inclination sensor), an angular velocity sensor, a six-axis sensor, an IMU, or the like.

[0281] It should be noted that the information on the direction of the upper turning body **3** with respect to the ground may be acquired from another device instead of or in addition to the machine attitude sensor S**4**. For example, a geomagnetic sensor may be mounted on the upper turning body **3**. In this case, the controller **30** can acquire information on the direction of the upper turning body **3** with respect to the ground from the geomagnetic sensor. In addition, for example, the controller **30** may determine the direction of the upper turning body **3** with respect to the ground by determining the direction in which a surrounding object (in particular, a fixed object such as a utility pole or a tree) is present on the basis of the output (captured image) of the space recognition device **70** (imaging device). That is, the information on the direction of the upper turning body **3** with respect to the ground may be acquired from the space recognition device **70** (imaging device).

[0282] The turning angle sensor S**5** acquires detection information on a relative turning angle of the upper turning body **3** with respect to the lower traveling body **1**. As a result, the turning angle sensor S**5** acquires the detection information regarding the turning angle of the upper turning body **3** with respect to, for example, a predetermined reference (for example, a state in which the forward movement direction of the lower turning body **1** coincides with the front of the upper turning body **3**). The turning angle sensor S**5** includes, for example, a potentiometer, a rotary encoder, a resolver, or the like. The turning angle sensor S**5** may include, for example, a combination of a geomagnetic sensor attached to the lower traveling body **1** and a geomagnetic sensor attached to the upper turning body **3**. The turning angle sensor S**5** may include a combination of a GNSS receiver attached to the lower traveling body **1** and a GNSS receiver attached to the upper turning body **3**.

[0283] The information on the direction of the upper turning body **3** with respect to the lower traveling body **1** may be acquired from another device instead of or in addition to the turning angle sensor S**5**. For example, the direction of the upper turning body **3** with respect to the lower turning body **1** may be determined by determining the direction of the reflected lower turning body **1** based on a captured image of the space recognition device **70** (imaging device) attached to the upper turning body **3**. Specifically, the controller **30** extracts the image of the lower traveling body **1** included in the captured image by performing known image processing. Then, the controller **30** may specify the longitudinal direction of the lower traveling body **1** using a known image recognition technique, and derive an angle formed between the direction of the longitudinal axis of the upper turning body **3** and the longitudinal direction of the lower traveling body **1**. At this time, the direction of the longitudinal axis of the upper turning body **3** can be derived from the attachment position of the space recognition device **70** that has acquired the captured image. In particular, since the crawler **1**C protrudes from the upper turning body **3**, the controller can specify the longitudinal direction of the lower traveling body **1** by extracting the image of the crawler **1**C. In addition, the direction of the upper turning body **3** with respect to the ground and the orientation of the upper turning body **3** with respect to the lower traveling body **1** may be simply assumed to be substantially the same. In this case, the turning angle sensor S**5** may be omitted.

Overview of Machine Guidance Function and Machine Control Function of Shovel

[0284] Next, an outline of the machine guidance function and the machine control function of the shovel **100** will be described with reference to FIG. **10**.

[0285] The controller **30** executes, for example, control of the shovel **100** related to a machine guidance function of guiding a manual operation of the shovel **100** by an operator.

[0286] For example, the controller **30** transmits work information such as a distance between the target work surface and the tip end portion of the attachment AT, that is, a predetermined work site of the bucket **6** (for example, a claw tip of the bucket **6**, a back surface of the bucket **6**, or the like) (hereinafter, simply referred to as a "work site") to the operator through the display device D**1**, the sound outputting device D**2**, or the like. To be specific, the controller acquires information from the boom angle sensor S**1**, the arm angle sensor S**2**, the bucket angle sensor S**3**, the machine attitude sensor S**4**, the turning angle sensor S**5**, the space recognition device **70**, the position measuring device **73**, the input device **72**, and the like. Then, for example, the controller **30** may calculate the distance between the bucket **6** and the target work surface based on the acquired information, and notify the operator of the calculated distance by an image displayed on the display device D**1** or a sound outputted from the sound outputting device D**2**. The data related to the target work surface is stored in an internal memory, an external storage device connected to the controller **30**, or the like, for example, based on a setting input through the input device **72** by the operator or by being downloaded from the outside (for example, a predetermined management server). The data related to the target work surface is represented by, for example, a reference coordinate system. The reference coordinate system is, for example, the world geodetic system. The world geodetic system is a three dimensional orthogonal XYZ coordinate system in which the origin is located at the center of gravity of the earth, the X-axis is in the direction of the intersection of the Greenwich meridian and the equator, the Y-axis is in the direction of 90 degrees east longitude, and the Z-axis is in the direction of the north pole. For example, an operator may determine an arbitrary point of the construction site as a reference point, and may set the target work surface based on a relative positional relationship with the reference point through the input device **72**. Accordingly, the controller **30** can notify the operator of the work information through the display device D**1**, the sound outputting device D**2**, and the like, and guide the operator to operate the shovel **100** through the operation device **26**.

[0287] In addition, the controller **30** executes control of the shovel **100** related to a machine control function of assisting manual operation of the shovel **100** by an operator or causing the shovel **100** to operate fully automatically or autonomously, for example.

[0288] The controller **30** automatically operates at least one of the boom **4**, the arm **5**, and the bucket **6** so that the target work surface coincides with a position serving as a control reference (hereinafter, simply referred to as a "control reference") set for the distal end portion of the attachment AT, specifically, the work part of the bucket **6**, for example, when an operator is manually performing ground excavation operations, leveling operations, or the like. The control reference can include, for example, a plane or a curved surface constituting a claw tip as a work part of the bucket **6**, a line segment defined on the plane or the curved surface, a point defined on the plane or the curved surface, and the like. In addition, the control reference may include, for example, a plane or a curved surface constituting the back surface as the work part of the bucket **6**, a line segment defined on the plane or the curved surface, a point defined on the plane or the curved surface, and the like. To be more specific, when the operator operates the arm **5** through the left operation lever **26**L while operating (pushing) the switch NS, the controller **30** automatically operates the boom **4**, the arm **5**, and the bucket **6** so that the target work surface and the control reference of the bucket **6** coincide with each other in response to the operation of the arm **5** by the operator. More specifically, as described above, the controller **30** controls the hydraulic control valve **32** to automatically operate the boom **4**, the arm **5**, and the bucket **6**. Accordingly, the operator can cause the shovel **100** to perform the excavation work, the leveling work, or the like along the target work surface only by operating the left operation lever **26**L in the front-rear direction.

[0289] The work part of the bucket **6** may be set, for example, according to a setting input through the input device **72** by an operator or the like. Further, the work part of the bucket **6** may be automatically set in accordance with the work content of the shovel **100**, for example. Specifically, the work part of the bucket **6** may be set at the claw tip of the bucket **6** when the work content of the shovel **100** is excavation work or the like, and may be set at the back surface of the bucket **6** when the work content of the shovel **100** is leveling work, rolling work, or the like. In this case, the work content of the shovel **100** may be automatically determined on the basis of the captured image or the like of the imaging device included in the space recognition device **70** (front sensor **70**F), or may be set in accordance with the selection content or the input content by selection or input by the operator or the like through the input device **72**.

[0290] For example, when the work part is the claw tip of the bucket **6**, the control reference in the work part of the bucket **6** (hereinafter simply referred to as "the control reference of the bucket **6**") may be set to one point on a curved surface or a plane constituting the claw tip of a specific one of the plurality of claws of the bucket **6**. Further, for example, when the work part is the back surface of the bucket **6**, the control reference of the bucket **6** can be arbitrarily set on a curved surface or a plane surface constituting the back surface of the bucket **6**. In this case, the controller **30** may set the control reference for the back surface of the bucket **6** in accordance with a setting operation performed by an operator or the like through the input device **72**, or may automatically set (change) the control reference for the back surface of the bucket **6** based on a predetermined condition as described later.

Configuration Relating to Operation-Assisted Machine Control Function

[0291] Next, with reference to FIG. **11**, a functional configuration related to the operation-assisted machine control function (semi-automatic operation function) will be described.

[0292] FIG. **11** is a functional block diagram illustrating an example of a functional configuration related to a machine control function of the shovel **100** according to another embodiment. Specifically, FIG. **11** is a functional block diagram illustrating a specific example of a functional configuration related to the operation-assisted machine control function of the shovel **100**.

[0293] The controller **30** includes an operation content acquisition unit **3001**, a target work surface acquisition unit **3002**, an excavation object recognition unit **3003**, a work environment determination unit **3004**, a target trajectory setting unit **3005**, a current position calculation unit **3006**, a target position calculation unit **3007**, and an operation command generation unit **3008** as functional units related to the operation-assisted machine control function.

[0294] The operation content acquisition unit **3001** acquires an operation content related to an operation (that is, a tilting operation in the front-rear direction) of the arm **5** in the left operation lever **26**L based on a detection signal taken in from the operation sensor **29**LA. For example, the operation content acquisition unit **3001** acquires (calculates) the operation direction (the arm opening operation or the arm closing operation) and the operation amount as the operation content.

[0295] For example, the target work surface acquisition unit **3002** acquires data related to the target work surface from an internal memory, a predetermined external storage device, or the like. The data relating to the target work surface may be manually input by the operator through the input device **72**, for example, or may be input (received) from the management device or the like through the communication device T**1**.

[0296] The excavation target recognition unit **3003** recognizes the shape of the ground as an excavation target based on the output of the space recognition device **70**.

[0297] The excavation target recognition unit **3003** may recognize the shape of the ground surface as an excavation target based on an output of a space recognition device outside the shovel **100**. The space recognition device outside the shovel **100** may include, for example, a space recognition device fixed to a utility pole or the like at a construction site or a space recognition device mounted on a drone (for example, a multicopter) flying over a construction site. In addition, the excavation target recognition unit **3003** may recognize the shape of the ground as the excavation target based on the movement trajectory of the work part of the bucket **6** at the time of the immediately previous (the most recent) excavation.

[0298] The work environment determination unit **3004** determines (specifies) the work environment of the shovel **100** for setting the target trajectory. The work environment of the shovel **100** includes a type of work site, a type of work target, a type of weather, and the like. The type of work target includes the type (difference) of the soil quality, hardness, and the like of the ground.

[0299] For example, the work environment determination unit **3004** determines (specifies) the work portion of the shovel **100**. Specifically, the work environment determination unit **3004** may specify one work site from among a plurality of work site candidates registered in advance on the basis of an output of the space recognition device **70** (an example of an acquisition device) and on the basis of a captured image of the work site and three dimensional data of topography. The work environment determination unit

3004 may communicate with a predetermined device installed in the work site through the communication device T**1** and determine (specify) the work site based on a signal returned from the device.

[0300] In addition, the work environment determination unit **3004** may determine the soil quality, hardness, weather, or the like of the ground of the work target in detail using the output or the like of the space recognition device **70**, for example.

[0301] The target trajectory setting unit **3005** sets a target trajectory of a work part (control reference) of the bucket **6** based on the shape of the excavation target (ground surface) recognized by the excavation target recognition unit **3003**, the determination result of the work environment determination unit **3004**, data related to the target work surface, and the like. For example, when rough excavation is performed in a state in which the distance between the actual landform and the target work surface is relatively large, the target trajectory setting unit **3005** sets the target trajectory of the work part of the bucket **6** within a range that does not go below the target work surface. The target trajectory setting unit **3005** sets the target trajectory of the work part of the bucket **6** so that the work part of the bucket **6** moves along the target work surface, for example, when finishing excavation work is performed or when leveling work or rolling work is performed in a state where the distance between the actual topography and the target work surface is relatively small. A method of setting the target trajectory during excavation will be described later (see FIGS. **13** and **14**).

[0302] The current position calculation unit **3006** calculates a control reference position (current position) of the bucket **6**. To be more specific, the current position calculation unit **3006** may calculate the control reference position of the bucket **6** based on the boom angle β_1, the arm angle β_2, and the bucket angle β_3 acquired based on the outputs of the boom angle sensor S**1**, the arm angle sensor S**2**, and the bucket angle sensor S**3**.

[0303] The target position calculation unit **3007** calculates the control reference target position of the bucket **6** based on the operation content (operation direction and operation amount) related to the operation of the arm **5** in the left operation lever **26**L, the information related to the set target trajectory, and the control reference current position of the bucket **6**. The target position is a position on a target work surface (in other words, a target trajectory) to be an arrival target in the current control cycle when it is assumed that the arm **5** operates in accordance with the operation direction and the operation amount of the arm **5** in the left operation lever **26**L. The target position calculation unit **3007** may calculate the control reference target position of the bucket **6** using, for example, a map, an arithmetic expression, or the like stored in advance in a non-volatile internal memory or the like.

[0304] The operation command generation unit **3008** generates a command value β_{1r} related to the operation of the boom **4** (hereinafter referred to as a "boom command value"), a command value β_{2r} related to the operation of the arm **5** (hereinafter referred to as an "arm command value"), and a command value β_{3r} related to the operation of the bucket **6** (hereinafter referred to as a "bucket command value") based on the target position of the control reference of the bucket **6**. For example, the boom command value β_{1r}, the arm command value β_{2r}, and the bucket command value β_{3r} are a boom angle, an arm angle, and a bucket angle, respectively, when the control reference of the bucket **6** can realize the target position. As a result, the controller **30** can realize a machine control function by converting the boom command value β_{1r}, the arm command value β_{2r}, and the bucket command value β_{3r} into operation commands for the boom **4**, the arm **5**, and the bucket **6** and controlling the hydraulic control valve **32**.

[0305] It should be noted that the boom command value, the arm command value, and the bucket command value may be angular velocities or angular accelerations of the boom **4**, the arm **5**, and the bucket **6** required for the control reference of the bucket **6** to realize the target position.

Configuration Regarding Fully Automatic Machine Control Function

[0306] Next, with reference to FIG. **12**, a functional configuration related to a fully automatic machine control function (fully automatic operation function) will be described.

[0307] FIG. **12** is a functional block diagram illustrating another example of the functional configuration related to the machine control function of the shovel **100** according to another embodiment. Specifically, FIG. **12** is a diagram illustrating a specific example of a functional configuration related to a fully automatic machine control function of the shovel **100**. Hereinafter, portions different from the above-described example (FIG. **11**) will be mainly described.

[0308] In this example, the controller **30** realizes a fully automatic machine control function (autonomous driving function) in response to a signal received from a predetermined external device (for example, a management device or the like) by the communication device T**1**.

[0309] The controller **30** includes a work start determination unit **3001**A, an operation content determination unit **3001**B, an operation condition setting unit **3001**C, and an operation start determination unit **3001**D as functional units related to the machine control function. As in the case of the above-described example (FIG. **11**), the controller **30** includes, as functional units related to the machine control function, a target work surface acquisition unit **3002**, an excavation object recognition unit **3003**, a work environment determination unit **3004**, a target trajectory setting unit **3005**, a current position calculation unit **3006**, a target position calculation unit **3007**, and an operation command generation unit **3008**.

[0310] The work start determination unit **3001**A determines the start of a predetermined work of the shovel **100**. The predetermined work is, for example, excavation work or the like. For example, when a start command is input from an external device through the communication device T**1**, the work start determination unit **3001**A determines the start of the work designated by the start command. In addition, in a case where a start command is input from an external device through the communication device T**1**, the work start determination unit **3001**A may determine the start of the work designated by the start command when it is determined by the periphery monitoring function that there is no object to be monitored in the monitoring range around the shovel **100**.

[0311] When the start of work is determined by the work start determination unit **3001**A, the operation content determination unit **3001**B determines the current operation content. For example, the operation content determination unit **3001**B determines whether or not the shovel **100** is performing an operation corresponding to a plurality of operations constituting the predetermined work based on the current position of the control reference of the bucket **6**. For example, the plurality of operations constituting the predetermined work include an excavation operation, a boom raising and turning operation, a dumping operation, a boom lowering and turning operation, and the like, in a case where the predetermined work is excavation work.

[0312] The operation condition setting unit **3001**C sets an operation condition related to execution of a predetermined work by the autonomous driving function. For example, when the predetermined work is excavation work, the operation condition may include a condition related to an excavation depth, an excavation length, or the like.

[0313] The operation start determination unit **3001**D determines the start of a predetermined operation constituting the predetermined work determined to be started by the work start determination unit **3001**A. The operation start determination unit **3001**D may determine that the excavation operation can be started, for example, when the operation content determination unit **3001**B determines that the boom lowering turning operation has ended and the control reference (claw tip) of the bucket **6** has reached the excavation start position. When it is determined that the excavation work can be started, the operation start determination unit **3001**D causes the target position calculation unit **3007** to input operation commands for operation elements (actuators) corresponding to the autonomous driving function generated in accordance with the setup of the predetermined work. Thus, the target position calculation unit **3007** can calculate the target position of the work part (control reference) of the bucket **6** in accordance with the operation command corresponding to the autonomous driving function.

[0314] As described above, in this example, the controller **30** can cause the shovel **100** to autonomously perform a predetermined operation (for example, an excavation operation) on the basis of a fully automatic machine control function (autonomous driving function).

Method of Setting Target Trajectory of Bucket at Time of Excavation

[0315] Next, with reference to FIGS. **13** and **14**, a description will be given of a method of setting a target function of a work part (claw tip) of the bucket **6** during excavation.

[0316] FIG. **13** is a diagram illustrating an example of parameters related to a trajectory **700** of the claw tip of the bucket **6** during excavation. In FIG. **13**, the trajectory **700** of the claw tip of the bucket **6** during excavation is represented by a broken line. FIG. **14** is a diagram illustrating an example of table information (table information **800**) related to parameters for each work site.

[0317] In this example, the controller **30** (the target trajectory setting unit **3005**) sets the target trajectory of the work part (the claw tip) of the bucket **6** at the time of excavation by setting a parameter related to the trajectory of the claw tip of the bucket **6** at the time of excavation with reference to a predetermined template.

[0318] For example, as illustrated in FIG. **13**, the controller **30** sets a part or all of the parameters A to E, thereby setting the target trajectory of the work part (claw tip) of the bucket **6** during excavation. The parameters A and B are parameters that define the dimensions of the trajectory **700** of the bucket **6** with respect to the ground **702** during excavation.

[0319] The trajectory **700** corresponding to the target trajectory of the bucket **6** during excavation is set in a range above the target work surface **704** or along the target work surface **704**. That is, the trajectory **700** corresponding to the target trajectory of the bucket **6** during excavation is set so as not to go below the target work surface **704** as described above. In addition, as described above, the controller grasps the shape of the ground **702** which is the excavation target based on the output of the space recognition device **70**. In addition, as described above, the controller **30** may grasp the shape of the ground **702** which is an excavation target based on an output of a space recognition device installed outside the shovel **100**, for example, a multicopter, a utility pole, or the like instead of the space recognition device **70**. In addition, as described above, the controller **30** may grasp the shape of the ground **702** which is the excavation target on the basis of the trajectory of the work site (for example, the tip of the bucket **6**) at the time of the previous excavation.

[0320] The parameter A represents the excavation length. The excavation length means a length (distance) in the horizontal direction from when the claw tip of the bucket **6** penetrates the ground **702** to when the claw tip of the bucket **6** is separated from the ground by scooping up earth and sand.

[0321] The parameter B represents the excavation depth. The excavation depth means the depth to the deepest point from the ground **702** in the trajectory of the claw tip of the bucket **6** during excavation.

[0322] The parameters C to E are parameters that define the angle of the trajectory of the bucket **6** with respect to the reference surface during excavation.

[0323] The parameter C represents the penetration angle. The penetration angle means an angle formed by a horizontal plane or a trajectory with respect to the ground **702** when the claw tip of the bucket **6** penetrates the ground **702**.

[0324] The parameter D represents the horizontal pulling angle. The horizontal pulling angle means an angle formed by the trajectory with respect to the horizontal plane or the ground **702** in a state (during horizontal pulling) in which the movement of the bucket **6** in the horizontal direction is dominant between the time when the claw tip of the bucket **6** penetrates into the ground **702** and the time when the bucket **6** is lifted from the ground **702**.

[0325] The parameter E represents the scooping angle. The scooping angle means an angle formed by a horizontal plane or a trajectory with respect to the ground **702** when the tip of the bucket **6** is separated from the ground **702** when the bucket **6** scoops earth and sand.

[0326] The target trajectory setting unit **3005** may simply set the target trajectory of the claw tip of the bucket **6** by setting the parameters A and B, for example. The target trajectory setting unit **3005** may set a more detailed target trajectory of the claw tip of the bucket **6**, for example, by setting at least one of the parameters C to E in addition to the parameters A and B. That is, by setting some or all of the parameters A to E, the target trajectory setting unit **3005** changes the trajectory of the template in accordance with the setting contents of the parameters A to E and sets the target trajectory.

[0327] It should be noted that the target trajectory setting unit **3005** may set another parameter instead of or in addition to the parameters A to E to change the trajectory of the template in accordance with the setting content of another parameter and set the target trajectory. The other parameters may include, for example, a relative attitude angle of the bucket **6** with respect to the ground or the trajectory of the claw tip. In this case, for example, one or a plurality of parameters corresponding to the attitude angle of the bucket **6** at the time of penetration of the claw tip of the bucket **6** into the ground, at the time of horizontal pulling, at the time of scooping, or the like may be defined.

[0328] The target trajectory setting unit **3005** sets a part or all of the parameters A to E based on the determination result of the work environment determination unit **3004**, that is, in accordance with the work environment of the shovel **100**.

[0329] For example, the target trajectory setting unit **3005** may set the parameters A to E depending on the work site determined (specified) by the work environment determination unit **3004**. Specifically, the target trajectory setting unit **3005** may set the parameters A to E in accordance with the work site specified by the work environment determination unit **3004** using table information in which the parameters A to E for each work site are defined. The table information is received from, for example, a predetermined external device (for example, a management device) through the communication device T**1**, and is stored in, for example, an internal memory (an example of a storage device) of the controller **30** such as an auxiliary storage device or an external storage device (an example of a storage device) communicable with the controller **30**.

[0330] For example, as illustrated in FIG. **14**, the table information **800** defines values of parameters A to E for each work site.

[0331] To be more specific, at the work site of "No. 1", the parameter A, the parameter B, the parameter C, the parameter D, and the parameter E are defined as a predetermined value PA**1**, a predetermined value PB**1**, a predetermined value PC**1**, a predetermined value PD**1**, and a predetermined value PE**1**, respectively.

[0332] When the work environment determination unit **3004** determines that the work site of the shovel **100** is the site of "No. 1", the target trajectory setting unit **3005** may refer to the table information **800** and set the above-described parameters A to E to the above-described predetermined values PA**1** to PE**1**.

[0333] In addition, at the work site of "No. 2", the parameter A, the parameter B, the parameter C, the parameter D, and the parameter E are defined as a predetermined value PA**2**, a predetermined value PB**2**, a predetermined value PC**2**, a predetermined value PD**2**, and a predetermined value PE**2**, respectively.

[0334] When the work environment determination unit **3004** determines that the work site of the shovel **100** is the site of "No. 2", the target trajectory setting unit **3005** may refer to the table information **800** and set the above-described parameters A to E to the above-described predetermined values PA**2** to PE**2**.

[0335] In addition, at the work site of "No. 3", the parameter A, the parameter B, the parameter C, the parameter D, and the parameter E are defined as a predetermined value PA**3**, a predetermined value PB**3**, a predetermined value PC**3**, a predetermined value PD**3**, and a predetermined value PE**3**, respectively.

[0336] When the work environment determination unit **3004** determines that the work site of the shovel **100** is the site of "No. 3", the target trajectory setting unit **3005** may refer to the table information **800** and set the above-described parameters A to E to the above-described predetermined values PA**3** to PE**3**.

[0337] The values of the parameters A to E for each work site in the table information **800** are defined in advance in consideration of work efficiency, energy consumption efficiency, machine damage level, and the like in accordance with characteristics (soil quality, ground hardness, and the like) for each work site. Thus, by using the table information **800**, the controller **30** can cause the shovel **100** to perform more efficient work in terms of work efficiency, energy consumption efficiency, degree of mechanical damage, and the like in accordance with the work environment of the work site of the shovel **100**.

[0338] For example, when the ground (excavation target) of the work site is relatively hard, the value of the parameter B (excavation depth) is defined to be relatively small, and the parameter A (excavation length) is defined to be relatively large (long). This is because the shovel **100** cannot excavate deeply due to the hardness of the object to be excavated, but a relatively long excavation length is secured to secure an excavation volume. Further, for example, in this case, the parameter C (penetration angle) is defined to be relatively close to perpendicular to the ground. This is to maximize the force acting on the ground in the vertical direction.

[0339] In addition, for example, when the ground surface (excavation target) of the work site is relatively soft, the excavation depth is defined to be relatively large, that is, to be close to a predetermined maximum value, and the excavation length is defined to be relatively small (short). This is because the shovel **100** can excavate more deeply depending on the softness of the excavation target.

[0340] The target trajectory setting unit **3005** may update the parameters A to E by performing reinforcement learning related to the parameters A to E in accordance with the progress of the actual excavation work with the parameters A to E set based on the table information **800** as a starting point. For example, the target trajectory setting unit **3005** performs reinforcement learning regarding the parameters A to E and updates the parameters A to E in accordance with the progress of the actual work so as to maximize the work time, the energy consumption rate (for example, the fuel consumption rate), the degree of mechanical damage, and the like as the evaluation index (reward). Thus, the controller **30** can update the parameters A to E in accordance with the actual work environment of the work site.

[0341] As described above, in this example, the controller **30** sets predetermined parameters (for example, the parameters A to E) related to the trajectory of the bucket **6** during excavation, and sets the target trajectory of the bucket **6** (for example, the target trajectory of the claw tip) on the basis of the predetermined parameters.

[0342] Thus, the controller **30** can set the target trajectory of the bucket **6** by setting the predetermined parameter. Therefore, the controller **30** can automatically and easily set the target trajectory of the bucket **6** in accordance with, for example, the work environment of the work site of the shovel **100**.

[0343] In addition, in the present example, the predetermined parameter is set based on a type of work environment of the shovel **100** including a type of work site of the shovel **100** or a type of excavation target.

[0344] Thus, the controller **30** can specifically set the target trajectory of the bucket **6** in accordance with the work environment of the shovel **100**. The target trajectory may include a target surface (design surface) serving as a construction target.

[0345] In the present example, the predetermined parameter is learned so that the evaluation index related to the excavation work becomes relatively high when the excavation work is actually executed.

[0346] Accordingly, the controller **30** can update the predetermined parameter to more appropriate content in accordance with the actual work environment of the shovel **100**.

[0347] In the present example, the predetermined parameter includes at least one of a parameter (for example, parameters A and B) related to the dimension of the trajectory of the claw tip of the bucket **6** during excavation with respect to the ground surface, a parameter (for example, parameters C to D) related to the angle of the trajectory of the claw tip of the bucket **6** during excavation with respect to the reference surface, and a parameter related to the attitude of the bucket **6** during excavation.

[0348] Thus, for example, the controller **30** can specifically set the target trajectory of the claw tip of the bucket **6** during excavation by changing the template representing the predetermined trajectory in accordance with the setting content of the predetermined parameter.

[0349] Further, in this example, the controller **30** sets the predetermined parameter based on the information on the work environment of the shovel **100** acquired by the space recognition device **70**.

[0350] As a result, the controller **30** can determine the work environment (work site) of the shovel **100** based on the output of the space recognition device **70**, and specifically set a predetermined parameter in accordance with the work environment.

[0351] For example, the controller **30** sets a predetermined parameter in accordance with the work environment of the shovel **100** by using information (for example, table information **800**) related to the predetermined parameter for each work environment of the shovel **100** stored in the internal memory or the like.

[0352] Thus, the controller **30** can specifically set a predetermined parameter in accordance with the work environment of the shovel **100**.

[0353] The preferred embodiments of the present invention have been described above in detail. However, the present invention is not limited to the embodiments described above. Various modifications, substitutions, or the like can be applied to the above-described embodiments without departing from the scope of the present invention. In addition, features described separately may be combined as long as no technical contradiction arises.

1. A shovel comprising:

a lower traveling body;

an upper turning body turnably mounted on the lower traveling body;

an attachment attached to the upper turning body; and

a control device configured to change a working angle formed by a plane or a line determined based on a shape of a bucket included in the attachment and a target surface,

wherein the control device changes the working angle in accordance with a positional relationship between the bucket and the target surface during execution of a machine control function.

2. The shovel according to claim **1**, wherein the control device changes the working angle in accordance with a distance between the bucket and the target surface.

3. The shovel according to claim **2**, wherein the control device changes the working angle in accordance with an operation speed of the bucket.

4. The shovel according to claim **1**, wherein the control device repeatedly calculates a target angle relating to the working angle in accordance with an attitude of the attachment and information related to the target surface, and executes control to make the working angle follow the target angle.

5. The shovel according to claim **1**, wherein the control device controls the attachment such that the bucket is closed as the bucket at a position higher than the target surface approaches the target surface.

6. The shovel according to claim **1**, wherein the control device controls the attachment such that the bucket is opened as the bucket at a position lower than the target surface approaches the target surface.

7. The shovel according to claim **1**,

wherein the control device sets a predetermined angle or a predetermined dimension relating to a trajectory of the bucket during excavation, and sets a target trajectory for the bucket based on the predetermined angle or the predetermined dimension, and

wherein the target trajectory includes the target surface.

8. The shovel according to claim **7**, wherein the predetermined angle or the predetermined dimension is set based on a working environment of the shovel, including a type of working environment of the shovel or a type of excavation target.

9. The shovel according to claim **7**, wherein the predetermined angle or the predetermined dimension is learned so that an evaluation index relating to an excavation work becomes relatively higher as the excavation work is actually performed.

10. The shovel according to claim **7**, wherein the predetermined dimension includes a dimension with respect to a ground of a trajectory of the bucket during excavation, and the predetermined angle includes an angle of a trajectory of the bucket with respect to a reference surface during excavation.

11. The shovel according to claim **1**, wherein the control device sets a predetermined angle or a predetermined dimension relating to a trajectory of the bucket during excavation, and sets a target trajectory of the bucket based on the predetermined angle or the predetermined dimension.

12. The shovel according to claim **11**, wherein the predetermined angle or the predetermined dimension is learned so that an evaluation index relating to an excavation work becomes relatively higher as the excavation work is actually performed.

13. A shovel control device including a lower traveling body, an upper turning body turnably mounted on the lower traveling body, and an attachment attached to the upper turning body, the shovel control device configured to change a working angle formed by a plane or a line determined based on a shape of a bucket included in the attachment and a target surface in accordance with a position relationship between the bucket and the target surface.

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