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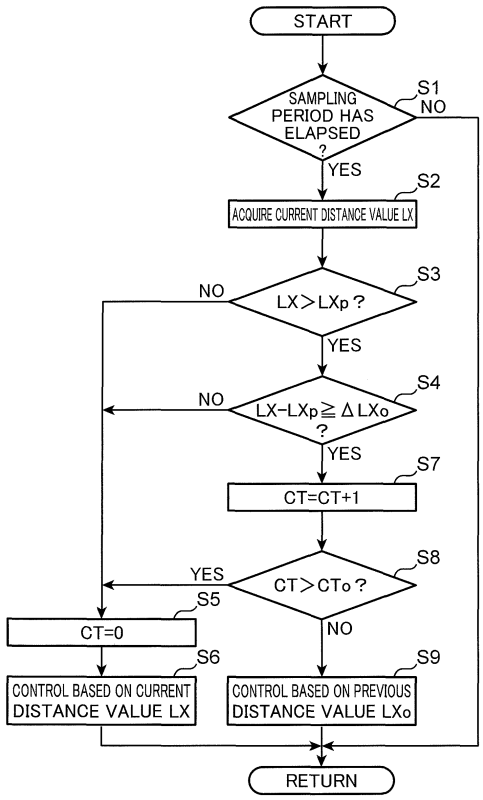
(54) **WORK MACHINE SAFETY DEVICE**

(57) Provided is a safety device capable of stably performing safety control for a work machine. The safety device comprises a position information acquisition part and a control part. The position information acquisition part periodically acquires position information on a position of a detection object around the work machine. The control part performs the safety control corresponding to current information that is the position information currently acquired when the current information is varied from previous information that is the position information previously acquired in a direction of approaching the work machine, executes a control change inhibition of inhibiting the safety control from being changed in response to the variation in the position information when a change inhibition condition including that the current information is varied from the previous information in a direction of separating from the work machine is satisfied, and releases the control change inhibition when a predetermined time has elapsed after the start of the control change inhibition.

FIG.5



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Description

Technical Field

[0001] The present invention relates to a safety device for a work machine.

Background Art

[0002] Conventionally known is a device configured to detect a detection object that is present around a work machine such as a hydraulic excavator to perform a safety control. For example, Patent Literature 1 discloses a device that performs determining a relative position of an obstacle to a virtual boundary surface set around an upper turning body of a work machine and limiting the motion speed of the upper turning body at a degree increased with a decrease in the distance from the virtual boundary surface to the obstacle.

[0003] Such a control based on the position information of the detection object (the obstacle in Patent Document 1) is likely to be unstable. Specifically, the determination of the position of the detection object is performed by use of a measurement value provided by a distance sensor such as an infrared depth sensor or a millimeter wave radar, or by processing the image data acquired by an imaging device (camera); the thus acquired position information is likely to be disturbed due to external factors such as the performance or characteristics of the sensor or the camera, or the shake of the vehicle body. Especially, the detection result provided by use of the imaging device is temporarily affected depending on a state or a posture of the detection object or a peripheral situation. For example, there is a possibility of a temporal non-detection state in spite of the actual presence of a detection object or a possibility of fluctuation in the detection result (for example, the distance from the work machine to the detection object) in spite of no variation in the position of the detection object. The safety control executed based on such unstable position information is likely to be unstable.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Granted Patent No. 6819462

Summary of Invention

[0005] The object of the present invention is to provide a device capable of stably performing safety control for a work machine.

[0006] Provided is a safety device that performs safety control of a work machine, comprising a position information acquisition part and a control part. The position information acquisition part periodically acquires position information on a position of a detection object around the work machine. The control part is configured to perform a safety control when current information, which is the position information currently acquired, is varied from previous information, which is the position information previously acquired, in a direction of approaching the work machine, the safety control corresponding to the current information, and configured to execute a control change inhibition of inhibiting the safety control from being changed in response to a variation in the position information when a change inhibition condition including that the current information is varied from the previous information in a direction of separating from the work machine is satisfied. The control part releases the control change inhibition at a point in time when a predetermined time has elapsed, for example, the position information has been acquired a predetermined number of times, after the start of the control change inhibition.

Brief Description of Drawings

[0007]

FIG. 1 is a side view showing a hydraulic excavator, which is an example of a work machine according to an embodiment of the present invention.

FIG. 2 is a plan view of the hydraulic excavator.

FIG. 3 is a block diagram showing a hydraulic circuit and a controller, which are installed on the hydraulic excavator.

FIG. 4 is a block diagram showing main functions of the controller.

FIG. 5 is a flowchart showing a speed limitation control that is executed by the controller.

FIG. 6 is a graph showing a first example of a temporal variation in a distance value acquired in the hydraulic excavator, wherein the detection of the detection object is interrupted during a specific period.

FIG. 7 is a graph showing a temporal change of the turning limitation command in each of the case where the control change inhibition is not performed when the change inhibition condition is satisfied and the case where the control change inhibition is performed when the change inhibition condition is satisfied, in the first example.

FIG. 8 is a graph showing a temporal change of a turning pilot pressure when the control change inhibition is not performed in the first example.

FIG. 9 is a graph showing a second example of the temporal variation in the distance value acquired in the hydraulic excavator, wherein the distance value is temporarily increased.

FIG. 10 is a graph showing a temporal change of the turning limitation command in each of the case where the control change inhibition is not performed when the change inhibition condition is satisfied and the case where the control change inhibition is per-

formed when the change inhibition condition is satisfied, in the second example.

FIG. 11 is a graph showing a temporal variation in the distance value in the case of adopting the moving average of the distance values in the second example.

FIG. 12 is a graph showing an example in which a process for limiting the rate of change of the turning limitation command is performed.

FIG. 13 is a plan view showing another example of a monitoring area set around the work machine.

FIG. 14 is a graph showing the relationship between a monitoring area set around the work machine and an inverse-proportion-valve instruction current value.

Detailed Description

[0008] Preferred embodiments of the present invention will be described with reference to the drawings.

[0009] FIGS. 1 and 2 show a hydraulic excavator, which is a work machine on which a control device according to an embodiment of the present invention is installed. The hydraulic excavator includes a lower traveling body 10 capable of traveling on the ground G, an upper turning body 12 mounted on the lower traveling body 10, a work device 14 mounted on the upper turning body 12, and a work driving device.

[0010] The lower traveling body 10 includes a pair of right crawlers 11R and a left crawler 11L disposed on the right and left sides, respectively. Each of the right and left crawlers 11R and 11L operates to make the lower traveling body 10 travel on the ground G.

[0011] The upper turning body 12 includes a turning frame 16 and a plurality of elements mounted thereon. The plurality of elements include an engine room 17 that accommodates an engine, a cab 18 that is an operation room, and a counterweight 19 that forms a rear end of the upper turning body 12.

[0012] The work device 14 includes a boom 21, an arm 22, and a bucket 24. The boom 21 is supported on the front end of the turning frame 16 capably of rising and falling. The arm 22 is coupled to the tip of the boom 21 capably of vertically rotational movement with respect to the boom 21. The bucket 24, which is a tip attachment for performing excavation work or the like, is attached to a tip of the arm 22 capably of vertically rotational movement with respect to the arm 22.

[0013] FIG. 3 shows a hydraulic circuit installed on the hydraulic excavator, a plurality of object detectors, an alarm unit 62, a display device 64, and a controller 70. The controller 70, which is composed of, for example, a microcomputer, controls the action of each element included in the hydraulic circuit. On the other hand, the controller 70 is electrically connected to the plurality of object detectors, the alarm unit 62, and the display device 64, to constitute a safety device in association therewith.

[0014] The hydraulic circuit includes a pump unit 30, a plurality of hydraulic actuators, a plurality of control valves, an operation device, a plurality of operation valves, and a plurality of pilot pressure sensors.

[0015] The pump unit 30 includes a plurality of hydraulic pumps, which include at least one main pump and a pilot pump. The plurality of hydraulic pumps are connected to a not-illustrated engine, which is a drive source, and driven by power output by the engine to discharge hydraulic fluid.

[0016] The plurality of hydraulic actuators are configured to actuate respective movable parts of the hydraulic excavator by the supply of hydraulic fluid from the pump unit 30, including a plurality of working hydraulic cylinders, a turning motor 32, a right traveling motor 33, and a left traveling motor 34.

[0017] The plurality of working hydraulic cylinders include a boom cylinder 26, an arm cylinder 27, and a bucket cylinder 28, which are shown in FIG. 1. The boom cylinder 26 is expanded and contracted by the supply of hydraulic fluid thereto so as to raise and lower the boom 21 with respect to the upper turning body 12. The arm cylinder 27 is expanded and contracted by the supply of hydraulic fluid thereto so as to rotationally move the arm 22 with respect to the boom 21. The bucket cylinder 28 is expanded and contracted by the supply of the hydraulic fluid thereto so as to rotationally move the bucket 24 with respect to the arm 22.

[0018] The turning motor 32, which includes a pair of rightward turning port and a leftward turning port, is operated by the supply of hydraulic fluid to one port of the rightward turning port and the leftward turning port so as to turn the upper turning body 12 in a direction corresponding to the one port, namely, a rightward turning direction or a leftward turning direction.

[0019] The right traveling motor 33, which includes a pair of right forward port and a right backward port, is operated by the supply of hydraulic fluid to one port of the right forward and backward ports so as to actuate the right crawler 11R in a direction corresponding to the one port, namely, a frontward direction or a backward direction. Similarly, the left traveling motor 34, which includes a pair of left forward port and a left backward port, is operated by the supply of hydraulic fluid to one port of the left forward and backward ports to actuate the left crawler 11L in a direction corresponding to the one port, namely, a forward direction or a rearward direction.

[0020] The plurality of control valves are valves that make respective open and close motions so as to enable respective movements of the plurality of hydraulic actuators to be controlled. The plurality of control valves include a turning control valve 36, a right traveling control valve 37 and a left traveling control valve 38, which are shown in FIG. 3.

[0021] The turning control valve 36 is interposed between the pump unit 30 and the turning motor 32 and configured to make open and close motions so as to change the direction and flow rate (turning flow rate) of the hydraulic fluid supplied from the pump unit 30 to the

turning motor 32. The turning control valve 36 is composed of a pilot-operated direction selector valve including a rightward turning pilot port and a leftward turning pilot port, configured to be opened by the input of the pilot pressure to the rightward turning pilot port so as to allow hydraulic fluid to be supplied to the rightward turning port of the turning motor 32 at a flow rate (rightward turning flow rate) corresponding to the magnitude of the pilot pressure, and configured to be opened by the input of the pilot pressure to the leftward turning pilot port so as to allow hydraulic fluid to be supplied to the leftward turning port of the turning motor 32 at a flow rate (leftward turning flow rate) corresponding to the magnitude of the pilot pressure.

[0022] The right traveling control valve 37 is interposed between the pump unit 30 and the right traveling motor 33 and configured to make open and close motions so as to change the direction and flow rate (right traveling flow rate) of the hydraulic fluid supplied from the pump unit 30 to the right traveling motor 33. The right traveling control valve 37 is composed of a pilot-operated direction selector valve including a right forward pilot port and a right backward pilot port, configured to be opened by the input of the pilot pressure to the right forward pilot port so as to allow hydraulic fluid to be supplied to the right forward port of the right traveling motor 33 at a flow rate (right forward flow rate) corresponding to the magnitude of the pilot pressure, and configured to be opened by the input of the pilot pressure to the right backward pilot port so as to allow hydraulic fluid to be supplied to the right backward port of the right traveling motor 33 at a flow rate (right backward flow rate) corresponding to the magnitude of the pilot pressure.

[0023] The left traveling control valve 38 is interposed between the pump unit 30 and the left traveling motor 34 and configured to make open and close motions so as to change the direction and flow rate (left traveling flow rate) of the hydraulic fluid supplied from the pump unit 30 to the left traveling motor 34. The left traveling control valve 38 is composed of a pilot-operated direction selector valve including a left forward pilot port and a left backward pilot port, configured to be opened by the input of the pilot pressure to the left forward pilot port so as to allow hydraulic fluid to be supplied to the left forward port of the left traveling motor 34 at a flow rate (left forward flow rate) corresponding to the magnitude of the pilot pressure, and configured to be opened by the input of the pilot pressure to the left backward pilot port so as to allow hydraulic fluid to be supplied to the left backward port of the left traveling motor 34 at a flow rate (left backward flow rate) corresponding to the magnitude of the pilot pressure.

[0024] The plurality of control valves further include a boom control valve, an arm control valve and a bucket control valve, which are provided for the boom cylinder 26, the arm cylinder 27 and the bucket cylinder 28, respectively.

[0025] The operation device is configured to allow an operation for moving the hydraulic excavator to be applied to the operation device and to input an operation signal to the controller 70. The operation device includes a plurality of operation units corresponding to the plurality of control valves, respectively. Each of the operation units is composed of a so-called remote-control valve connected to the pilot pump, configured to be opened so as to allow a pilot pressure corresponding to the operation applied to the remote-control valve to be applied to the corresponding control valve.

[0026] The operations to be applied to the operation device include a plurality of control target operations that are targets of a safety control. In the present embodiment, the plurality of control target operations include a turning operation for turning the upper turning body 12 with respect to the lower traveling body 10, and a right traveling operation and a left traveling operation for moving the right and left crawlers 11R and 11L, respectively, each of the right traveling operation and the left traveling operation corresponding to a traveling operation for making the lower traveling body 10 perform a traveling motion.

[0027] FIG. 3 shows a turning operation unit 42, a right traveling operation unit 43 and a left traveling operation unit 44, each being an operation unit to which the control target operation is applied, each included in the plurality of operation units.

[0028] The turning operation unit 42 includes a turning lever and a turning pilot valve connected to the turning lever. The turning pilot valve is opened so as to let a pilot pressure having a magnitude corresponding to the magnitude of the turning operation be supplied to the pilot port corresponding to the direction of the turning operation applied to the turning lever, the pilot port selected from the rightward turning port and the leftward turning pilot port of the turning control valve 36. The right traveling operation unit 43 includes a right traveling lever and a right traveling pilot valve connected to the right traveling lever. The right traveling pilot valve is opened so as to let a pilot pressure having a magnitude corresponding to the magnitude of the right traveling operation be supplied to the pilot port corresponding to the direction of the right traveling operation applied to the right traveling lever, the pilot port selected from the right forward and left forward pilot ports of the right traveling control valve 37. Similarly, the left traveling operation unit 44 includes a left traveling lever and a left traveling pilot valve connected to the left traveling lever, configured to be opened so as to let a pilot pressure having a magnitude corresponding to the magnitude of the left traveling operation be supplied to the pilot port corresponding to the direction of the left traveling operation applied to the left traveling lever, the pilot port selected from the left forward and the left forward pilot ports of the left traveling control valve 38.

[0029] In addition to the turning operation unit 42, the right traveling and left traveling operation units 43, 44, the plurality of operation units include a boom operation unit, an arm operation unit, and a bucket operation unit. The

boom operation unit allows a boom operation for moving the boom 21 to be applied to the boom operation unit to allow a pilot pressure to be supplied to the boom control valve. The arm operation unit allows an arm operation for moving the arm 22 to be applied to the arm operation unit to allow a pilot pressure to be supplied to the arm control valve. The bucket operation device allows a bucket operation for moving the bucket 24 to be applied to the bucket operation device to allow a pilot pressure to be supplied to the bucket control valve. The boom operation, the arm operation and the bucket operation, although each being an operation for moving the work device 14, are excluded from the control target operation in the present embodiment.

[0030] The plurality of operation valves are interposed between the turning operation unit 42, the right traveling operation unit 43 and the left traveling operation unit 44, and respective control valves corresponding to the operating units, namely, the turning control valve 36, the right traveling control valve 37 and the left traveling control valve 38, respectively, enabling the turning pilot pressure and the right and left traveling pilot pressures to be limited by the controller 70. Specifically, each of the operation valves is composed of an electromagnetic pressure reducing valve, which limits the pilot pressure at a degree corresponding to the value of an instruction current, which is a limitation command to be input to the pressure reducing valve. Each of the pressure reducing valves according to the present embodiment is a solenoid inversely proportional pressure reducing valve, configured to limit the pilot pressure at a degree increased with an increase in the limitation command. The pressure reducing valve may also be a solenoid proportional pressure reducing valve.

[0031] Specifically, the plurality of operation valves include a rightward turning operation valve 46R and a leftward turning operation valve 46L, a right forward traveling operation valve 47F and a right backward traveling operation valve 47B, and a left forward traveling operation valve 48F and a left backward traveling operation valve 48B, which are shown in FIG. 3.

[0032] The rightward turning operation valve 46R is interposed between the turning operation unit 42 and the rightward turning pilot port of the turning control valve 36, and operated to limit the rightward turning pilot pressure to be input from the turning operation unit 42 to the rightward turning pilot port at a degree corresponding to a rightward turning limitation command input from the controller 70 to the rightward turning operation valve 46R. Similarly, the leftward turning operation valve 46L is interposed between the turning operation unit 42 and the leftward turning pilot port of the turning control valve 36, and operated to limit the leftward turning pilot pressure input from the turning operation unit 42 to the leftward turning pilot port at a degree corresponding to a leftward turning limitation command input to the leftward turning operation valve 46L from the controller 70.

[0033] The right forward traveling operation valve 47F is interposed between the right traveling operation unit 43 and the right forward pilot port of the right traveling control valve 37, and operated to limit the right forward pilot pressure input from the right traveling operation unit 43 to the right forward pilot port at a degree corresponding to a right forward traveling limitation command input from the controller 70 to the right forward traveling operation valve 47F. Similarly, the right backward traveling operation valve 47R is interposed between the right traveling operation unit 43 and the right backward pilot port of the right traveling control valve 37, and operated to limit the right backward pilot pressure input from the right traveling operation unit 43 to the right backward travel pilot port at a degree corresponding to a right backward traveling limitation command input from the controller 70 to the right backward traveling operation valve 47R.

[0034] The left forward traveling operation valve 48F is interposed between the left traveling operation unit 44 and the left forward pilot port of the left traveling control valve 38, and operated to limit the left forward pilot pressure input from the left traveling operation unit 44 to the left forward pilot port at a degree corresponding to a left forward traveling limitation command input from the controller 70 to the left forward traveling operation valve 48F. Similarly, the left backward traveling operation valve 48R is interposed between the left traveling operation unit 44 and the left backward pilot port of the left traveling control valve 38, and operated to limit a left backward pilot pressure input from the left traveling operation unit 44 to the left backward pilot port at a degree corresponding to a left backward traveling limitation command input from the controller 70 to the left backward traveling operation valve 48R.

[0035] The plurality of pilot pressure sensors are operation amount detectors that detect respective magnitudes (operation amounts) of the turning operation, the right traveling operation and the left traveling operation. Specifically, the plurality of pilot pressure sensors, each composed of a pressure sensor, detect respective pilot pressures input to the turning control valve 36, the right traveling control valve 37, and the left traveling control valve 38 and input respective detection signals corresponding to respective magnitudes of the pilot pressures, i.e., respective detection signals corresponding to the target operation amounts, to the controller 70. Specifically, the plurality of pilot pressure sensors include a rightward turning pilot pressure sensor 52R that detects the rightward turning pilot pressure, a leftward turning pilot pressure sensor 52L that detects the leftward turning pilot pressure sensor, a right forward pilot pressure sensor 53F that detects the right forward pilot pressure, a right backward pilot pressure sensor 53B that detects the right backward pilot pressure, a left forward pilot pressure sensor 54F that detects the left forward pilot pressure, and a left backward pilot pressure sensor 54B that detects the left backward pilot pressure.

[0036] In the hydraulic circuit, the turning motor 32, the turning control valve 36, and the rightward turning and the

leftward turning operation valves 46R, 46L constitute a turning drive circuit for turning the upper turning body 12, in association with the pump unit 30. Similarly, the right traveling motor 33, the right traveling control valve 37, and the right forward and reverse traveling operation valves 47F, 47B constitute a right traveling drive circuit for driving the right crawler 11R, in association with the pump unit 30, and the left traveling motor 34, the left traveling control valve 38, and the left forward and reverse traveling operation valves 48F. 48B constitute a left traveling drive circuit for driving the left crawler 11L, in association with the pump unit 30.

[0037] The plurality of object detectors are disposed in respective specific parts of the hydraulic excavator, and configured to detect a detection object present around the hydraulic excavator, to generate detection signals to allow position information about the detection object to be acquired and to input the generated detection signals to the controller 70. The position information includes an object distance, which is a distance from the specific part to the detection object. Each of the object detectors in the present embodiment is composed of an imaging device such as a monocular camera or a stereo camera, generating a captured image containing the detection object.

[0038] Specifically, the plurality of object detectors according to the embodiment are disposed in the upper turning body 12, including a right object detector 60R, a left object detector 60L and a back object detector 60B, which are shown in FIG. 2. The right object detector 60R is disposed on a right side portion of the upper turning body 12 so as to be able to detect at least a detection object lying rightward of the upper turning body 12. The left object detector 60L is disposed on a left side portion of the upper turning body 12 so as to be able to at least a detection object lying leftward of the upper turning body 12. The back object detector 60B is disposed at a back end portion of the upper turning body 12 so as to be able to detect at least a detection object lying backward of the upper turning body 12.

[0039] The alarm unit 62 outputs an alarm upon the input of an alarm command from the controller 70 to the alarm unit 62. The alarm unit 62 may be either one configured to alarm through a sound, such as a buzzer, or one configured to alarm through light, such as a warning lamp.

[0040] The display device 64 has a screen capable of displaying a surrounding image containing the detection object, disposed in the cab 18 so as to allow an operator to visually recognize the screen. The display device 64 displays an image corresponding to a display command signal that is input from the controller 70.

[0041] Based on the image signal input from each of the object detectors 60R, 60L, 60B, the controller 70 determines the presence or absence of a detection object around the hydraulic excavator and a detection distance when a detection object is present, and the controller 70 executes the safety control when the detection distance is equal to or less than a preset allowable distance. The detection distance is the distance from the reference position to the detection object, namely, the detected object distance, and the reference position in the present embodiment is the position at which each of the object detectors 60R, 60L, 60B is disposed, that is, each of the positions of the specific parts. The detection distance according to the embodiment is the object distance from each of the object detectors 60R, 60L, 60B to the detection object detected by each of the object detectors 60R, 60L, 60B.

[0042] The safety control in the present embodiment includes a speed limitation control, an alarm control, and a display control. The speed limitation control is a control for limiting the speed of a preset limitation target motion out of motions of the hydraulic excavator in accordance with the detection distance, allowed to include a control for rendering the speed zero, namely, a stop control for forcibly stopping the limitation target motion. In the present embodiment, the limitation target motion includes at least a turning motion of the upper turning body 12 with respect to the lower traveling body 10, and further includes a traveling motion made by the right crawler 11R and the left crawler 11L depending on a situation. The limitation target motion, alternatively, may include a motion of the work device 14, for example, rising and falling movements of the boom 21 and a rotational movement of the arm 22. The alarm control is a control of making the alarm unit 62 output an alarm based on the detection of the detection object. The display control is a control of making the display device 64 display a warning image based on the detection of the detection object. The warning image is, for example, a surrounding image that is captured by each of the object detectors 60R, 60L, 60B and contains the detection object.

[0043] The controller 70 includes a plurality of functions as shown in FIG. 4 to execute the safety control, the plurality of functions including a position information generation part 72, a safety control determination part 74, a turning limitation command part 76, a traveling limitation command part 78, an alarm command part 82 and a display command part 84. These functions are implemented, for example, by the execution of a program prestored in a memory included in the controller 70 by a CPU included in the controller 70.

[0044] The position information generation part 72 takes in the image signal that is input from each of the object detectors 60R, 60L, 60B, periodically (specifically, every time a preset sampling period has elapsed), and processes the image signal. The position information generation part 72 thereby determines the presence or absence of the detection object in the imaging area of each of the object detector 60R, 60L, 60B, and a distance value corresponding to the detection distance when the detection object is present, and generates position information containing the position of the detection object and the distance value. The detection distance is the object distance, being the distance, in the present embodiment, from the position at which each of the object

detectors 60R, 60L, 60B is disposed to the detection object. The position information generation part 72, thus, constitutes a position information acquisition part that periodically acquires the position information, in association with the object detectors 60R, 60L, 60B. The detection object preferably includes at least a person (worker) and may include an object other than a person.

[0045] The safety control determination part 74 determines the necessity of execution of the safety control and the content of the safety control based on the position information generated by the position information generation part 72. Specifically, when judging the safety control to be necessary, the safety control determination part 74 according to the present embodiment determines a motion whose speed should be limited and the degree of the limitation of the speed of the limitation target motion corresponding to the detection distance. The limitation of the speed also includes a forcible stop.

[0046] Moreover, the safety control determination part 74 stores a predetermined change inhibition condition, and performs control change inhibition only when the position information periodically generated by the position information generation part 72 satisfies the change inhibition condition. The change inhibition condition is a condition preset in order to determine the necessity of the control change inhibition, including that current information is varied from previous information in a direction of separating from the hydraulic excavator. The current information is the position information acquired currently, and the previous information is the information acquired immediately before the current information (by the sampling period), that is, the position information acquired previously. The change inhibition condition according to the present embodiment, thus, includes that the detection distance is increased. The control change inhibition is to inhibit the safety control from being changed in response to a variation in the position information (an increase in the detection distance), contributing to the stabilized safety control. The control change inhibition according to the present embodiment is to maintain the safety control based on the previous information regardless of the current information.

[0047] In addition, the safety control determination part 74 releases the control change inhibition at a preset inhibition release time point. The inhibition release time point is a point in time when a predetermined time has elapsed after the control change inhibition is started, being the point in time when, in the present embodiment, the position information has been acquired by a predetermined number of times after the start of the control change inhibition. The predetermined time according to the embodiment, therefore, is the time obtained by multiplying the sampling period by the predetermined number of times.

[0048] The turning limitation command part 76 generates a turning limitation command signal. The turning limitation command signal is a signal for executing the turning limitation control included in the safety control to be determined by the safety control determination part 74, specifically, a signal for limiting the speed of the rightward turning motion or the leftward turning motion at the limitation degree determined with respect to the limitation of the speed (turning speed) when the control for limiting the speed of the rightward turning motion or the leftward turning motion is determined (including the forcible stop). The turning limitation command part 76 inputs the turning limitation command signal to the operation valve corresponding to the limitation target motion between the rightward turning operation valve 46R and the leftward turning operation valve 46L (for example, the rightward turning operation valve 46R when the rightward turning motion is limited).

[0049] The traveling limitation command part 78 generates a traveling limitation command signal. The traveling limitation command signal is a signal for executing the traveling limitation control included in the safety control to be determined by the safety control determination part 74, specifically, for limiting the speed of the forward traveling motion or the backward traveling motion at the limitation degree determined with respect to the speed (traveling speed) when the control of the forward traveling motion or the backward traveling motion is specified (including a forced stop). The traveling limitation command part 78 inputs the turning limitation command signal to the operation valve corresponding to the limitation target motion among the right forward traveling operation valve 47F, the right backward traveling operation valve 47B, the left forward traveling operation valve 48F and the left backward traveling operation valve 48B (for example, the right backward traveling operation valve 47B and the left backward traveling operation valve 48B when the backward traveling motion is limited).

[0050] The alarm command part 82 generates an alarm command signal when the safety control determination part 74 judges the safety control to be necessary, and inputs the alarm command signal to the alarm unit 62 to thereby make the alarm unit 62 output an alarm.

[0051] The display command part 84 generates a display command signal when the safety control determination part 74 judges the safety control to be necessary, and inputs the display command signal to the display device 64 to thereby make the display device 64 display the warning image.

[0052] Next will be more specifically described the content of the safety control to be performed by the controller 70 with reference to the flowchart of FIG. 5.

[0053] The position information generation part 72 of the controller 70 takes in the image signal that is input from the object detector 60R, 60L, 60B every time a preset sampling period (for example, 50ms) elapses (YES in step S1), and acquires position information containing the current distance value LX based on the image signal (step S2). Specifically, the position information generation part 72 processes the image signal to thereby generate position information of the detection object. The current distance value LX is the digitized detection dis-

tance contained in the current information that is the position information currently generated. When a plurality of object detectors among the object detectors 60R, 60L, 60B simultaneously detect a detection object, the value corresponding to the distance detected by the object detector closest to the detection object among the plurality of object detectors, in other words, the smallest value of respective values corresponding to the detection distances, is adopted as the current distance value LX.

[0054] Based on the acquired current distance value LX, the safety control determination part 74 of the controller 70 judges whether or not the preset change inhibition condition is satisfied (step S3, S4). The change inhibition condition is a condition set for determining the necessity of the control change inhibition. Specifically, unconditionally adopting the current distance value LX and executing the safety control based on the adopted current distance value LX generates a possibility of involving a trouble as will be described below; this is the reason for the necessity of inhibiting the safety control from being changed in response to a variation in the distance value. In consideration with this, the change inhibition condition is set, requiring, in the present embodiment, both of the following two conditions A and B to be satisfied.

[0055] (Condition A) The current distance value LX is greater than the previous distance value LXp (LX > LXp: YES in step S3). The previous distance value LXp is the distance value that is previously acquired.

[0056] (Condition B) The difference between the current distance value LX and the previous distance value LXp exceeds a preset allowable distance difference ΔLXo (LX-LXp > Δ LXo: YES in step S4).

[0057] In other words, when the change inhibition condition is not satisfied, executed is a normal safety control, specifically as follows.

[0058] When the current distance value LX does not exceed the previous distance value LXp (NO in step S3), that is, when the distance value is not varied in the direction of increasing (when the position information of the detection object is not varied in the direction away from the reference position), the controller 70 clears a detection count value CT to 0 (step S5) and executes the control based on the current distance value LX (step S6). The detection count value CT is a value set for counting the number of times of detection for each sampling period after the control change inhibition is started. "When the current distance value LX does not exceed the previous distance value LXp" includes not only the case where the current distance value LX is equal to or less than the previous distance value LXp ($LX \leq LXp$) but also the following case CS1 and case CS2. The case CS1 is the case where neither of the current distance value LX and the previous distance value LXp has been acquired, that is, the case where any presence of a detection object has not been detected by either of the object detectors 60R, 60L, 60B previously or currently; the case CS2 is the case where no previous distance value LXp has been acquired but a current distance value LX has been acquired for the first time, that is, the case where any presence of a detection object has not been detected by either of the object detectors 60R, 60L, 60B during the previous acquisition of the position information but the presence of a detection object is detected for the first time during the current acquisition of the position information.

[0059] The "control based on the current distance value LX" (step S6) also includes the determination of the necessity of the safety control based on the judgement on whether or not the current distance value LX is acquired. For example, when no detection object is detected by either of the object detectors 60R, 60L, 60B, no safety control is executed. In contrast, when the current distance value LX is acquired and the current distance value LX is equal to or less than the previous distance value LXp, that is, when it is judged that the position of the detection object relative to the reference position is not varied or that the detection object is approaching the reference position, executed are the speed limitation control, the alarm control, and the display control based on the current distance value LX.

[0060] Specifically, the safety control determination part 74 stores relationship information that is preset with respect to the relationship between the distance value LX and the speed limitation degree, for example, in the form of a relational expression or a map, and determines the speed limitation degree corresponding to the distance value LX based on the relationship information. In accordance with the thus determined speed limitation degree, at least one of the turning limitation command part 76 and the traveling limitation command part 78 of the controller 70 performs generation and output of the limitation command signal. The controller 70 may be configured to suspend limiting the speed when the distance value LX is acquired but exceeds a preset allowable distance value LXo. In summary, it may be set the condition LX > LXo as the speed limitation condition.

[0061] The safety control may be performed either whenever the current distance value LX is acquired, that is, whenever the detection object is detected, or only when the operation detected by each of the pilot pressure sensors 52R, 52L, 53F, 53B, 54F, 54B (turning operation and traveling operation) is an operation in a direction of making the hydraulic excavator approach the detection object. The speed limitation control may be performed on all of the turning motion and the traveling motion, but is preferably a control of limiting the speed of only the motion that causes the upper turning body 12 (or the upper turning body 12 and the lower traveling body 11) to approach the detection object out of all of the motions. For example, when a detection object is detected only by the right object detector 60R or the left object detector 60L in the posture shown in FIG. 2 whereas no detection object is detected by the back object detector 60B, the traveling motion is not absolutely required. Thus determining the motion to be limited taking account of the

actual position of the detection object and the direction of the operation enables workability to be inhibited from being deteriorated by unnecessary motion limitation.

[0062] When the current distance value LX is greater than the previous distance value LXp but the difference therebetween (= LX - LXp) is less than the allowable distance difference ΔLXo (NO in step S4), the control based on the current distance value LX is also performed (step S6). In short, no control change inhibition is performed. That is because the change of the safety control based on the current distance value LX in response to the variation in the position information is small, if the difference is small, that is, if the variation in the position information is small, involving no substantial inconvenience, namely, significant instability of the safety control. In other words, it is preferable to set the allowable distance difference ΔLXo so as to prevent such inconvenience from occurring. This makes it possible to effectively inhibit work efficiency from being deteriorated while securing the stability of the safety control.

[0063] On the other hand, when the change inhibition condition is satisfied, that is, when the current distance value LX is greater than the previous distance value LXp (YES in step S3) and the difference (= LX - LXp) exceeds the allowable distance difference ΔLXo (YES in Step S4), the controller 70 performs the control change inhibition until the position information for each sampling period is acquired a predetermined number of times. Specifically, the controller 70 updates the detection count value CT to the value obtained by adding 1 to the detection count value CT as a new detection count value CT (the increment of the detection count value CT: Step S7), and executes the control based on the previous distance value LXo until the thus updated detection count value CT reaches the predetermined count value CTo (e.g., 4) corresponding to the predetermined number of times (NO in step S8 and step S9). For example, even if the current distance value LX is significantly increased from the previous distance value LXo, that is, even if the detection object can be judged to make great relative movement to the reference position in the direction of separating from the reference position, namely, the safety direction, based on only the currently acquired position information, the safety control is continued based on the previous distance value LXo corresponding to the previously acquired position information. In summary, the relaxation of the safety control is temporarily suspended. This inhibits the safety control from being made unstable by the below-described temporary disturbance of the position information, enabling higher safety to be secured.

[0064] At the point in time when the detection frequency count value CT reaches the predetermined count value CTo (YES in step S8), that is, the point in time when the time obtained by multiplying the sampling period by the predetermined number of times has elapsed after the control change inhibition is started, namely, the inhibition release point in time, the controller 70 releases the control change inhibition. Specifically, the controller 70 resets the detection count value CT to zero (step S5) and restarts the normal safety control based on the current distance value LX (step S6).

[0065] Hereinafter will be described the effect of the control change inhibition more specifically.

[0066] The safety control is performed based on the positional information periodically acquired as described above, while the position information is likely to be disturbed. In particular, when each of the object detectors 60R, 60L, 60B is composed of a relatively inexpensive imaging device, for example, a monocular camera, and the identification of the detection object and the measurement of the detection distance thereof (the object distance from the reference position to the detection object) are performed by processing the image acquired by the imaging device, the possibility of disturbance of the position information of the detection object is rendered higher.

[0067] Specifically, the distance measurement by the image processing of the monocular camera is achieved by the calculation of the object distance based on the height and angle of the position of the camera and the position of the area in which the detection object is detected in the photographed image or the calculation of the object distance with the position of the specific part of the detection object (for example, the position of the foot of the person) as a reference, each of the cases involving a possibility of a large variation in the measurement value. For example, the distance measurement with the foot position of the person as a reference has a possibility of failing to accurately extract the foot position due to the influence of the ground or the background, which may cause great variation in the measurement result of the foot position. Furthermore, in the case where the foot of the person is hidden behind another object to disable the foot position from being determined, the object distance is estimated based on the size and the position on the image of another part of the human body (for example, the head); the thus estimated value is likely to be greatly affected by the relative relationship between the human body and the background or the orientation of the human body, which may further increase the variation. Depending on the condition, there may occur a temporal non-detection state in spite of the actual presence of the detection object or a misdetection of an object which does not actually exist.

[0068] The safety control, if unconditionally performed in quick response to the position information thus likely to be disturbed, is likely to be unstable. For example, in the case of the safety control including the speed limitation control, changing the degree of limiting the speed of the limitation target motion in response to the disturbance of the position information is likely to render the limitation target motion unsmooth. Besides, in the case of the safety control including the alarm control or the display control, the warning action through the alarm or display may be irregularly rendered discontinuous. Furthermore, if the object distance is erroneously detected in a direc-

tion of increasing, i.e., the direction of separating from the reference position, the safety control may be inappropriately relaxed or suspended in spite of no variation or a decrease in the object distance.

[0069] FIG. 6 shows a first example of the temporal variation in the distance value LX acquired in the embodiment, in which the detection of the detection object is erroneously temporarily interrupted due to some cause in the specific period TL. In the first example, if the speed limitation control was executed in unconditional response to the distance value LX regardless of the temporary disturbance of the position information caused by the non-detection, the limitation command (turning limitation command in FIG. 6) would temporarily fail to be generated in the specific period TL as indicated by a solid line in FIG. 7, involving an inappropriate increase in the pilot pressure (turning pilot pressure in FIG. 8), that is, inappropriate relaxation of the speed limitation, i.e., acceleration. In contrast, the continuation of the safety control based on the previous distance value LXp as shown in FIG. 5 (Step S9), that is, holding the previous distance value LXp as shown by the dashed line in FIG. 6, keeps the limitation command (turning limitation command in FIG. 7) as indicated by the dashed line in FIG. 7 regardless of the temporary disturbance of the position information to prevent the pilot pressure (turning pilot pressure) from being inappropriately increased as shown in FIG. 8, that is, to prevent the speed limitation from being inappropriately relaxed. Besides, in the case of the safety control including the alarm control or the display control, the warning also can be prevented from being inappropriately interrupted due to the disturbance of the position information.

[0070] FIG. 9 shows a second example of the temporal variation in the distance value acquired in the embodiment, in which the distance value is erroneously temporarily increased in a plurality of periods. In also the second example, if the speed limitation control was executed in unconditional response to the distance value LX regardless of the temporary disturbance of the position information due to the erroneous measurement of the object distance, the limitation command (the turning limitation command in FIG. 10) would be temporarily decreased, that is, the speed limitation would be relaxed, as shown by the solid line in FIG. 10, involving a risk of inappropriate increase in the pilot pressure (the turning pilot pressure in FIG. 10) similarly to the first example. In contrast, the above-described execution of the control change inhibition keeps constant the limitation command (the turning limitation command in FIG. 10) as indicated by a broken line in FIG. 10 regardless of the temporary increase in the distance value LX, thereby enabling the speed limitation to be prevented from being inappropriately relaxed, i.e., acceleration. It is also similar to the first example that, in the case of the safety control including the warning control, the warning action can be prevented from being inappropriately interrupted.

[0071] On the other hand, in the case of unsatisfaction of the change inhibition condition, especially, in the case where the current distance value LX is equal to or less than the previous distance value LXp (NO in step S3 in FIG. 5), that is, the case where the relative position of the detection object to the reference position can be judged to be non-varied or to approach the reference position based on the previous information and the current information, the normal safety control based on the current distance value LX is continued (step S6), enabling high safety to be secured.

[0072] Although the instability of the safety control caused by the above-described disturbance of the position information can be inhibited also by smoothing the distance value LX as shown by a broken line in FIG. 11 (moving average in the example of the drawing), it is difficult to secure the safety that could be acquired by the original safety control. Specifically, in the example shown in FIG. 11, when the actual distance value LX as indicated by the solid line is LX1, the smoothed distance value indicated by the broken line is larger than the distance value LX1 by the amount indicated by an arrow A1 shown in FIG. 11, by which amount the safety control is relaxed. Besides, the judgement that the distance value LX has been decreased to the value LX1 is delayed by the moving average by the time T1, whereby the detection object may be permitted to approach the work machine by the amount. In contrast, executing the control change inhibition only when the change inhibition condition is satisfied makes it possible to stabilize the safety control while securing high safety that can be achieved by the safety control.

[0073] The present invention is not limited to the embodiments that has been described. The present invention encompasses, for example, the following aspects.

(1) Control change inhibition

[0074] The control change inhibition according to the present invention is not limited to maintaining the safety control based on the previous distance value LX (previous information) as it is, that is, holding the previous information as it is. For example, in the case of the safety control including the speed limitation control, the control change inhibition may be either to perform the speed limitation based on the position information obtained by reducing the variation in the position information from the previous information to the current information to thereby indirectly reduce the relaxation of the speed limitation or to directly reduce the relaxation of the limitation of the speed in response to the variation from the previous information to the current information.

[0075] FIG. 12 shows an example of applying a so-called rate limiter that limits the change rate of the turning limitation command as an example of directly reducing the relaxation of the speed limitation. In FIG. 12, in a period TA in which the turning limitation command is decreased with time and the change inhibition condition is satisfied, the change in the turning limitation command

is smoothed by limiting the temporal reduction rate of the turning limitation command to a value less than or equal to a fixed value, and the reduction in the turning limitation command itself is also limited to restrain the limitation from being inappropriately relaxed. On the other hand, in a period TB in which the turning limitation command is increased and the change inhibition condition is not satisfied, the turning limitation command calculated based on the acquired position information (current information) is directly applied to the speed limitation, allowing high safety to be secured. Such an effect can be provided by performing another smoothing means, for example, the moving average shown in FIG. 11, on the turning limitation command only when the change inhibition condition is satisfied, i.e., only in the period TA in FIG. 12, or smoothing the position information (for example, the distance value LX shown in FIG. 6, FIG. 9) similarly to the turning limitation command.

[0076] The period in which the control change inhibition should be performed may be set based on not the number of times of detection as in the embodiment but the time itself.

(2) Change inhibition condition

[0077] The change inhibition condition according to the present invention has only to include that the current information is varied from the reference position in the direction of separating from the reference position, namely, the condition A in the above embodiment, while other conditions can be omitted or arbitrarily set. For example, in place of the condition B that the difference between the current distance value LX and the previous distance value LXp exceeds the allowable distance difference ΔLXo, or in addition thereto, the change inhibition condition may include that the position information about the detection object according to the current information has already been acquired more than or equal to a preset number of times. This makes it possible to prevent the control change inhibition from being inappropriately executed when the presence of a detection object is temporarily erroneously detected.

(3) Position information and position information acquisition part

[0078] The position information according to the present invention has only to be information about the relative position of the detection object to the reference position set for the work machine, allowed to include either only information about the object distance that is the distance from the reference position to the detection object or other information. For example, there may be provided a turning angle sensor to detect the turning angle of the upper turning body 12 to the lower traveling body 10, allowing the position coordinates of a detection object to be determined based on the turning angle detected by the turning angle sensor.

[0079] The reference position does not absolutely have to be the position at which the object detector is disposed. In other words, the object distance does not have to be the distance from the object detector to the detection object. The reference position may be either a position deviated from the position at which the object detector is disposed or a position set around the work machine. For example, there may be determined the part of the work machine that is closest to the detection object based on the detection signal generated by the target object detector, the position of the determined part being set to the reference position. In summary, the reference position may be set so as to enable the shortest distance to be always calculated as the object distance.

[0080] The object detector constituting the position information acquisition part according to the present invention is not limited to one including an imaging device. For example, the object detector may be a distance detector such as an infrared depth sensor or a millimeter wave radar if there is no special limitation on the detection object, that is, if the detection object is not required to be identified. The object detector, alternatively, may be an imaging device that is not a monocular camera but one capable of providing three-dimensional information, for example, a stereo camera. For the machine where the position information acquisition part includes a combination of the imaging device and the image processing as described above, however, the application of the safety control and the control change inhibition according to the present invention is more effective because the combination, although having a merit of identifying the detection object with use of an inexpensive imaging device, is likely to cause a disturbance of position information.

(4) Speed limitation control

[0081] In the case of executing the speed limitation control in the present invention, specific means for executing the speed limitation control is not limited. For example, in a work machine where each of the turning operation unit 42 and the traveling operation units 43, 44 is composed of an electric lever device configured to generate an electric signal corresponding to an operation input by an operator and to input the electric signal to the controller, and the controller is configured to operate respective solenoid valves interposed between a pilot hydraulic source and control valves, e.g., the turning control valve 36 and the traveling control valve 37, 38, based on the electric signal, the speed limitation of limiting the actual speed below the speed corresponding to the operation may be performed by changing the command to be input to the solenoid valves.

[0082] Although the speed limitation control to be executed, in the above embodiment, is determined based on only the object distance from the reference position to the detection object, the present invention encompasses also a case where a monitoring area is set around the work machine to have an arbitrary shape including a

speed limitation area and the control part is configured to execute the speed limitation control only when a detection object is judged to be present in the speed limitation area. In this case, the control part can be configured to perform the control change inhibition by maintaining the safety control that has been performed in an in-area detection state where the detection object is detected in the monitoring area when the detection object is shifted from the in-area detection state to an in-area non-detection state where the detection object is not detected in the monitoring area.

[0083] For example, there may be a case where right side areas AR1, AR2, back areas AB1, AB2 and left side areas AL1, AL2 are set as indicated by respective two-dot chain lines correspondingly to respective detection ranges of the object detectors 60R, 60L and 60B around (rearward, rightward and leftward) of the hydraulic excavator shown in FIG. 2, while the safety control determination part 74 is configured to determine the motion (the turning motion or traveling motion) whose speed should be limited based on which area the detection object is present in.

[0084] Specifically, it is preferable that, among the areas AR1, AR2, AB1, AB2, AL1 and AL2, each of the areas AR1, AB1 and AL1, which are inner areas on the side closer to the upper turning body 12, is set to a stop area Asp, while each of the areas AR2, AB2 and AL2, which are outer areas on the side farther from the upper turning body 12, is set to a speed limitation area Alm.

[0085] Alternatively, as shown in FIG. 13, there may be set a single stop area Asp around the hydraulic excavator and a single speed limitation area Alm on the outer side of the single stop area Asp.

[0086] In each case, the controller 70 is preferably configured to execute a forcible stop control of forcibly stopping the limitation target motion as the safety control when the detection object is detected in the stop area Asp, that is, any of the areas AR1, AB1 and AL1 in FIG. 2, and configured to perform a speed limitation control as the safety control when the detection object is detected in the speed limitation area Alm, that is, any of the areas AR2, AB2 and AL2 in FIG. 2.

[0087] FIG. 14 shows an example of respective inverse-proportional-valve instruction current values for the stop area and the speed limitation area which are set as described above. The inverse-proportional-valve instruction current value is the value of an instruction current that is a limitation command to be input to each of the target inverse proportional valves from the controller 70, the target inverse proportional valve being the solenoid reverse proportional pressure reducing valve that composes each of the operation valves, namely, the operation valves 46R, 46L, 47F, 47B, 48F and 48B shown in FIG. 3, disposed to limit the motions of the hydraulic excavator (work machine) shown in FIG. 2 or FIG. 13.

[0088] As shown in FIG. 14, the inverse-proportional-valve instruction current value for the stop area Asp is set to the maximum value in order to forcibly stop the control target operation of the work machine. For the limitation area Alm, the inverse-proportional-valve instruction current value is set so as to be gradually decreased from the maximum value with an increase in the object distance in order to limit the speed of the limitation target motion at a degree increased with a decrease in the object distance, in other words, in order to relax the limitation of the speed of the limitation target motion with an increase in the object distance. Besides, for the area outside the monitoring area, the inverse-proportional-valve instruction current value is set to the minimum value in order to release the limitation of the speed of the control target motion.

[0089] In also this example, it is preferable that the controller 70 inhibits, as the control change inhibition, the limitation of the speed of the limitation target motion from being relaxed in response to the variation from the previous information to the current information. For example, when a detection target is detected in the speed limitation area Alm according to the previous information and the object distance of the detection object according to the current information is increased from that according to the previous information, it is preferable as the control change inhibition to maintain the speed limitation corresponding to the previous information. Besides, when the detection object is detected in the stop area Asp according to the previous information whereas the detection object is shifted to a state of not being detected (including a state where the detection object is detected at the speed limitation area Alm or outside the monitoring area), it is preferable to continue the forcible stop of the control target motion.

[0090] In each case, it is more preferable that the change inhibition condition for executing the control change inhibition includes that the difference between the object distance according to the current information and the object distance according to the previous information exceeds a preset allowable difference.

[0091] As has been described, according to the present invention, there is provided a device capable of stably performing safety control for a work machine. Provided is a safety device that performs safety control of a work machine, comprising a position information acquisition part and a control part. The position information acquisition part periodically acquires position information on a position of a detection object around the work machine. The control part is configured to perform a safety control when current information, which is the position information currently acquired, is varied from previous information, which is the position information previously acquired, in a direction of approaching the work machine, the safety control corresponding to the current information, and configured to execute a control change inhibition of inhibiting the safety control from being changed in response to a variation in the position information when a change inhibition condition including that the current information is varied from the previous information in a direction of separating from the work

machine is satisfied. The control part releases the control change inhibition at a point in time when a predetermined time has elapsed, for example, the position information has been acquired a predetermined number of times, after the start of the control change inhibition.

[0092] The execution of the control change inhibition when the change inhibition condition is satisfied makes it possible to execute the stable safety control while securing the safety of the work machine even when the acquisition of the position information is unstable. For example, when the detection object temporarily fails to be detected in spite of the actual presence of the detection object or when the position information is temporarily varied in a direction of going away in spite that the detection object actually does not go away, the control part does not unconditionally execute the safety control in immediate response to the variation but execute the control change inhibition of inhibiting the change of the safety control (the change in a direction of relaxing the safety control) if the change inhibition condition is satisfied, thereby allowing the safety control to be stabilized. Moreover, the control change inhibition is released at the point in time when a predetermined time has elapsed, for example, when the position information has been acquired by a preset number of times, after the start of the control change inhibition, which prevents the safety control based on the previous information from being excessively continued. On the other hand, when the position information is varied in the direction of approaching the work machine, the execution of the safety control based on the current information enables high safety of the work machine to be secured.

[0093] The safety control preferably includes a speed limitation control. The speed limitation control is a control of limiting the speed of a limitation target motion that is preset among motions of the work machine at a degree increased with a decrease in an object distance, which is a distance from a reference position that is set for the work machine to the detection object, when the object distance is within a preset speed limitation range. The speed limitation control may include a control of rendering the speed of the limitation target motion zero, that is, a stop control of forcibly stopping the limitation target motion. The control change inhibition corresponding to the speed limitation control, that is, inhibiting the limitation of the speed of the limitation target motion from being relaxed in response to the variation from the previous information to the current information, prevents the limitation of the speed from being unnecessarily relaxed due to the temporary disturbance of the acquired position information, thereby inhibiting the motion of the work machine from being made instable and enabling the safety to be further enhanced.

[0094] In the case where the work machine includes a hydraulic circuit for performing the limitation target motion and the hydraulic circuit is configured to limit the limitation target motion in response to a limitation command that is input to the hydraulic circuit, it is preferable that the control part is configured to generate the limitation command and inputs the limitation command to the hydraulic circuit when performing the speed limitation control and configured to inhibit the limitation command from being changed as the control change inhibition.

[0095] More specifically, in the case where the work machine includes a lower traveling body and an upper turning body mounted on the lower traveling body capably of turning and the hydraulic circuit includes a circuit for turning the upper turning body, it is preferable that the position information acquired by the position information acquisition part contains information about an object distance, which is a distance from a reference position that is set for the upper turning body to the detection object, the limitation target motion including at least a turning motion of the upper turning body, the limitation command including a turning limitation command for limiting the turning motion.

[0096] The safety control, alternatively, may be a control of making an alarm unit that is further provided in the safety device output an alarm. In also this aspect, the control change inhibition can prevent the alarm from being inappropriately interrupted by the disturbance of the acquired position information.

[0097] As the control change inhibition, it is effective, for example, to continue safety control based on the previous information regardless of the current information, that is, to hold the previous information as the position information for determining the safety control.

[0098] In the case where the safety control is the speed limitation control, the control change inhibition, alternatively, may be either to limit the speed of the limitation target motion based on position information obtained by reducing the variation from the previous information to the current information or to directly reduce the relaxation itself of the limitation of the speed of the limitation target motion in response to the variation from the previous information to the current information. For example, in a mode where the control part inputs the limitation command to the hydraulic circuit, the control change inhibition may be a limitation of the temporal change rate of the limitation command.

[0099] The change inhibition condition may further include that the variation from the previous information to the current information is large, specifically, that the difference between the current information and the previous information exceeds a preset allowable difference. In other words, when the current information is varied from the previous information in a direction of approaching the work machine but the variation is small, that is, when the change of the safety control in accordance with the variation will not impart significant influence on the safety of the safety control, the control change inhibition may be suspended. This can prevent work efficiency from being deteriorated by frequent performance of the control change inhibition, that is, the inhibition of the relaxation of the safety control.

[0100] The change inhibition condition may further in-

clude that the position information about the detection object related to the current information has already been acquired more than or equal to a preset number of times. This can prevent the control change inhibition from being inappropriately executed when the presence of the detection object is temporarily erroneously detected.

[0101] The present invention, although not intending to limit the specific configuration of the position information acquisition part, is especially effective in the case where the position information acquisition part includes an imaging device that generates a captured image containing the detection object and a position information generation unit that processing the captured image to thereby generate the position information. Since the position information acquired by the image processing from the captured image generated by the imaging device is likely to be unstable due to various factors, the control change inhibition that enables safety control to be stable in spite of the instability of the position information is particularly effective.

[0102] The control part may be configured to execute the safety control when the detection object is detected in a monitoring area set around the work machine. In this case, the control part is preferably configured to maintain the safety control that has been performed in an in-area detection state where the detection object is detected in the monitoring area as the control change inhibition when the detection object is shifted from the in-area detection state to an in-area non-detection state where the detection object is not detected in the monitoring area. This inhibits the safety control from being inappropriately stopped when the detection object temporarily fails to be detected in the monitoring area due to the disturbance of the acquired position information.

[0103] Specifically, it is preferable that the monitoring area includes a stop area and a speed limitation area, and the control part is configured to execute a forcible stop control as the safety control when the detection object is detected in the stop area and configured to execute a speed limitation control as the safety control when the detection object is detected in the speed reduction control area. The forcible stop control is a control of forcibly stopping a limitation target motion preset among motions of the work machine, and the speed limitation control is a control of limiting the speed of the limitation target motion at a degree increased with a decrease in an object distance, which is a distance from a reference position set for the work machine to the detection object. In this case, the control change inhibition preferably includes inhibiting the speed limitation of the limitation target motion from being relaxed in response to the variation from the previous information to the current information.

[0104] In also this case, it is preferable that the change inhibition condition further includes that the difference between the object distance according to the current information and the object distance according to the previous information exceeds a preset allowable difference.

Claims

1. A safety device for performing a safety control of a work machine, comprising:

   a position information acquisition part that periodically acquires position information on a position of a detection object around the work machine; and
   a control part, wherein
   the control part is configured to perform the safety control when current information, which is the position information currently acquired, is varied from previous information, which is the position information previously acquired, in a direction of approaching the work machine, the safety control corresponding to the current information, configured to execute a control change inhibition of inhibiting the safety control from being changed in response to a variation in the position information when a change inhibition condition including that the current information is varied from the previous information in a direction of separating from the work machine is satisfied, and configured to release the control change inhibition at a point in time when a predetermined time has elapsed after the control change inhibition is started.

2. The safety device of the work machine according to claim 1, wherein the control part releases the control change inhibition at a point in time when the position information has been acquired a predetermined number of times after the start of the control change inhibition.

3. The safety device of the work machine according to claim 1, wherein the safety control includes a speed limitation control, which is a control of limiting a speed of a limitation target motion that is preset among motions of the work machine at a degree increased with a decrease in an object distance, which is a distance from a reference position that is set for the work machine to the detection object, when the object distance is within a preset speed limitation range, and the control change inhibition includes inhibiting a limitation of the speed of the limitation target motion from being relaxed in response to the variation from the previous information to the current information.

4. The safety device of the work machine according to claim 3, wherein: the work machine includes a hydraulic circuit for performing the limitation target motion; the hydraulic circuit is configured to limit the limitation target motion in accordance with a limitation command that is input to the hydraulic circuit; and the control part is configured to generate

the limitation command and to input the limitation command to the hydraulic circuit when performing the speed limitation control and configured to inhibit, as the control change inhibition, the limitation command from being changed.

5. The safety device of the work machine according to claim 4, wherein: the work machine includes a lower traveling body and an upper turning body mounted on the lower traveling body capably of turning; the hydraulic circuit includes a circuit for turning the upper turning body; the position information acquired by the position information acquisition part includes information about the object distance, which is a distance from a reference position set for the upper turning body to the detection object; the limitation target motion includes at least a turning motion of the upper turning body; and the limitation command includes a turning limitation command for limiting the turning motion.

6. The safety device of the work machine according to claim 1, further comprising an alarm unit, wherein the safety control includes a control of making the alarm unit output an alarm.

7. The safety device of the work machine according to claim 1, wherein the control change inhibition is to continue the safety control based on the previous information regardless of the current information.

8. The safety device of the work machine according to claim 3, wherein the control change inhibition is to limit the speed of the limitation target motion based on position information obtained by reducing the variation from the previous information to the current information.

9. The safety device of the work machine according to claim 3, wherein the control change inhibition is to directly reduce the relaxation itself of the limitation of the speed of the limitation target motion in response to the variation from the previous information to the current information.

10. The safety device of the work machine according to claim 1, wherein the change inhibition condition further includes that a difference between the current information and the previous information exceeds a preset allowable difference.

11. The safety device of the work machine according to claim 1, wherein the change inhibition condition further includes that the position information about the detection object related to the current information has already been acquired more than or equal to a preset number of times.

12. The safety device of the work machine according to claim 1, wherein the position information acquisition part includes an imaging device that generates a captured image containing the detection object and a position information generation unit that processes the captured image to thereby generate the position information.

13. The safety device of the work machine according to claim 1, wherein the control part is configured to execute the safety control when the detection object is detected in a monitoring area set around the work machine and configured to maintain the safety control that has been performed in an in-area detection state where the detection object is detected in the monitoring area, as the control change inhibition, when the detection object is shifted from the in-area detection state to an in-area non-detection state where the detection object is not detected in the monitoring area.

14. The work machine safety device according to claim 13, wherein: the monitoring area includes a stop area and a speed limitation area; the control part is configured to execute a forcible stop control as the safety control when the detection object is detected in the stop area, the forcible stop control being a control of forcibly stopping a limitation target motion preset among motions of the work machine, and configured to execute a speed limitation control as the safety control when the detection object is detected in the speed reduction control area, the speed limitation control being a control of limiting the speed of the limitation target motion at a degree increased with a decrease in an object distance, which is a distance from a reference position set for the work machine to the detection object; and the control change inhibition includes inhibiting the limitation of the speed of the limitation target motion from being relaxed in response to the variation from the previous information to the current information.

15. The safety device of the work machine according to claim 14, wherein the change inhibition condition further includes that a difference between the object distance according to the current information and the object distance according to the previous information exceeds a preset allowable difference.

FIG.1

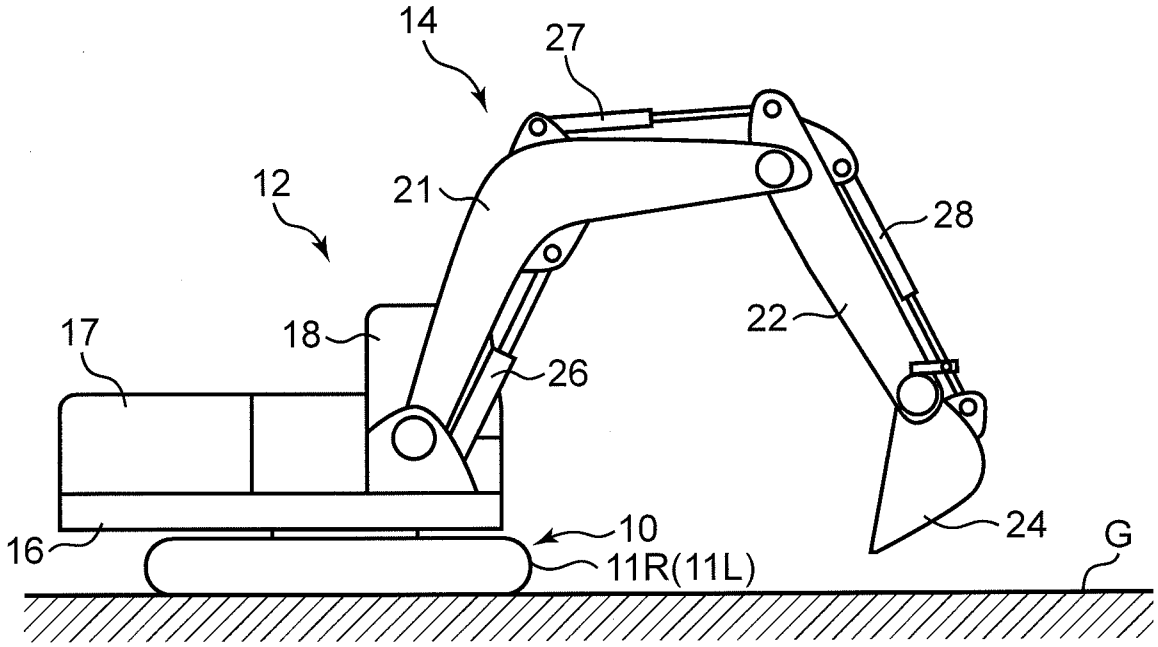


FIG.2

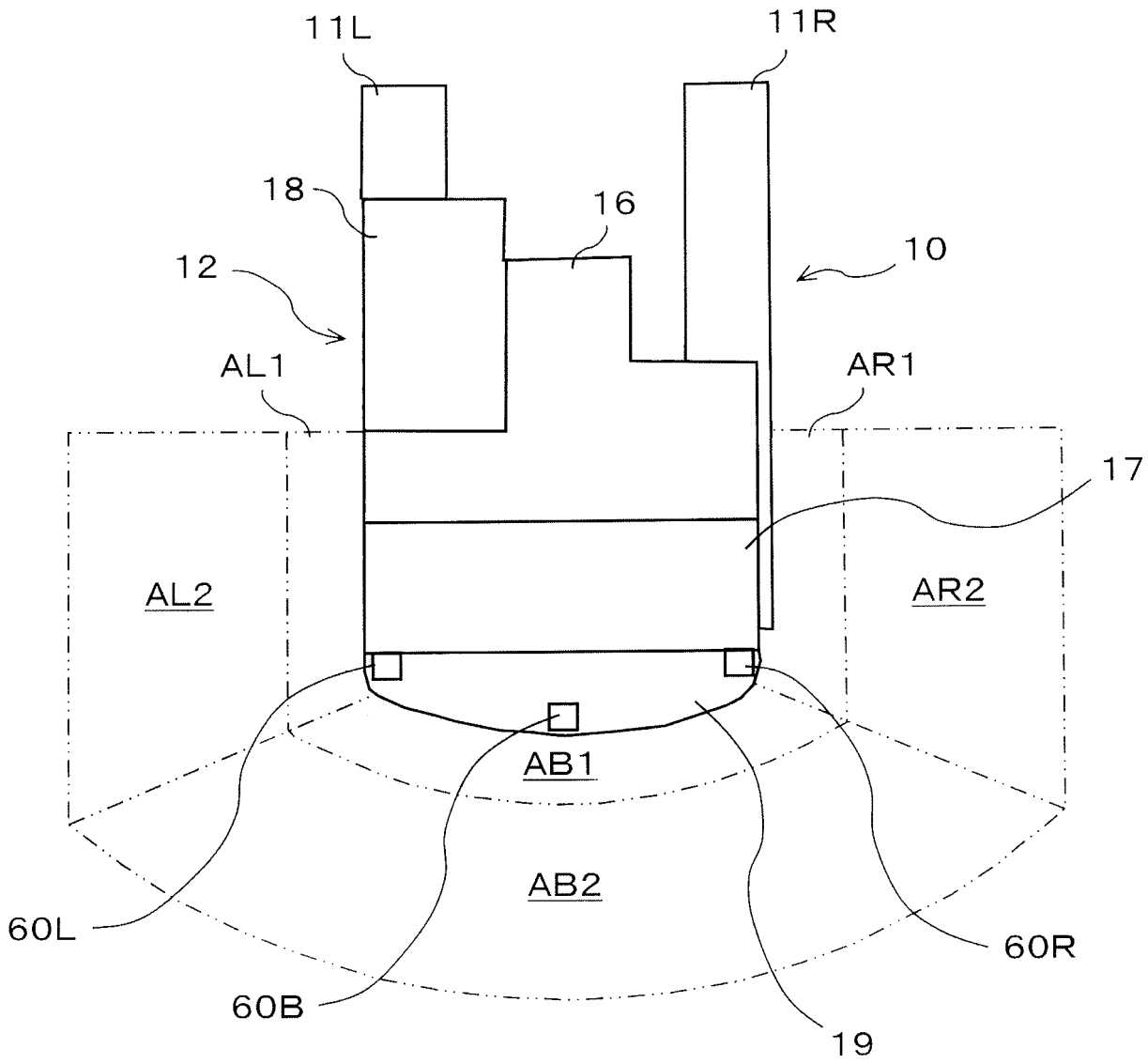


FIG.3

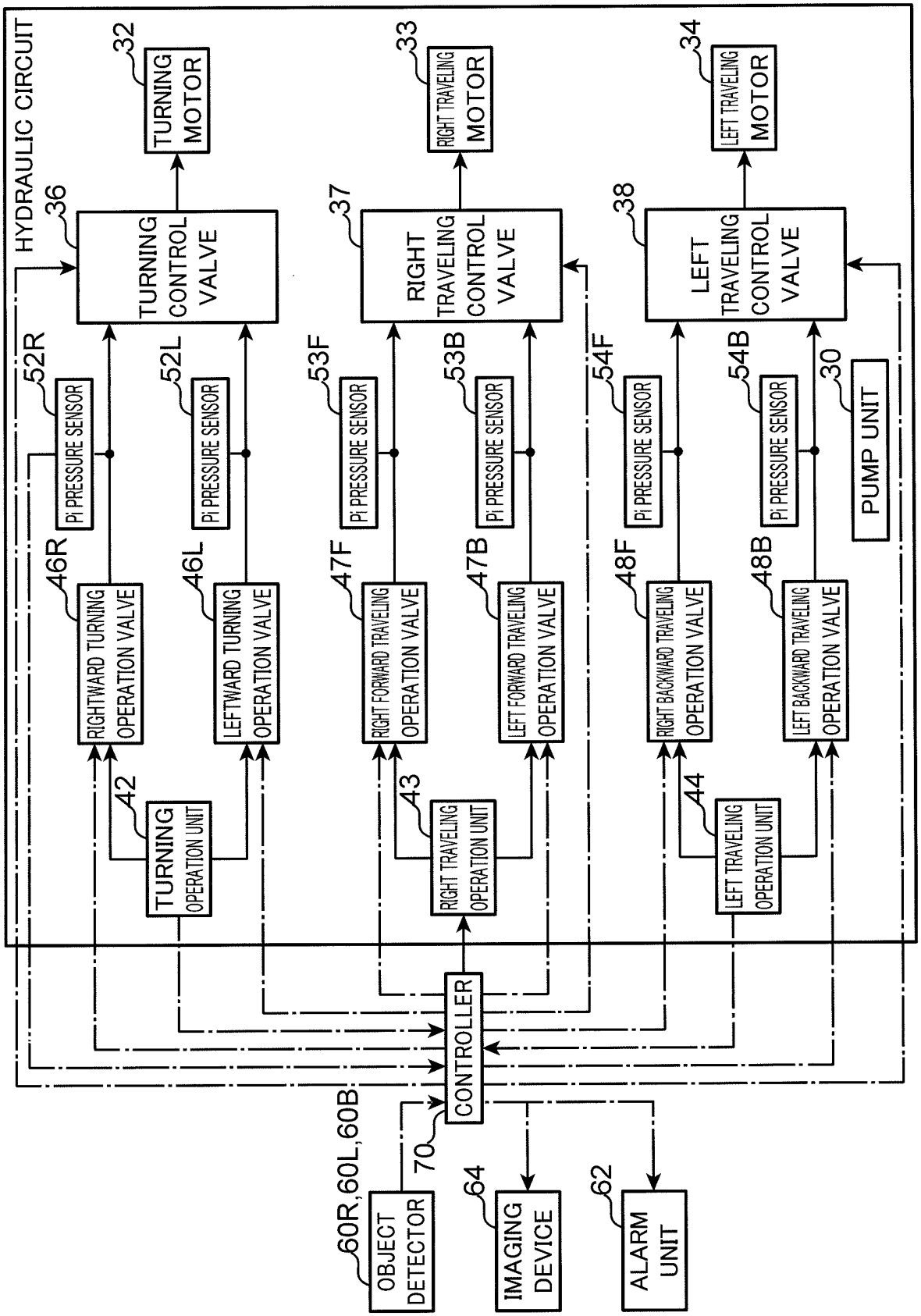

HYDRAULIC CIRCUIT
32
TURNING MOTOR
33
RIGHT TRAVELING MOTOR
34
LEFT TRAVELING MOTOR
36
TURNING CONTROL VALVE
37
RIGHT TRAVELING CONTROL VALVE
38
LEFT TRAVELING CONTROL VALVE
52R
Pi PRESSURE SENSOR
52L
Pi PRESSURE SENSOR
53F
Pi PRESSURE SENSOR
53B
Pi PRESSURE SENSOR
54F
Pi PRESSURE SENSOR
54B
Pi PRESSURE SENSOR
30
PUMP UNIT
46R
RIGHTWARD TURNING OPERATION VALVE
46L
LEFTWARD TURNING OPERATION VALVE
47F
RIGHT FORWARD TRAVELING OPERATION VALVE
47B
LEFT FORWARD TRAVELING OPERATION VALVE
48F
RIGHT BACKWARD TRAVELING OPERATION VALVE
48B
LEFT BACKWARD TRAVELING OPERATION VALVE
42
TURNING OPERATION UNIT
43
RIGHT TRAVELING OPERATION UNIT
44
LEFT TRAVELING OPERATION UNIT
CONTROLLER
70
60R, 60L, 60B
OBJECT DETECTOR
64
IMAGING DEVICE
62
ALARM UNIT

FIG.4

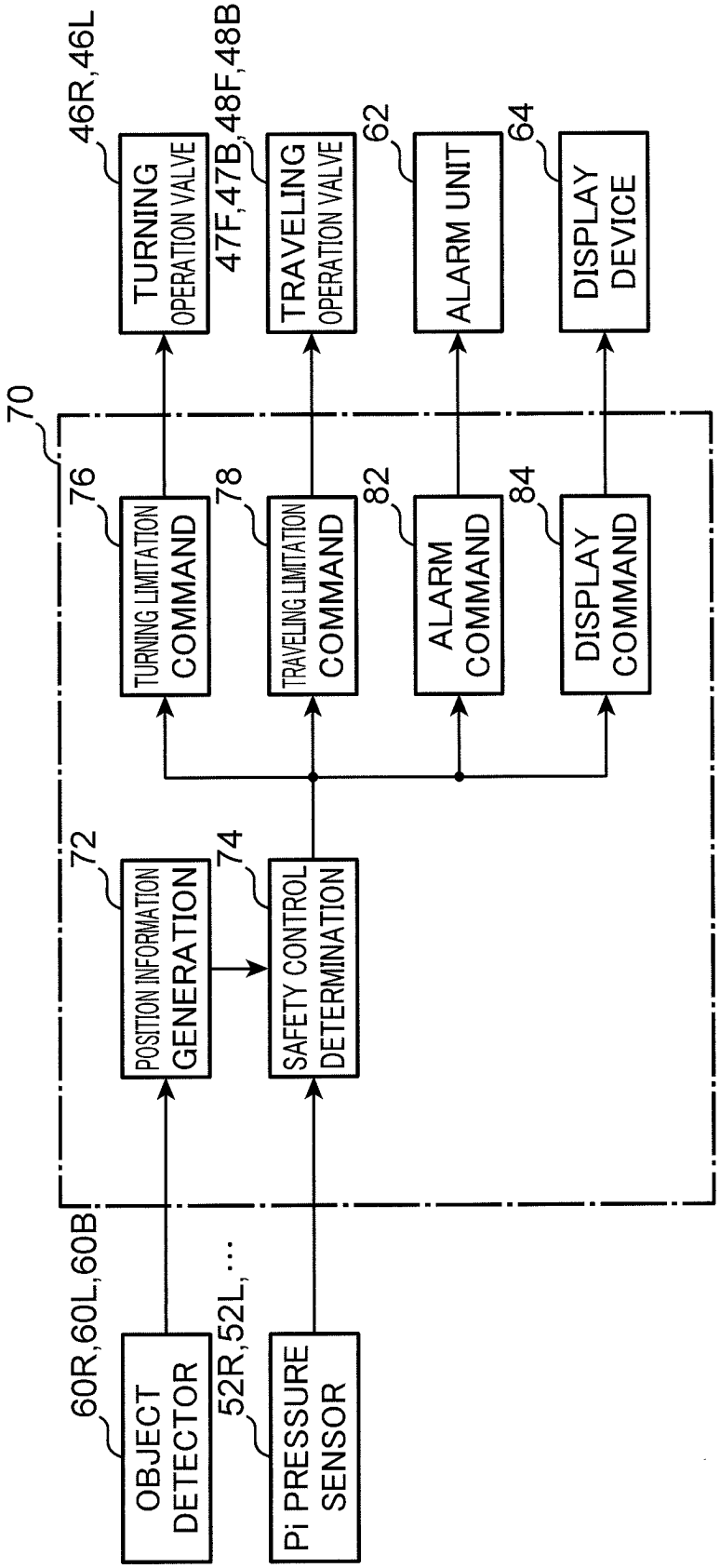

60R,60L,60B
OBJECT DETECTOR
52R,52L,...
Pi PRESSURE SENSOR
70
72
POSITION INFORMATION GENERATION
74
SAFETY CONTROL DETERMINATION
76
TURNING LIMITATION COMMAND
78
TRAVELING LIMITATION COMMAND
82
ALARM COMMAND
84
DISPLAY COMMAND
46R,46L
47F,47B,48F,48B
TURNING OPERATION VALVE
TRAVELING OPERATION VALVE
62
ALARM UNIT
64
DISPLAY DEVICE

FIG.5

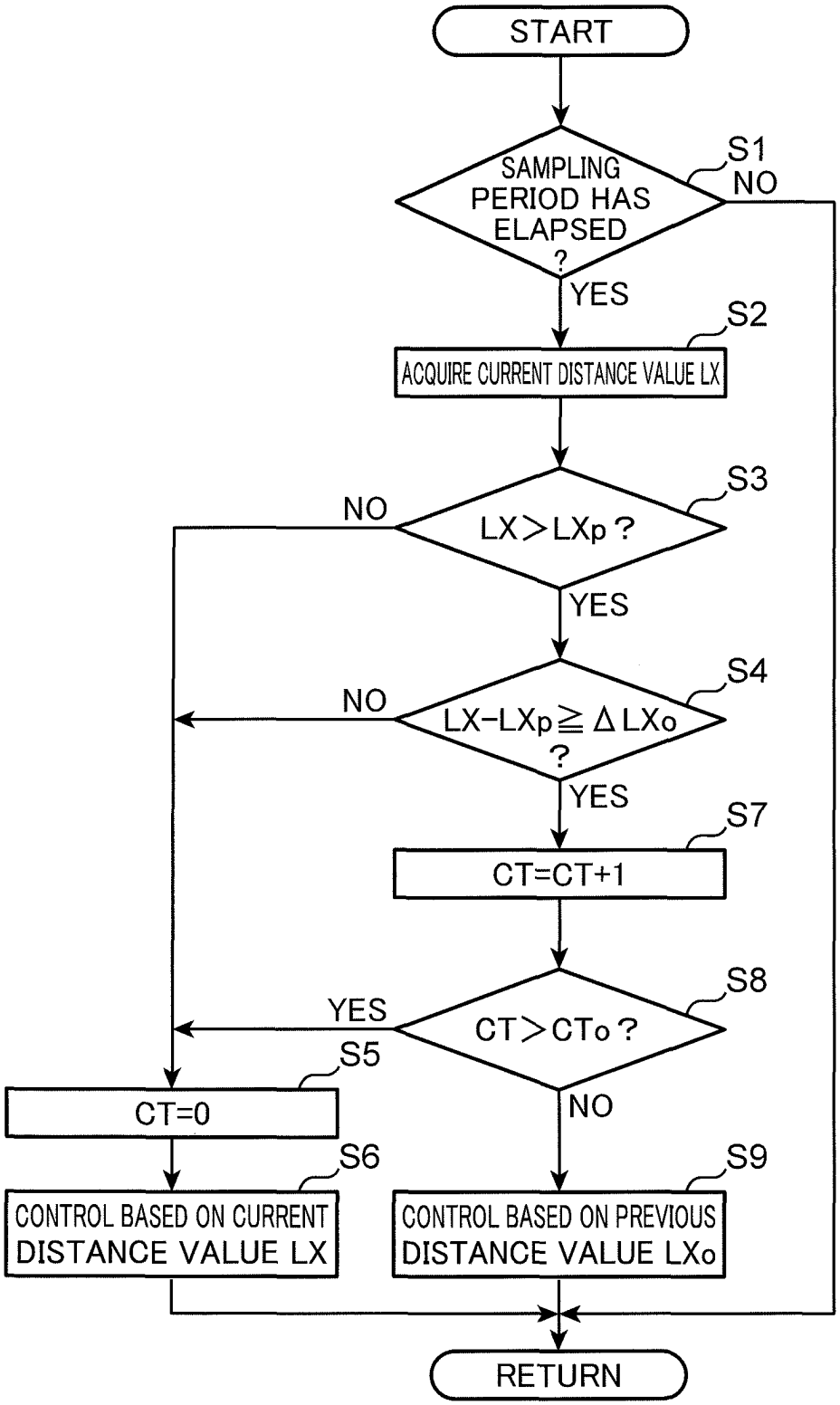

START
SAMPLING PERIOD HAS ELAPSED ?
S1
NO
YES
S2
ACQUIRE CURRENT DISTANCE VALUE LX
S3
NO
LX > LXp ?
YES
S4
NO
LX-LXp ≧ Δ LXo ?
YES
S7
CT=CT+1
S8
YES
CT > CTo ?
S5
NO
CT=0
S6
S9
CONTROL BASED ON CURRENT DISTANCE VALUE LX
CONTROL BASED ON PREVIOUS DISTANCE VALUE LXo
RETURN

FIG.6

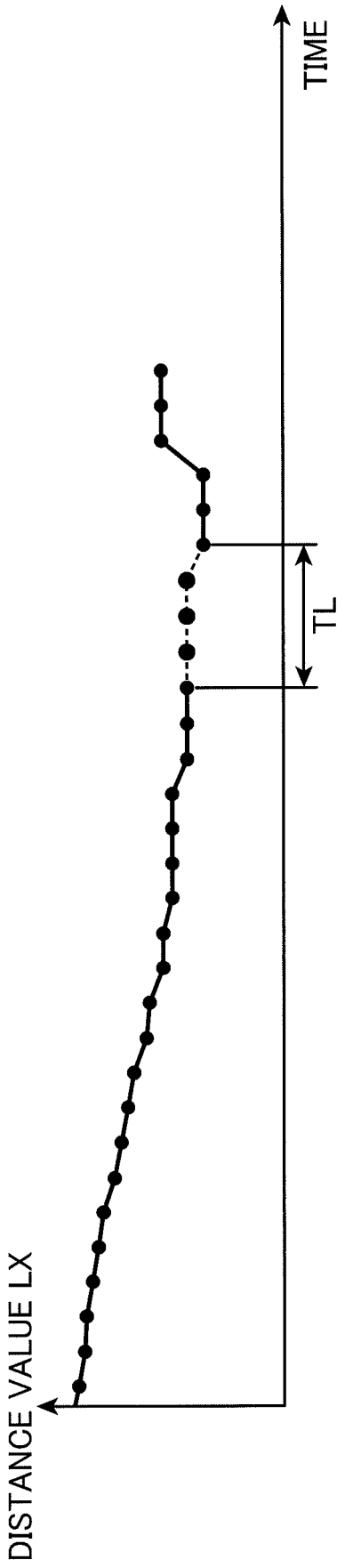


FIG.7

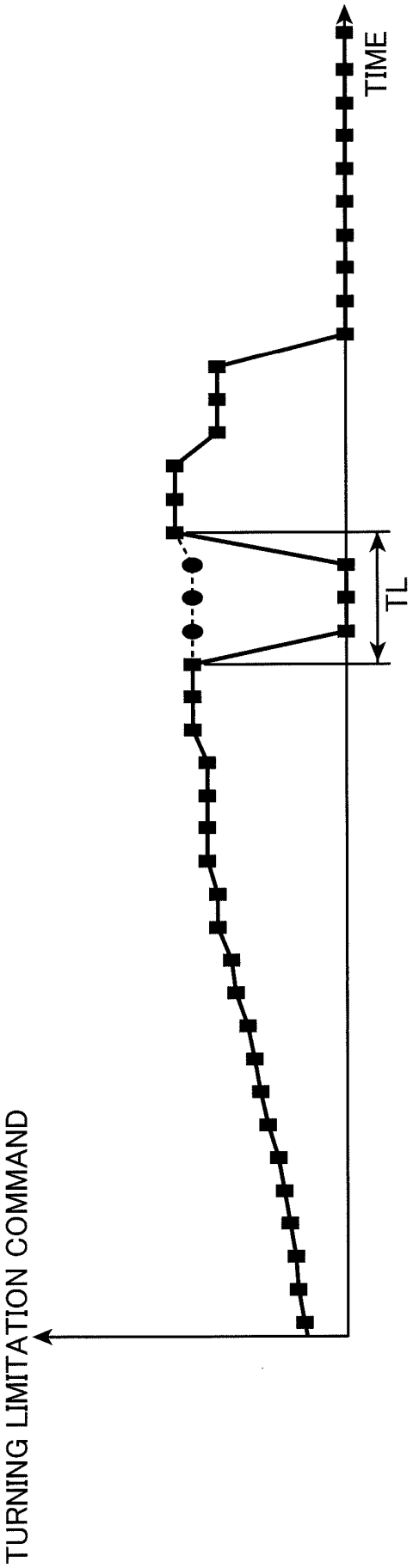


FIG.8

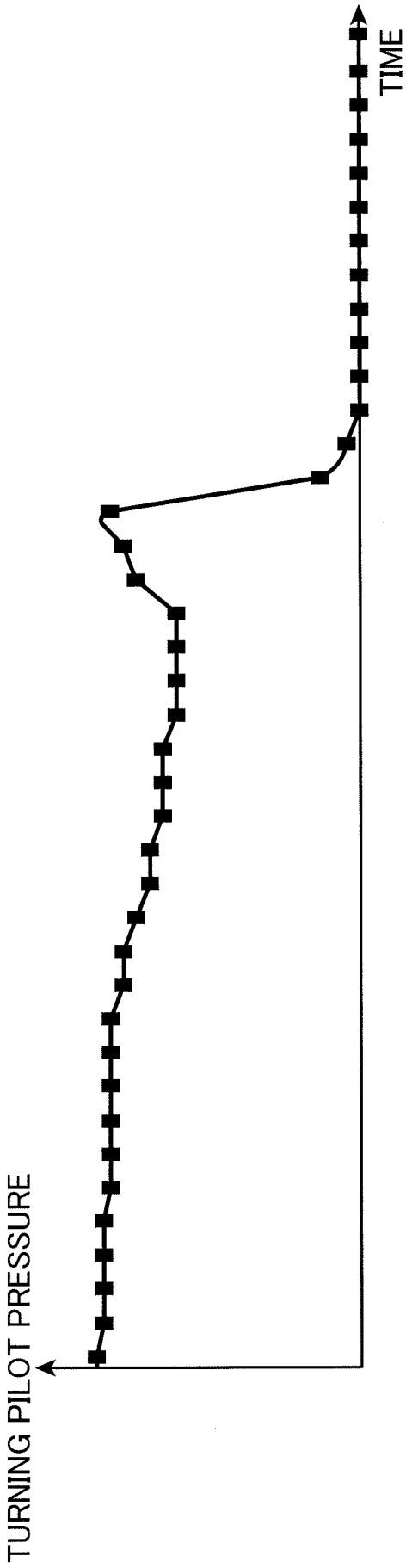


FIG.9

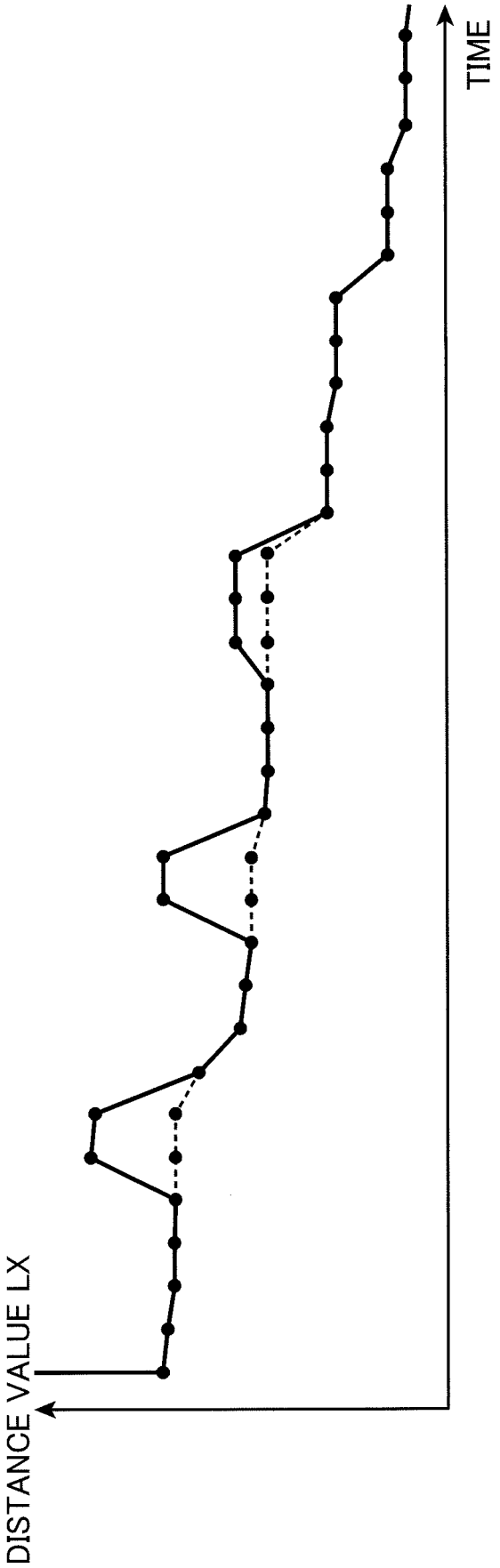


FIG.10

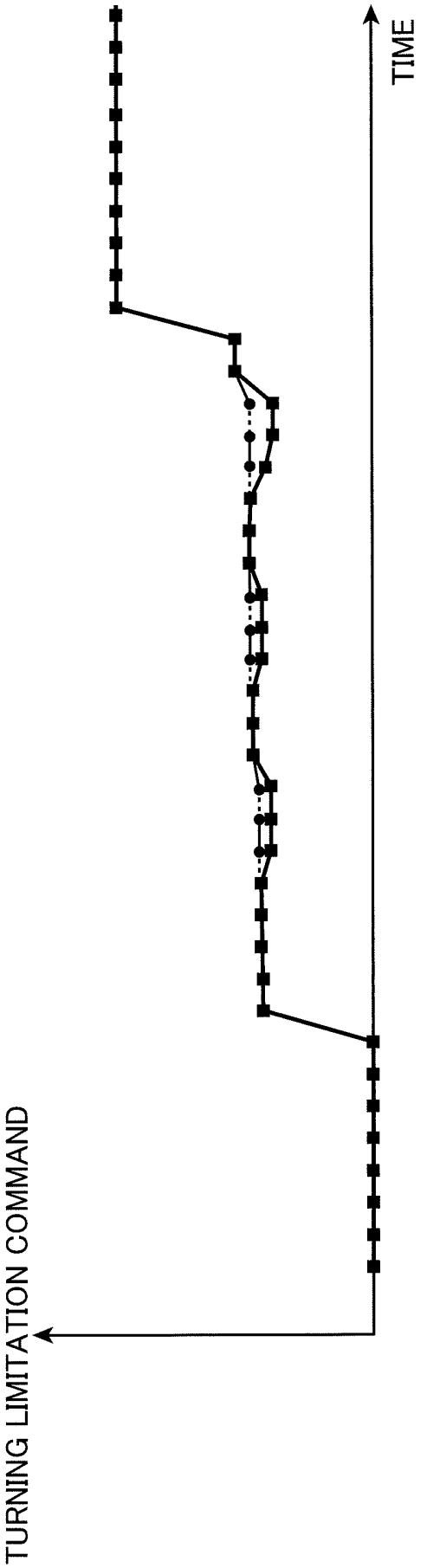


FIG.11

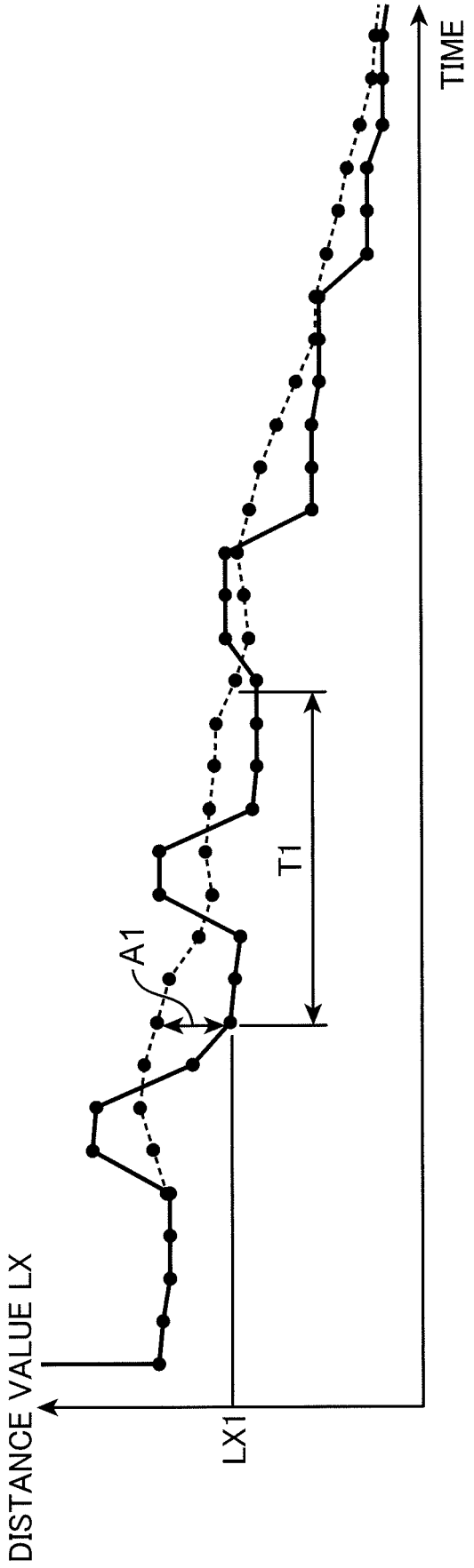


FIG.12

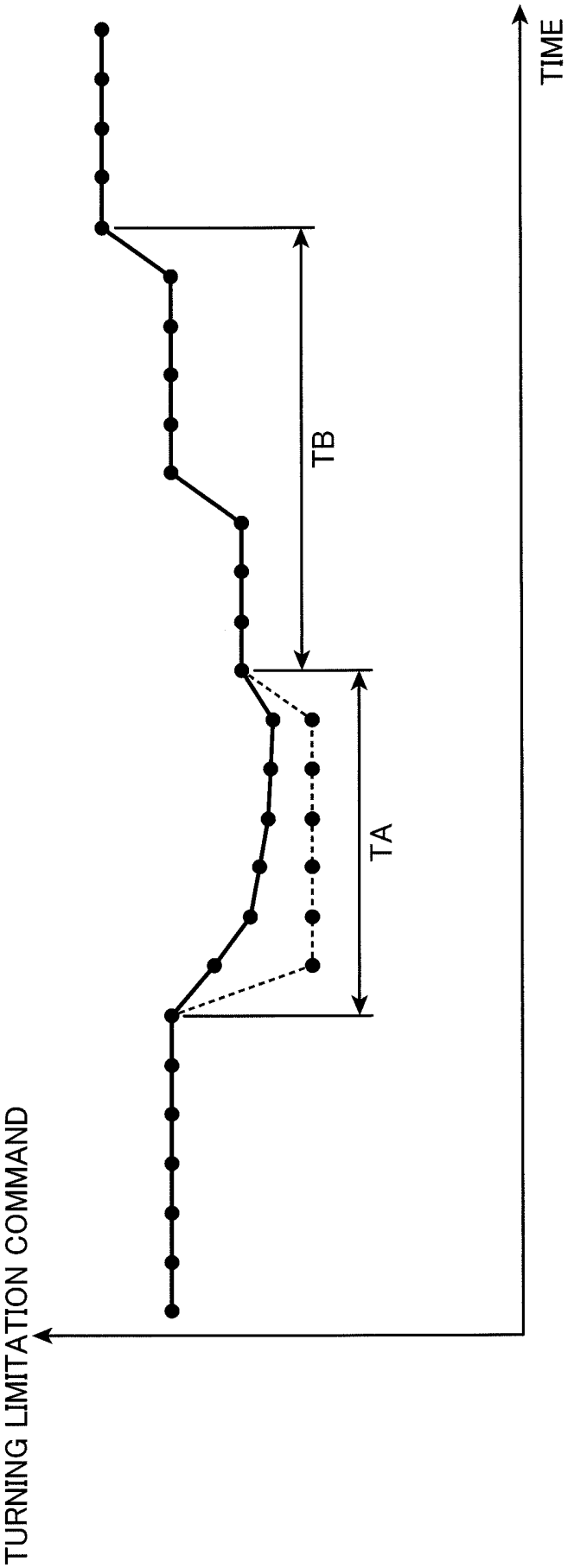


FIG.13

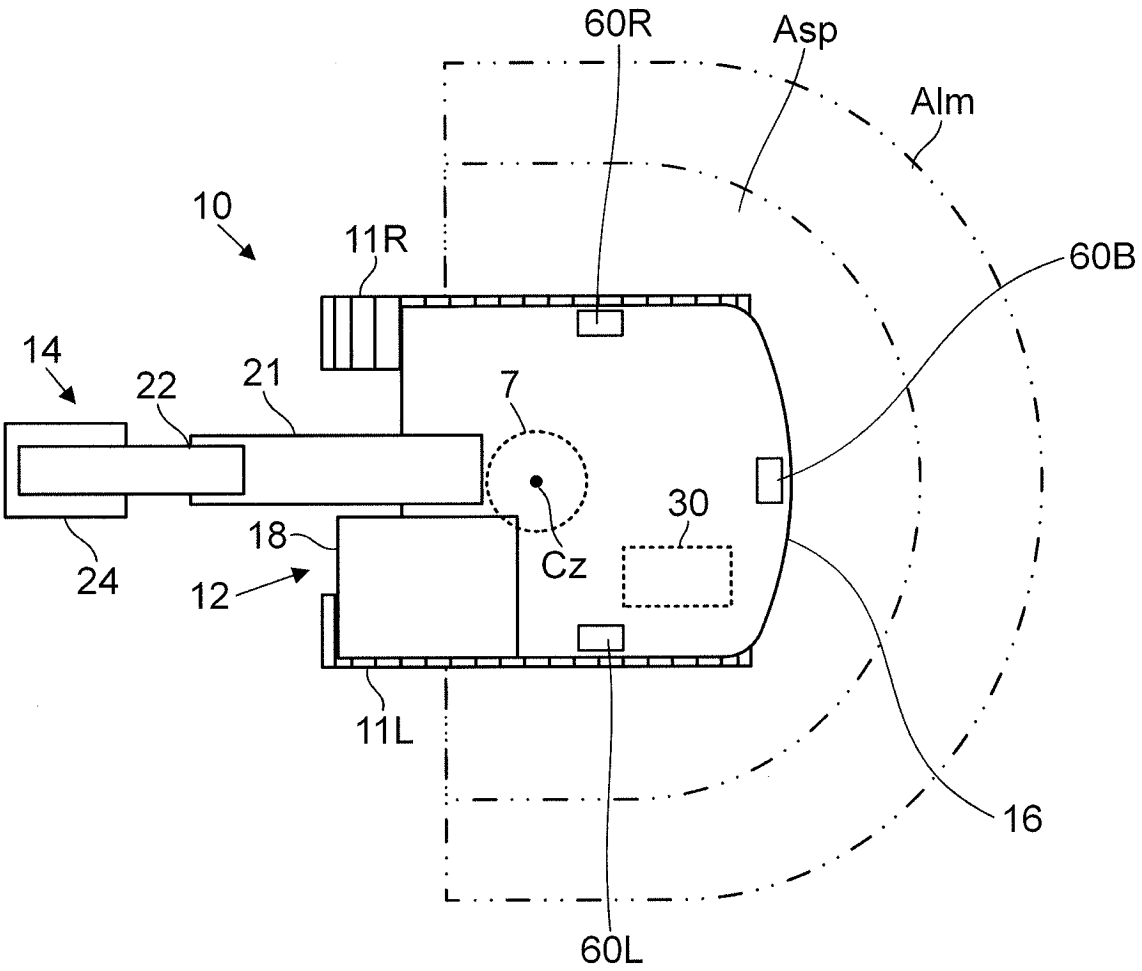
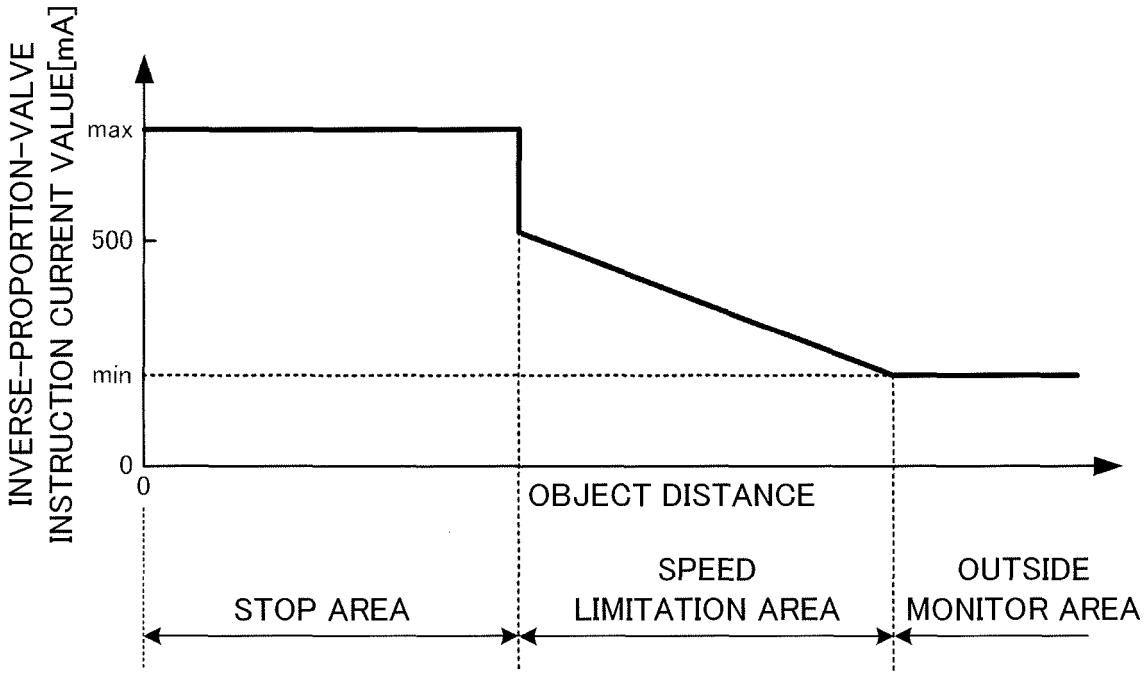


FIG.14


INVERSE-PROPORTION-VALVE INSTRUCTION CURRENT VALUE[mA]
max
500
min
0
0
OBJECT DISTANCE
STOP AREA
SPEED LIMITATION AREA
OUTSIDE MONITOR AREA

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/017136

A. CLASSIFICATION OF SUBJECT MATTER

E02F 3/43(2006.01)i; ***E02F 9/20***(2006.01)i; ***E02F 9/24***(2006.01)i; ***E02F 9/26***(2006.01)i
FI: E02F9/20 Q; E02F9/24 G; E02F9/26 A; E02F9/24 B; E02F3/43 M

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02F3/43; E02F9/20; E02F9/24; E02F9/26

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2021-14736 A (KOMATSU LTD.) 12 February 2021 (2021-02-12) paragraphs [0006], [0018], [0051]-[0061], fig. 4	1-2, 6-13
Y		3-5, 14-15
Y	JP 2014-218849 A (SUMITOMO CONSTR MACHINERY MFG) 20 November 2014 (2014-11-20) paragraphs [0043]-[0051], [0063]	3-5, 14-15
Y	JP 4-140333 A (YUTANI HEAVY IND LTD) 14 May 1992 (1992-05-14) p. 3, lower left column, line 19 to p. 4, lower right column, line 4	14-15

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 June 2023	**20 June 2023**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/017136

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2021-14736 A	12 February 2021	US 2022/0251803 A1 paragraphs [0006], [0024], [0059]-[0068], fig. 4 WO 2021/010249 A1 KR 10-2021-0152558 A CN 113950556 A	
JP 2014-218849 A	20 November 2014	(Family: none)	
JP 4-140333 A	14 May 1992	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 6819462 B **[0004]**