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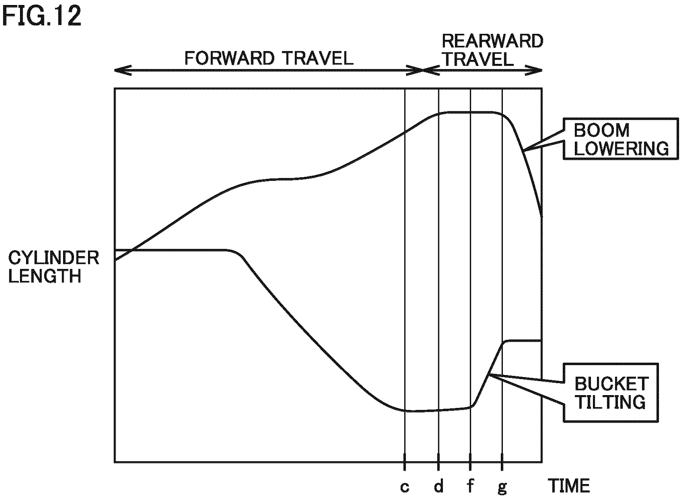
(54) **WORK MACHINE, SYSTEM INCLUDING WORK MACHINE, AND METHOD FOR CONTROLLING WORK MACHINE**

(57) A work machine capable of reliably ejecting loads loaded in a bucket is provided. A travel sensor detects a state of travel of a travel unit. A work implement posture sensor detects a posture of a work implement. An object sensor detects an object around a main body. A controller provides a command to drive a work implement actuator based on detection values from the travel sensor, the work implement posture sensor, and the object sensor. The controller recognizes a loading target into which the loads in the bucket are to be loaded, based on detection of the object. The controller controls the work implement actuator and the travel unit such that the bucket is set to a full dump state while a feature point of the bucket is located above the loading target and such that the travel unit travels rearward with the full dump state being maintained.

FIG.12



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a work machine, a system including a work machine, and a method of controlling a work machine.

BACKGROUND ART

[0002] WO2016/152994 (PTL 1) discloses control to move a boom and a bucket to target positions obtained in accordance with a moving distance of a wheel loader when the wheel loader is in a state of unloaded rearward travel in which the wheel loader travels rearward with the bucket being unloaded.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: WO2016/152994

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] A wheel loader that repeatedly performs an excavation work and a loading work has been demanded to reliably eject loads loaded in a bucket from the bucket in the loading work.

[0005] The present disclosure proposes a work machine, a system including a work machine, and a method of controlling a work machine that allow reliable ejection of loads loaded in a bucket in a loading work.

SOLUTION TO PROBLEM

[0006] Each of a work machine and a system including the work machine according to one aspect of the present disclosure includes a main body of a work machine, a work implement, a work implement actuator, a travel sensor, a work implement posture sensor, an object sensor, and a controller. The main body of the work machine includes a travel unit. The work implement is attached in front of the main body of the work machine. The work implement includes a bucket at a tip end. The work implement actuator drives the work implement with respect to the main body of the work machine. The travel sensor detects a state of travel of the travel unit. The work implement posture sensor detects a posture of the work implement. The object sensor detects an object around the main body of the work machine. The controller provides a command to drive the work implement actuator based on detection values from the travel sensor, the work implement posture sensor, and the object sensor. The controller recognizes a loading target into which loads in the bucket are to be loaded, based on detection of the object. The controller controls the work implement actuator and the travel unit such that the bucket is in a full dump state while a feature point of the bucket is located above the loading target and such that the travel unit travels rearward with the full dump state being maintained.

[0007] A method of controlling a work machine according to one aspect of the present disclosure includes recognizing a loading target into which loads in a bucket are to be loaded, based on an object detection signal, moving a feature point of the bucket to above the loading target, setting the bucket into a full dump state while the feature point is located above the loading target, and controlling a travel unit to travel rearward with the full dump state being maintained.

ADVANTAGEOUS EFFECTS OF INVENTION

[0008] According to the work machine, the system including the work machine, and the method of controlling the work machine in the present disclosure, loads loaded in the bucket can reliably be ejected in the loading work.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

Fig. 1 is a side view of a wheel loader as an exemplary work machine.
Fig. 2 is a block diagram showing an overall configuration of a control system that controls the wheel loader.
Fig. 3 is a plan view of the wheel loader that performs excavation and loading works.
Fig. 4 is a block diagram showing a configuration of an automatic control system that controls the wheel loader.
Fig. 5 is a flowchart showing a flow of operations to load loads carried in a bucket into a loading target under automatic control.
Fig. 6 is a diagram schematically showing arrangement of a vessel and the wheel loader at the time of start of dump approach.
Fig. 7 is a diagram schematically showing a posture of the wheel loader when a bucket dump operation is stopped.
Fig. 8 is a diagram schematically showing a posture of the wheel loader when a boom raising operation is stopped.
Fig. 9 is a diagram schematically showing a posture of the wheel loader when a bucket tilt operation is started.
Fig. 10 is a diagram schematically showing a posture of the wheel loader when the bucket tilt operation is stopped.
Fig. 11 is a diagram schematically showing the wheel loader that has moved away from a dump truck.

Fig. 12 shows a graph of change in cylinder length during a loading work.

DESCRIPTION OF EMBODIMENTS

[0010] An embodiment will be described below with reference to the drawings. The same components and constituent elements in the description below have the same reference characters allotted and their labels and functions are also the same. Therefore, detailed description thereof will not be repeated. Extraction of any features from the embodiment and any combination thereof are also originally intended.

<Overall Construction of Wheel Loader 1>

[0011] In an embodiment, a wheel loader 1 as an exemplary work machine will be described. Fig. 1 is a side view of wheel loader 1 as an exemplary work machine.

[0012] As shown in Fig. 1, wheel loader 1 includes a vehicular body frame 2, a work implement 3, a travel apparatus 4, and a cab 5. A vehicular body of wheel loader 1 is composed of vehicular body frame 2, cab 5, and the like. Work implement 3 and travel apparatus 4 are attached to the vehicular body of wheel loader 1. A main body of wheel loader 1 includes the vehicular body and travel apparatus 4.

[0013] Travel apparatus 4 serves for travel of the vehicular body of wheel loader 1 and includes running wheels 4a and 4b. Wheel loader 1 is a wheeled vehicle provided with running wheels 4a and 4b as rotational bodies for travel, on opposing sides in a lateral direction of the vehicular body. Wheel loader 1 is self-propelled as running wheels 4a and 4b are rotationally driven and can perform desired works with work implement 3. Travel apparatus 4 corresponds to an exemplary "travel unit."

[0014] A direction in which wheel loader 1 travels straight is herein referred to as a fore/aft direction of wheel loader 1. In the fore/aft direction of wheel loader 1, a side where work implement 3 is arranged with respect to vehicular body frame 2 is defined as the fore direction and a side opposite to the fore direction is defined as the aft direction. The lateral direction of wheel loader 1 refers to a direction orthogonal to the fore/aft direction when wheel loader 1 on a flat ground is viewed in a plan view. A right side and a left side in the lateral direction when one faces the fore direction are defined as a right direction and a left direction, respectively. An upward/downward direction of wheel loader 1 is a direction orthogonal to the plane defined by the fore/aft direction and the lateral direction. A side where the ground is located and a side where the sky is located in the upward/downward direction are defined as a lower side and an upper side, respectively.

[0015] Vehicular body frame 2 includes a front frame 2a and a rear frame 2b. Front frame 2a is arranged in front of rear frame 2b. Front frame 2a and rear frame 2b are attached to each other as being laterally swingable.

[0016] A pair of steering cylinders 11 is attached across front frame 2a and rear frame 2b. Steering cylinder 11 is a hydraulic cylinder. As steering cylinder 11 extends and contracts with hydraulic oil from a steering pump, a direction of travel of wheel loader 1 laterally changes. Vehicular body frame 2 in an articulated structure is composed of front frame 2a and rear frame 2b. Wheel loader 1 is an articulated work machine in which front frame 2a and rear frame 2b are coupled to allow a flection operation.

[0017] Work implement 3 and a pair of running wheels (front wheels) 4a are attached to front frame 2a. Work implement 3 is attached in front of the main body of wheel loader 1. Work implement 3 is supported by the vehicular body of wheel loader 1. Work implement 3 includes a boom 14 and a bucket 6. Bucket 6 is arranged at a tip end of work implement 3. Bucket 6 is a work tool for excavation and loading. A cutting edge 6a is a tip end portion of bucket 6. A rear surface 6b is a part of an outer surface of bucket 6. Rear surface 6b is formed from a plane. Rear surface 6b extends rearward from cutting edge 6a.

[0018] Boom 14 has a base end portion rotatably attached to front frame 2a by a boom pin 9. Bucket 6 is rotatably attached to boom 14 by a bucket pin 17 located at a tip end of boom 14. Boom pin 9 and bucket pin 17 correspond to "a plurality of articulations" of work implement 3.

[0019] Work implement 3 further includes a bell crank 18 and a link 15. Bell crank 18 is rotatably supported on boom 14 by a support pin 18a located substantially in a center of boom 14. Link 15 is coupled to a coupling pin 18c provided at a tip end portion of bell crank 18. Link 15 couples bell crank 18 and bucket 6 to each other.

[0020] Front frame 2a and boom 14 are coupled to each other by a pair of boom cylinders 16. Boom cylinder 16 is a hydraulic cylinder. Boom cylinder 16 rotationally drives boom 14 upward and downward around boom pin 9. Boom cylinder 16 has a base end attached to front frame 2a. Boom cylinder 16 has a tip end attached to boom 14. Boom cylinder 16 is a hydraulic actuator that operates boom 14 upward and downward with respect to front frame 2a. With movement upward and downward of boom 14, bucket 6 attached at the tip end of boom 14 also moves upward and downward.

[0021] A bucket cylinder 19 couples bell crank 18 and front frame 2a to each other. Bucket cylinder 19 has a base end attached to front frame 2a. Bucket cylinder 19 has a tip end attached to a coupling pin 18b provided at a base end portion of bell crank 18. Bucket cylinder 19 is a hydraulic actuator to cause bucket 6 to pivot upward and downward with respect to boom 14. Bucket cylinder 19 is a work tool cylinder that drives bucket 6. Bucket cylinder 19 rotationally drives bucket 6 around bucket pin 17. Bucket 6 is constructed as being operable with respect to boom 14. Bucket 6 is constructed as being operable with respect to front frame 2a.

[0022] Boom cylinder 16 and bucket cylinder 19 correspond to an exemplary "work implement actuator" that drives work implement 3.

[0023] Cab 5 on which an operator rides and a pair of running wheels (rear wheels) 4b are attached to rear frame 2b. Cab 5 in a box shape is arranged in the rear of boom 14. Cab 5 is carried on vehicular body frame 2. In cab 5, a seat where the operator of wheel loader 1 is seated, an operation apparatus 8 which will be described later, and the like are arranged.

<System Configuration>

[0024] Fig. 2 is a block diagram showing an overall configuration of a control system that controls wheel loader 1.

[0025] An engine 21 is a drive source that generates drive force to drive work implement 3 and travel apparatus 4, and it is, for example, a diesel engine. A motor driven by a power storage, instead of engine 21, may be employed as the drive source, or both of the engine and the motor may be employed. Output from engine 21 is controlled by adjustment of an amount of fuel to be injected into a cylinder of engine 21.

[0026] Drive force generated by engine 21 is transmitted to a transmission 23. Transmission 23 converts drive force into appropriate torque and a rotation speed. An axle 25 is connected to an output shaft of transmission 23. Drive force converted by transmission 23 is transmitted to axle 25. Drive force is transmitted from axle 25 to running wheels 4a and 4b (Fig. 1). Wheel loader 1 thus travels. In wheel loader 1 in the embodiment, both of running wheel 4a and running wheel 4b implement drive wheels for travel of wheel loader 1 upon receiving drive force.

[0027] Some of drive force from engine 21 is transmitted to a work implement pump 13. Work implement pump 13 is a hydraulic pump driven by engine 21 to activate work implement 3 with hydraulic oil it delivers. Work implement 3 is driven by hydraulic oil from work implement pump 13. Hydraulic oil delivered by work implement pump 13 is supplied to boom cylinder 16 and bucket cylinder 19 through a main valve 32. As boom cylinder 16 extends and contracts upon receiving supply of hydraulic oil, boom 14 moves upward and downward. As bucket cylinder 19 extends and contracts upon receiving supply of hydraulic oil, bucket 6 pivots upward and downward.

[0028] Wheel loader 1 includes a vehicular body controller 50. Vehicular body controller 50 includes an engine controller 60, a transmission controller 70, and a work implement controller 80.

[0029] Vehicular body controller 50 is generally implemented by reading of various programs by a central processing unit (CPU). Vehicular body controller 50 includes a not-shown memory. The memory functions as a work memory, and various programs for performing functions of wheel loader 1 are stored in the memory.

[0030] Operation apparatus 8 is provided in cab 5. Operation apparatus 8 is operated by an operator. Operation apparatus 8 includes a plurality of types of operation members operated by the operator to operate wheel loader 1. Operation apparatus 8 includes an accelerator pedal 41 and a work implement control lever 42. Operation apparatus 8 may include a steering wheel, a shift lever, and the like which are not shown.

[0031] Accelerator pedal 41 is operated to set the target number of rotations of engine 21. Engine controller 60 controls output from engine 21 based on an amount of operation onto accelerator pedal 41. With increase in amount of operation (amount of pressing) onto accelerator pedal 41, output from engine 21 increases. With decrease in amount of operation onto accelerator pedal 41, output from engine 21 decreases. Transmission controller 70 controls transmission 23 based on the amount of operation onto accelerator pedal 41.

[0032] Work implement control lever 42 is operated to operate work implement 3. Work implement controller 80 controls electromagnetic proportional control valves 35 and 36 based on the amount of operation onto work implement control lever 42.

[0033] Electromagnetic proportional control valve 35 switches main valve 32 such that bucket cylinder 19 contracts to move bucket 6 in a dump direction (a direction in which the cutting edge of bucket 6 is lowered). Electromagnetic proportional control valve 35 switches main valve 32 such that bucket cylinder 19 extends to move bucket 6 in a tilt direction (a direction in which the cutting edge of bucket 6 is raised). Electromagnetic proportional control valve 36 switches main valve 32 such that boom cylinder 16 contracts to lower boom 14. Electromagnetic proportional control valve 36 switches main valve 32 such that boom cylinder 16 extends to raise boom 14.

[0034] A machine monitor 51 shows various types of information upon receiving input of a command signal from vehicular body controller 50. The various types of information shown on machine monitor 51 may be, for example, information on works performed by wheel loader 1, vehicular body information such as an amount of remaining fuel, a temperature of coolant, and a temperature of hydraulic oil, an image of surroundings obtained by image pick-up of the surroundings of wheel loader 1, and the like. Machine monitor 51 may be implemented by a touch panel, and in this case, a signal generated by touching by the operator onto a part of machine monitor 51 is outputted from machine monitor 51 to vehicular body controller 50.

<Excavation and Loading Works>

[0035] Wheel loader 1 in the present embodiment performs excavation and loading works to scoop an excavation target such as soil and to load the excavation target onto a loading target such as a dump truck. Fig. 3 is a plan view of wheel loader 1 that performs excavation and loading works. Fig. 3 illustrates wheel loader 1 that performs what is called a V shape work.

[0036] Fig. 3 (A) illustrates wheel loader 1 that performs what is called unloaded forward travel. Wheel loader 1 travels forward along an excavation path R1 toward an excavation target 310 such as soil. Wheel loader 1 plunges bucket 6 into excavation target 310 and stops forward travel. By raising bucket 6 with cutting edge 6a of bucket 6 dug into excavation target 310, the excavation work to scoop excavation target 310 in bucket 6 is performed.

[0037] Fig. 3 (B) illustrates wheel loader 1 that performs what is called loaded rearward travel. Excavation target 310 has been loaded in bucket 6. Wheel loader 1 travels rearward along excavation path R1 to a position from which it started forward travel in Fig. 3 (A).

[0038] Fig. 3 (C) illustrates wheel loader 1 that performs what is called loaded forward travel. With excavation target 310 having been loaded in bucket 6, wheel loader 1 travels forward toward a vessel 301 of a dump truck 300. Wheel loader 1 travels forward along a loading path R2 from the position where it started forward travel in Fig. 3 (A) toward dump truck 300. When wheel loader 1 approaches dump truck 300 and reaches a prescribed position, it loads excavation target 310 in bucket 6 into vessel 301. Vessel 301 corresponds to an exemplary "loading target" into which loads in bucket 6 are to be loaded.

[0039] Fig. 3 (D) illustrates wheel loader 1 that performs what is called unloaded rearward travel. While bucket 6 is empty as a result of full ejection of excavation target 310 in bucket 6 into vessel 301 of dump truck 300, wheel loader 1 travels rearward along loading path R2 to the position where it started forward travel in Fig. 3 (C).

[0040] Wheel loader 1 can thus repeatedly perform a series of works including excavation, rearward travel, dump approach, soil ejection, and rearward travel.

<Automatic Control System that Controls Wheel loader 1>

[0041] In automating a loading work for loading onto dump truck 300 by wheel loader 1, in order to more quickly perform the loading work while an amount of works is ensured without contact of bucket 6 with vessel 301, reproduction of operations of work implement 3 by a skilled operator under automatic control has been desired. Fig. 4 is a block diagram showing a configuration of an automatic control system that controls wheel loader 1.

[0042] An automation controller 100 is configured to transmit and receive a signal to and from vehicular body controller 50 described with reference to Fig. 2. Automation controller 100 is configured to transmit and receive a signal to and from an external information obtaining unit 110. External information obtaining unit 110 includes a perception device 111 and a positional information obtaining device 112. Perception device 111 and positional information obtaining device 112 are mounted on wheel loader 1.

[0043] Perception device 111 obtains information on surroundings of wheel loader 1. Perception device 111 is attached, for example, to an upper front surface of cab 5. Perception device 111 corresponds to an exemplary "object sensor" that detects an object around the main body of wheel loader 1.

[0044] Perception device 111 contactlessly detects a direction of an object outside wheel loader 1 and a distance to the object. Perception device 111 is implemented, for example, by light detection and ranging (LiDAR) that obtains information on an object by emission of laser beams. Perception device 111 may be implemented by a visual sensor including a camera. Perception device 111 may be implemented by radio detection and ranging (Radar) that obtains information on an object by emission of radio waves. Perception device 111 may be implemented by an infrared sensor.

[0045] Positional information obtaining device 112 obtains information on a current position of wheel loader 1. Positional information obtaining device 112 obtains, for example, positional information of wheel loader 1 in a global coordinate system with the Earth being defined as a reference, with the use of a satellite positioning system. Positional information obtaining device 112 uses, for example, global navigation satellite systems (GNSS) and includes a GNSS receiver. The satellite positioning system calculates a position of wheel loader 1 by computing a position of an antenna of the GNSS receiver based on a positioning signal received from a satellite by the GNSS receiver.

[0046] External information on the outside of wheel loader 1 obtained by perception device 111 and positional information of wheel loader 1 obtained by positional information obtaining device 112 are inputted to automation controller 100.

[0047] Vehicular body controller 50 is configured to transmit and receive a signal to and from a vehicle information obtaining unit 120, and receives input of information on wheel loader 1 obtained by vehicle information obtaining unit 120. Vehicle information obtaining unit 120 is composed of various sensors mounted on wheel loader 1. Vehicle information obtaining unit 120 includes an articulation angle sensor 121, a vehicle speed sensor 122, a boom angle sensor 123, a bucket angle sensor 124, and a boom cylinder pressure sensor 125.

[0048] Articulation angle sensor 121 detects an articulation angle which is an angle formed between front frame 2a and rear frame 2b, and generates a signal indicating the detected articulation angle. Articulation angle sensor 121 outputs a signal indicating the articulation angle to vehicular body controller 50.

[0049] Vehicle speed sensor 122 detects a speed of movement of wheel loader 1 by travel apparatus 4, for example, by detection of a rotation speed of an output shaft of transmission 23 and generates a signal indicating the detected vehicle speed. Vehicle speed sensor 122 outputs the signal indicating the vehicle speed to vehicular body controller 50. Vehicle speed sensor 122 corresponds to an exemplary "travel sensor" that detects a status of travel of travel apparatus 4 (travel unit).

[0050] Boom angle sensor 123 is implemented, for example, by a rotary encoder provided in boom pin 9 which is a portion of attachment of boom 14 to vehicular body frame 2. Boom angle sensor 123 detects an angle of boom 14 with respect to a horizontal direction and generates a signal indicating the detected angle of boom 14. Boom angle sensor 123 outputs the signal indicating the angle of boom 14 to vehicular body controller 50.

[0051] Bucket angle sensor 124 is implemented, for example, by a rotary encoder provided in support pin 18a which is a rotation shaft of bell crank 18. Bucket angle sensor 124 detects an angle of bucket 6 with respect to boom 14 and generates a signal indicating the detected angle of bucket 6. Bucket angle sensor 124 outputs the signal indicating the angle of bucket 6 to vehicular body controller 50.

[0052] Boom angle sensor 123 and bucket angle sensor 124 correspond to an exemplary "work implement posture sensor" that detects a posture of work implement 3.

[0053] Boom cylinder pressure sensor 125 detects a pressure on a bottom side (boom bottom pressure) of boom cylinder 16 and generates a signal indicating the detected boom bottom pressure. The boom bottom pressure becomes higher while bucket 6 is loaded and becomes lower while the bucket is unloaded. Boom cylinder pressure sensor 125 outputs a signal indicating the boom bottom pressure to vehicular body controller 50.

[0054] Vehicular body controller 50 outputs information inputted from vehicle information obtaining unit 120 to automation controller 100. Automation controller 100 receives detection values from vehicle speed sensor 122, boom angle sensor 123, and bucket angle sensor 124 through vehicular body controller 50.

[0055] An actuator 140 is configured to transmit and receive a signal to and from vehicular body controller 50. Upon receiving a command signal from vehicular body controller 50, actuator 140 is driven. Actuator 140 includes a brake EPC (electromagnetic proportional control valve) 141 for activation of a brake of travel apparatus 4, a steering EPC 142 for adjustment of a travel direction of wheel loader 1, a work implement EPC 143 for operations of work implement 3, and a hydraulic mechanical transmission (HMT) 144.

[0056] Electromagnetic proportional control valves 35 and 36 shown in Fig. 2 implement work implement EPC 143. Transmission 23 shown in Fig. 2 is implemented as HMT 144 that utilizes electronic control. Transmission 23 may be a hydro-static transmission (HST). A power transmission apparatus that transmits motive power from engine 21 to running wheels 4a and 4b may include an electric drive apparatus such as a diesel electric drive apparatus, and may include any combination of the HMT, the HST, and the electric drive apparatus.

[0057] Transmission controller 70 includes a brake control unit 71 and an accelerator control unit 72. Brake control unit 71 outputs a command signal for control of activation of the brake to brake EPC 141. Accelerator control unit 72 outputs a command signal for control of the vehicle speed to HMT 144.

[0058] Work implement controller 80 includes a steering control unit 81 and a work implement control unit 82. Steering control unit 81 outputs a command signal for control of the travel direction of wheel loader 1 to steering EPC 142. Work implement control unit 82 outputs a command signal for control of operations of work implement 3 to work implement EPC 143.

[0059] Automation controller 100 includes a position estimator 101, a path planning unit 102, and a path tracking control unit 103.

[0060] Position estimator 101 estimates an own position of wheel loader 1 based on the positional information obtained by positional information obtaining device 112. Position estimator 101 recognizes a target position based on the external information obtained by perception device 111. The target position is, for example, a position of excavation target 310 or dump truck 300 shown in Fig. 3. Perception device 111 may recognize the target position and input the target position to automation controller 100, or position estimator 101 may recognize the target position based on a result of detection by perception device 111.

[0061] Path planning unit 102 generates an optimal path that connects the own position of wheel loader 1 and the target position to each other. The optimal path includes a path for travel by travel apparatus 4 and a path for operations of work implement 3.

[0062] Path tracking control unit 103 controls the accelerator, the brake, and steering such that wheel loader 1 travels as following the optimal path generated by path planning unit 102. Path tracking control unit 103 outputs a command signal for travel of wheel loader 1 along the optimal path to brake control unit 71, accelerator control unit 72, and steering control unit 81. Path tracking control unit 103 controls boom cylinder 16 and bucket cylinder 19 such that work implement 3 operates along the optimal path generated by path planning unit 102. Path tracking control unit 103 outputs a command signal for movement of work implement 3 along the optimal path to work implement control unit 82.

[0063] An interface 130 is configured to transmit and receive a signal to and from vehicular body controller 50. Interface 130 includes an automation switch 131, an engine emergency stop switch 132, and a mode indicator 133.

[0064] Automation switch 131 is operated by the operator. The operator operates automation switch 131 to switch between a manual operation of wheel loader 1 and automatic control of wheel loader 1. Engine emergency stop switch 132 is operated by the operator. When an event that requires emergency stop of engine 21 occurs, the operator operates engine emergency stop switch 132. A signal resulting from an operation onto automation switch 131 and engine emergency stop switch 132 is inputted to vehicular body controller 50.

[0065] Mode indicator 133 indicates whether wheel loader 1 is currently in a mode of the manual operation by the operator or an automatic control mode. Vehicular body controller 50 outputs a command signal for control of turn-on of the indicator to mode indicator 133.

<Flow of Automatic Loading on Dump>

[0066] Fig. 5 is a flowchart showing a flow of operations to load loads carried in bucket 6 into the loading target under automatic control of wheel loader 1.

[0067] Initially, as advance preparation, before start of the loading work, in step S100, a shape of vessel 301 of dump truck 300 which is the loading target is recognized. For example, the shape of dump truck 300 is obtained by LiDAR which is perception device 111. Point group data indicating three-dimensional coordinate values of measurement points on dump truck 300 is obtained by irradiating dump truck 300 with laser beams from LiDAR. Dump truck 300 is sensed from four directions of the fore direction, the aft direction, the right direction, and the left direction, and the shape of vessel 301 can be recognized based on information on a point group. The recognized shape of vessel 301 is inputted to automation controller 100.

[0068] In step S101, perception device 111 recognizes a reference point P of dump truck 300. Dump truck 300 is sensed by LiDAR which is perception device 111. Automation controller 100 recognizes the position of vessel 301 based on comparison between the point group sensed by perception device 111 and a master point group representing the shape of vessel 301. Automation controller 100 sets as reference point P, an upper end of a side surface of vessel 301 of dump truck 300 recognized by LiDAR which is perception device 111.

[0069] In step S102, automation controller 100 sets coordinates with respect to reference point P, of target positions c, d, f, and g of cutting edge 6a of bucket 6 moved under automatic control. Cutting edge 6a of bucket 6 corresponds to an exemplary "feature point" set in work implement 3. The feature point is not limited to cutting edge 6a of bucket 6, and another point of work implement 3 may be set as the feature point.

[0070] Reference point P and target positions c, d, f, and g will now be described. Fig. 6 is a diagram schematically showing arrangement of vessel 301 and wheel loader 1 at the time of start of dump approach. Fig. 6 and subsequent Figs. 7 to 11 schematically show vessel 301 viewed from the fore/aft direction of dump truck 300, and schematically show a part on a front side of wheel loader 1 that approaches vessel 301 from the left side or the right side of dump truck 300.

[0071] Target position c is set as a position through which cutting edge 6a of bucket 6 passes during forward travel of wheel loader 1 toward dump truck 300. In order to load loads in bucket 6 into vessel 301 during forward travel of wheel loader 1, the operation of work implement 3 to move bucket 6 in the dump direction is performed. A position where that operation of bucket 6 in the dump direction is stopped is target position c. When cutting edge 6a of bucket 6 is located at target position c, bucket 6 is in a full dump state. When cutting edge 6a of bucket 6 is located at target position c, a length of bucket cylinder 19 is minimized. Target position c is located above vessel 301.

[0072] Target position d is set as a position where cutting edge 6a of bucket 6 passes after it passes through target position c. In order to avoid interference with vessel 301 by work implement 3, wheel loader 1 during forward travel toward dump truck 300 is performing the operation to raise boom 14. The operation to raise boom 14 is continued during a period from start of dump approach by wheel loader 1 until cutting edge 6a of bucket 6 reaches target position d. Target position d is a position where the operation to raise boom 14 is stopped. While cutting edge 6a of bucket 6 is located at target position d, boom 14 is located at an uppermost position. While cutting edge 6a of bucket 6 is located at target position d, a length of boom cylinder 16 is maximized. Target position d is located above vessel 301. Target position d is set to be closer to reference point P than target position c.

[0073] Target position f is set as a position through which cutting edge 6a of bucket 6 passes after passage through target position d. Bucket 6 maintains the full dump state during a period from passage of cutting edge 6a of bucket 6 through target position c until the cutting edge reaches target position f. Target position f is a position of start of the operation of bucket 6 in the tilt direction. Target position f is located above vessel 301. Target position f is set to be closer to reference point P than target position d. Boom 14 is maintained at the uppermost position during a period from passage of cutting edge 6a of bucket 6 through target position d until the cutting edge reaches target position f.

[0074] Target position g is set as a position where cutting edge 6a of bucket 6 passes after passage through target position f. Target position g is a position where the operation of bucket in the tilt direction is stopped. The operation of bucket 6 in the tilt direction is continued during a period from passage of cutting edge 6a of bucket 6 through target position f until the cutting edge reaches target position g. Target position g is located above reference point P. Boom 14 is maintained at the uppermost position during a period from passage of cutting edge 6a of bucket 6 through target position d until the cutting edge reaches target position g.

[0075] As shown in Fig. 6, an xy coordinate system with reference point P being defined as an origin is set. An x axis represents the lateral direction of dump truck 300 that passes through reference point P. A direction away from vessel 301 with reference point P being defined as the reference is defined as a +x direction. A y axis represents the upward/downward direction that passes through reference point P. An upward direction from reference point P is defined as a +y direction.

[0076] A bucket angle θ shown in Fig. 6 represents an angle formed between the ground and rear surface 6b of bucket 6. Bucket angle θ may be an angle formed between rear surface 6b of bucket 6 and a horizontal plane with the vehicular body being defined as the reference.

[0077] Target positions c, d, f, and g are determined by giving horizontal and vertical positions, that is, an x coordinate and a y coordinate, of cutting edge 6a of bucket 6 with reference point P being defined as the reference. Target position c is set as a position where a height position of cutting edge 6a is lowest (the y coordinate having a minimum value) during soil ejection from bucket 6. Target position c is set at a position where the y coordinate is on a negative side. Target positions d, f, and g are set at positions where the y coordinate is on a positive side.

[0078] Target positions c, d, and f are set at positions where the x coordinate is on the negative side. Target position g is set at a position where the x coordinate is zero.

[0079] Bucket angle θ at the time when cutting edge 6a of bucket 6 is located at each target position is also set. The posture of work implement 3 at the time when cutting edge 6a of bucket 6 is located at each target position is determined by the x coordinate and the y coordinate of each target position and bucket angle θ at each target position. The posture (a target posture) of work implement 3 at the time when cutting edge 6a of bucket 6 is located at each target position is stored in automation controller 100. The length of boom cylinder 16 and the length of bucket cylinder 19 at the time when cutting edge 6a of bucket 6 is located at each target position are determined based on the target posture at the time when cutting edge 6a of bucket 6 is located at each target position.

[0080] The x coordinate and the y coordinate of each target position and bucket angle θ at each target position can be determined by analyzing a trace of cutting edge 6a when the skilled operator performs the loading work to extract a characterizing position and extracting the posture of work implement 3 at that characteristic position.

[0081] Fig. 7 is a diagram schematically showing the posture of wheel loader 1 when a dump operation of bucket 6 is stopped. Fig. 8 is a diagram schematically showing the posture of wheel loader 1 when the operation to raise boom 14 is stopped. Fig. 9 is a diagram schematically showing the posture of wheel loader 1 when the operation to tilt bucket 6 is started. Fig. 10 is a diagram schematically showing the posture of wheel loader 1 when the operation to tilt bucket 6 is stopped. Fig. 11 is a diagram schematically showing wheel loader 1 that has moved away from dump truck 300. In Fig. 7, cutting edge 6a of bucket 6 is located at target position c. In Fig. 8, cutting edge 6a is located at target position d. In Fig. 9, cutting edge 6a is located at target position f. In Fig. 10, cutting edge 6a is located at target position g.

[0082] Fig. 12 shows a graph of change in cylinder length during the loading work. The abscissa in Fig. 12 represents lapse of time and extension lines are drawn at times when cutting edge 6a passes through target positions c, d, f, and g. The ordinate in Fig. 12 represents the lengths of boom cylinder 16 and bucket cylinder 19.

[0083] As shown in Fig. 12 and Figs. 6 and 7, before cutting edge 6a reaches target position c, wheel loader 1 is traveling forward. The length of boom cylinder 16 increases, and hence boom 14 is being raised. The length of bucket cylinder 19 decreases during a certain period before the cutting edge reaches target position c, and therefore, during that period, bucket 6 is operating in the dump direction. At a time point when cutting edge 6a reaches target position c, bucket 6 is in a full dump posture, and the dump operation of bucket 6 is stopped. At the time point when cutting edge 6a reaches target position c, the length of bucket cylinder 19 is minimized.

[0084] During the dump operation of bucket 6, boom 14 keeps rising. During soil ejection from bucket 6, boom 14 keeps rising. During loading of loads into dump truck 300, boom 14 keeps rising. During the dump operation of bucket 6, wheel loader 1 moves toward vessel 301 of dump truck 300, and hence it also continues forward travel.

[0085] As shown in Fig. 12 and Figs. 7 and 8, at the time when cutting edge 6a passes through target position c, wheel loader 1 is traveling forward, and at the time when cutting edge 6a passes through target position d, wheel loader 1 is traveling rearward. While cutting edge 6a is moving between target position c and target position d, the travel direction of wheel loader 1 is switched from forward travel to rearward travel. The length of boom cylinder 16 keeps increasing, and hence boom 14 keeps rising. The length of bucket cylinder 19 is constant, and hence the posture of bucket 6 with respect to the vehicular body is constant. Target position c is the position where the operation of bucket 6 in the dump direction is stopped, and while cutting edge 6a is moving from target position c to target position d, bucket 6 keeps the full dump posture.

[0086] As shown in Fig. 12 and Figs. 8 and 9, until cutting edge 6a reaches target position f after it passes through target position d, wheel loader 1 continues rearward travel. The length of boom cylinder 16 is constant, and therefore the posture of boom 14 with respect to the vehicular body is constant. At this time, the height position of boom 14 is highest. At the time when boom 14 stops rising, loads in bucket 6 have already been loaded in vessel 301 and bucket 6 is in an unloaded state. The length of bucket cylinder 19 is constant, and therefore the posture of bucket 6 with respect to the vehicular body is constant. While cutting edge 6a is moving from target position d to target position f, wheel loader 1 is traveling rearward with the full dump state of bucket 6 being maintained.

[0087] As shown in Fig. 12 and Figs. 9 and 10, until cutting edge 6a reaches target position g after it passes through target position f, wheel loader 1 continues rearward travel. The length of boom cylinder 16 is constant, and therefore the posture of boom 14 with respect to the vehicular body is constant. At the time point when cutting edge 6a reaches target position f, the operation of bucket 6 in the tilt direction is started, and bucket 6 keeps operating in the tilt direction until it reaches target position g. The length of bucket cylinder 19 keeps increasing. At the time point when cutting edge 6a reaches target position g, the operation of bucket 6 in the tilt direction is stopped. Target position f is the position where the tilt operation of bucket 6 is started. Target position g is the position where the tilt operation of bucket 6 is stopped. While cutting edge 6a is moving from target position f to target position g, wheel loader 1 is traveling rearward with bucket 6 performing the tilt operation. Wheel loader 1 performs the loading work for loading into dump truck 300, and thereafter performs the tilt operation of bucket 6 during rearward travel to move away from dump truck 300.

[0088] During the tilt operation of bucket 6, the posture of boom 14 is kept constant. After completion of ejection of loads from bucket 6, boom 14 is held and the tilt operation of bucket 6 is performed. During this tilt operation of bucket 6, wheel loader 1 continues rearward travel and travels in the direction away from vessel 301 of dump truck 300.

[0089] As shown in Fig. 12 and Figs. 10 and 11, after cutting edge 6a passes through target position g, wheel loader 1 continues rearward travel. The length of boom cylinder 16 has decreased, and hence boom 14 has been lowered. The length of bucket cylinder 19 is constant, and therefore the posture of bucket 6 with respect to the vehicular body is constant.

[0090] Loads in bucket 6 can be loaded into vessel 301 without contact of bucket 6 and the vehicular body with vessel 301, by moving cutting edge 6a of bucket 6 to sequentially pass through target position c, target position d, target position f, and target position g. By applying automatic control to thus move bucket 6 to wheel loader 1, operations of work implement 3 equivalent to operations performed by the skilled operator can be realized.

[0091] Referring back to Fig. 5, description of the loading work under automatic control is continued. In step S103, automation controller 100 recognizes the current positions of wheel loader 1 and work implement 3. Positional information obtaining device 112 obtains the current position of the vehicular body of wheel loader 1 and obtains the posture of the work implement with respect to the vehicular body with boom angle sensor 123 and bucket angle sensor 124, to thereby recognize the current positions of wheel loader 1 and work implement 3 in the global coordinate system. The position of cutting edge 6a of bucket 6 relative to vessel 301 of dump truck 300 can be calculated based on the current positions of wheel loader 1 and work implement 3 and the current position of dump truck 300 in the global coordinate system.

[0092] Alternatively, perception device 111 may be used to obtain the direction and the distance of reference point P of vessel 301 of dump truck 300 from a position of arrangement of perception device 111, to thereby calculate the current position of cutting edge 6a of bucket 6 relative to reference point P.

[0093] At which position with respect to each of target positions c, d, f, and g cutting edge 6a of bucket 6 is located is recognized based on the current position of work implement 3. For example, cutting edge 6a is recognized as not having reached target position c yet, cutting edge 6a is recognized as having passed through target position c and being located between target position c and target position d, cutting edge 6a is recognized as having passed through target position d and being located between target position d and target position f, etc. Furthermore, a target position to which cutting edge 6a is headed next is recognized. For example, when cutting edge 6a has not yet reached target position c, target position c is recognized as a position to which the cutting edge is headed next, when cutting edge 6a is located between target position c and target position d, target position d is recognized as a position to which the cutting edge is headed next, etc.

[0094] In step S104, automation controller 100 recognizes the length of boom cylinder 16 and the length of bucket cylinder 19 at the current position. Boom angle sensor 123 detects the angle of boom 14. Bucket angle sensor 124 detects the angle of bucket 6. The posture of work implement 3 is determined by the angle of boom 14 and the angle of bucket 6. The length of boom cylinder 16 and the length of bucket cylinder 19 at the current position are recognized based on the posture of the work implement.

[0095] Instead of or in addition to boom angle sensor 123 and bucket angle sensor 124, an angle sensor that detects an angle of bell crank 18 and an angle sensor that detects an angle of link 15 may be provided. A stroke sensor that detects a length of a cylinder stroke may be provided in boom cylinder 16 and bucket cylinder 19.

[0096] In step S105, automation controller 100 calculates a difference between the length of boom cylinder 16 and the length of bucket cylinder 19 at the current position recognized in step S104 and the length of boom cylinder 16 and the length of bucket cylinder 19 (which will be referred to as a target cylinder length below) at the target position to which cutting edge 6a is headed next. Automation controller 100 calculates how much the cylinder is to be moved until cutting edge 6a reaches the next target position.

[0097] In step S106, automation controller 100 refers to a current vehicle speed and determines a target cylinder stroke speed that achieves the target cylinder length at the time when cutting edge 6a reaches the target position to which the cutting edge is headed next. Automation controller 100 controls boom cylinder 16 and bucket cylinder 19 such that work implement 3 takes, when cutting edge 6a reaches the target position to which it is headed next, a target posture corresponding to that target position. The current vehicle speed is obtained by vehicle speed sensor 122. Time until the cutting edge reaches the next target position can be calculated based on the current position of cutting edge 6a and the current vehicle speed. The target cylinder stroke speed can be determined by dividing the difference in cylinder length calculated in step S105 by time until the cutting edge reaches the next target position.

[0098] An amount of cylinder stroke while wheel loader 1 travels a unit distance may be determined. Travel of the unit distance by wheel loader 1 may be determined based on the vehicle speed or may be sensed by perception device 111.

[0099] In step S107, automation controller 100 outputs a command current corresponding to the target cylinder stroke speed to vehicular body controller 50. Automation controller 100 outputs a command to extend and contract boom cylinder 16 and bucket cylinder 19 at the target cylinder stroke speed to work implement control unit 82 of work implement controller 80. The command to extend and contract boom cylinder 16 and bucket cylinder 19 at the target cylinder stroke speed is outputted from work implement control unit 82 to work implement EPC 143.

[0100] In step S108, as work implement EPC 143 that has received the command signal adjusts an opening, appropriate hydraulic oil is supplied to boom cylinder 16 and bucket cylinder 19. Boom cylinder 16 and bucket cylinder 19 thus operate.

[0101] In step S109, automation controller 100 recognizes the current lengths of boom cylinder 16 and bucket cylinder 19 as in step S104. Automation controller 100 determines whether or not the current lengths of boom cylinder 16 and bucket cylinder 19 have reached the target cylinder lengths.

[0102] When determination as having reached the target cylinder lengths is made in determination in step S109 (YES in step S109), the process proceeds to step S110 and automation controller 100 determines whether or not there is a next target position.

[0103] When determination as not having reached the target cylinder length is made in determination in step S109 (NO in step S109) and when it is determined in step S 110 that there is a next target position (YES in step S110), the process returns to step S103 and processing for extending and contracting boom cylinder 16 and bucket cylinder 19 based on the current position of work implement 3 is repeated. The cylinder speed is successively changed in accordance with the current position of cutting edge 6a of bucket 6. When the current position of cutting edge 6a is displaced from a position based on the cylinder speed set in previous processing, the cylinder speed is adjusted.

[0104] When it is determined in step S110 that there is no next target position (NO in step S110), the loading work ends, which corresponds to a case where the next target position is not set after the end of target position g in the present embodiment.

<Functions and Effects>

[0105] Characteristic features and functions and effects of the present embodiment will be summarized as below, although some description may overlap with the description above.

[0106] As shown in Figs. 7 to 9 and 12, while cutting edge 6a of bucket 6 is located at target position c above vessel 301, bucket 6 is set to the full dump state. The travel direction of wheel loader 1 is switched from forward travel to rearward travel between target position c and target position d. During the period from start of rearward travel of wheel loader 1 until cutting edge 6a of bucket 6 reaches target position f, wheel loader 1 continues rearward travel with the full dump state of bucket 6 being maintained.

[0107] As bucket 6 is in the full dump posture, such a situation that loads in bucket 6 tend to fall from bucket 6 and to be ejected from bucket 6 is set. Rearward travel with bucket 6 being in the full dump state leads to application of inertial force to remaining loads in the event that the loads remain in bucket 6. Ejection from bucket 6, of the loads that remain in bucket 6 can thus be expedited. Since the loads loaded in bucket 6 can reliably be ejected from bucket 6, the loading work can reliably be finished.

[0108] As shown in Figs. 7 to 9 and 12, at the time point when cutting edge 6a reaches target position f at which a horizontal distance from reference point P is equal to or smaller than a prescribed value as a result of rearward travel of wheel loader 1 with the full dump state of bucket 6 being maintained, the operation of bucket 6 in the tilt direction is started. As bucket 6 in the full dump posture approaches a prescribed position on the side surface of vessel 301, bucket 6 performs the tilt operation to move as eluding vessel 301. As the loading work for loading onto dump truck 300 is performed and thereafter bucket 6 performs the tilt operation before cutting edge 6a of bucket 6 moves over the side surface of vessel 301, cutting edge 6a and rear surface 6b of bucket 6 can be prevented from coming in contact with vessel 301.

[0109] Rearward travel for movement of wheel loader 1 away from dump truck 300 and the tilt operation of bucket 6 are simultaneously performed, and a plurality of operations are performed as temporally overlapping. As the tilt operation of bucket 6 is performed during rearward travel, wheel loader 1 can move away from dump truck 300 more quickly than in an example where rearward travel is started after the tilt operation of bucket 6. Therefore, a cycle time of the loading work can be reduced and workability can be improved.

[0110] As shown in Figs. 10 and 12, at the time point when cutting edge 6a of bucket 6 reaches target position g directly above reference point P and moves beyond reference point P, the tilt operation of bucket 6 is stopped. Contact of bucket 6 with vessel 301 can thus reliably be avoided. The tilt operation of bucket 6 more than necessary is avoided but the tilt operation to such an extent that bucket 6 can move as reliably eluding vessel 301 is performed, and thereafter the posture of bucket 6 can be held. Bucket 6 can thus promptly make transition to the posture for next excavation works.

[0111] As shown in Figs. 8 to 9 and 12, while cutting edge 6a moves from target position d to target position f, wheel loader 1 travels rearward with the posture of boom 14 being maintained and the full dump state of bucket 6 being maintained. Loads loaded in bucket 6 can thus reliably be ejected from bucket 6.

[0112] Timing to switch the travel direction of wheel loader 1 from forward travel to rearward travel is not limited to timing when cutting edge 6a of bucket 6 is located between target position c and target position d. For example, being triggered by bucket 6 being set to the full dump state when cutting edge 6a of bucket 6 is located at target position c, the travel direction of wheel loader 1 may be switched from forward travel to rearward travel. Timing to switch the travel direction is not strict, and fluctuation to some extent of timing to switch the travel direction is permitted so long as bucket 6 is substantially in the full dump state where loads can be ejected therefrom.

[0113] As shown in Figs. 9 to 10 and 12, while cutting edge 6a moves from target position f to target position g, wheel loader 1 causes bucket 6 to perform the tilt operation with the posture of boom 14 being maintained. Contact of bucket 6 with vessel 301 can thus reliably be avoided.

[0114] As shown in Figs. 10 to 12, at the time point when cutting edge 6a of bucket 6 moves beyond the upper end of the side surface of vessel 301 set as reference point P, the operation to lower boom 14 is started. Boom 14 can thus promptly make transition to the posture for the next excavation works. Since rearward travel of wheel loader 1 and the operation to lower boom 14 are simultaneously performed and a plurality of operations are performed as temporally overlapping, the cycle time of works can be reduced and workability can be improved.

[0115] As shown in Figs. 7 to 8 and 12, boom 14 keeps rising during a period from start of the dump operation of bucket 6 until the bucket is in the full dump posture. After bucket 6 is set to the full dump state, the operation to raise boom 14 is stopped. When rise of boom 14 is stopped after boom 14 is raised to the highest position with bucket 6 having been loaded, the vehicular body may sway forward and rearward and become unstable by being affected by inertia. By bringing boom 14 to the highest position and stopping the same after bucket 6 is set to the full dump state and loads in bucket 6 are ejected, sway of the vehicle by inertia can be suppressed.

[0116] As shown in Figs. 7 to 10, the target postures of work implement 3 when cutting edge 6a of bucket 6 is located at target positions c, d, f, and g are stored in automation controller 100. Automation controller 100 controls boom cylinder 16 and bucket cylinder 19 to set work implement 3 into the target postures when cutting edge 6a reaches target positions c, d, f, and g. With such an operation, loads loaded in bucket 6 can reliably be ejected from bucket 6 and contact between work implement 3 and vessel 301 can reliably be avoided.

[0117] Automation controller 100 included in the automatic control system for wheel loader 1 described in the embodiment above does not necessarily have to be mounted on wheel loader 1. Such a system that a controller mounted on wheel loader 1 performs processing for transmitting information obtained by external information obtaining unit 110, vehicle information obtaining unit 120, and the like to an external controller and the external controller that receives a signal automatically controls wheel loader 1 may be configured. The external controller may be arranged at a worksite of wheel loader 1 or at a remote location distant from the worksite of wheel loader 1.

[0118] In the embodiment, an example in which wheel loader 1 is a manned vehicle including cab 5 on which the operator rides is described. Wheel loader 1 may be an unmanned vehicle. Wheel loader 1 does not have to include cab 5 on which the operator rides for performing operations. Wheel loader 1 does not have to be equipped with a function for manipulating by the operator who rides on the cab. Wheel loader 1 may be a work machine dedicated for remote control. Wheel loader 1 may be manipulated through a wireless signal from a remote control device.

<Additional Aspects>

[0119] The description above includes features additionally described below.

(Additional Aspect 1)

[0120] A work machine includes

a main body including a travel unit,
a work implement attached in front of the main body, the work implement including a bucket at a tip end,
a work implement actuator that drives the work implement with respect to the main body,
a travel sensor that detects a state of travel of the travel unit,
a work implement posture sensor that detects a posture of the work implement,
an object sensor that detects an object around the main body, and
a controller that provides a command to drive the work implement actuator based on detection values from the travel sensor, the work implement posture sensor, and the object sensor, and
the controller recognizes a loading target into which loads in the bucket are to be loaded, based on detection of the object, and controls the work implement actuator and the travel unit such that the bucket is in a full dump state while a feature point of the bucket is located above the loading target and such

that the travel unit travels rearward with the full dump state being maintained.

(Additional Aspect 2)

[0121] In the work machine according to Additional Aspect 1, the controller sets an upper end of a side surface of the loading target recognized by the object sensor as a reference point, and starts drive of the work implement actuator to operate the bucket in a tilt direction at a time point when a horizontal distance between the reference point and the feature point becomes equal to or smaller than a prescribed value.

(Additional Aspect 3)

[0122] In the work machine according to Additional Aspect 2, the controller stops drive of the work implement actuator to operate the bucket in the tilt direction at a time point when the feature point moves beyond the reference point.

(Additional Aspect 4)

[0123] In the work machine according to any one of Additional Aspects 1 to 3,

the work implement has a boom coupled to the main body, and
the controller controls the travel unit to travel rearward with the full dump state being maintained while a posture of the boom with respect to the main body is held.

(Additional Aspect 5)

[0124] In the work machine according to any one of Additional Aspect 2, Additional Aspect 3, and Additional Aspect 4 dependent on Additional Aspect 2,

the work implement has a boom coupled to the main body, and
the controller controls the bucket to operate in the tilt direction while a posture of the boom with respect to the main body is held.

(Additional Aspect 6)

[0125] In the work machine according to any one of Additional Aspect 2, Additional Aspect 3, Additional Aspect 4 dependent on Additional Aspect 2, and Additional Aspect 5,

the work implement has a boom coupled to the main body, and
the controller starts drive of the work implement actuator to lower the boom at the time point when the feature point moves beyond the reference point.

[0126] It should be understood that the embodiment disclosed herein is illustrative and non-restrictive in every respect. The scope of the present invention is defined by the terms of the claims rather than the description above and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0127] 1 wheel loader; 2 vehicular body frame; 2a front frame; 2b rear frame; 3 work implement; 4 travel apparatus; 4a, 4b running wheel; 5 cab; 6 bucket; 8 operation apparatus; 9 boom pin; 11 steering cylinder; 13 work implement pump; 14 boom; 15 link; 16 boom cylinder; 17 bucket pin; 18 bell crank; 18a support pin; 18b, 18c coupling pin; 19 bucket cylinder; 21 engine; 23 transmission; 25 axle; 32 main valve; 35, 36 electromagnetic proportional control valve; 41 accelerator pedal; 42 work implement control lever; 50 vehicular body controller; 51 machine monitor; 60 engine controller; 70 transmission controller; 71 brake control unit; 72 accelerator control unit; 80 work implement controller; 81 steering control unit; 82 work implement control unit; 100 automation controller; 101 position estimator; 102 path planning unit; 103 path tracking control unit; 110 external information obtaining unit; 111 perception device; 112 positional information obtaining device; 120 vehicle information obtaining unit; 121 articulation angle sensor; 122 vehicle speed sensor; 123 boom angle sensor; 124 bucket angle sensor; 125 boom cylinder pressure sensor; 130 interface; 131 automation switch; 132 engine emergency stop switch; 133 mode indicator; 140 actuator; 141 brake EPC; 142 steering EPC; 143 work implement EPC; 144 HMT.

Claims

1. A work machine comprising:

a main body including a travel unit;
a work implement attached in front of the main body, the work implement including a bucket at a tip end;
a work implement actuator that drives the work implement with respect to the main body;
a travel sensor that detects a state of travel of the travel unit;
a work implement posture sensor that detects a posture of the work implement;
an object sensor that detects an object around the main body; and
a controller that provides a command to drive the work implement actuator based on detection values from the travel sensor, the work implement posture sensor, and the object sensor, wherein
the controller recognizes a loading target into

which loads in the bucket are to be loaded, based on detection of the object, and controls the work implement actuator and the travel unit such that the bucket is in a full dump state while a feature point of the bucket is located above the loading target and such that the travel unit travels rearward with the full dump state being maintained.

2. The work machine according to claim 1, wherein the controller sets an upper end of a side surface of the loading target recognized by the object sensor as a reference point, and starts drive of the work implement actuator to operate the bucket in a tilt direction at a time point when a horizontal distance between the reference point and the feature point becomes equal to or smaller than a prescribed value.

3. The work machine according to claim 2, wherein the controller stops drive of the work implement actuator to operate the bucket in the tilt direction at a time point when the feature point moves beyond the reference point.

4. The work machine according to any one of claims 1 to 3, wherein

the work implement has a boom coupled to the main body, and
the controller controls the travel unit to travel rearward with the full dump state being maintained while a posture of the boom with respect to the main body is held.

5. The work machine according to claim 2 or 3, wherein

the work implement has a boom coupled to the main body, and
the controller controls the bucket to operate in the tilt direction while a posture of the boom with respect to the main body is held.

6. The work machine according to claim 3, wherein

the work implement has a boom coupled to the main body, and
the controller starts drive of the work implement actuator to lower the boom at the time point when the feature point moves beyond the reference point.

7. A system including a work machine, the system comprising:

a work machine main body including a travel unit;
a work implement attached in front of the work machine main body, the work implement including a bucket at a tip end;
a work implement actuator that drives the work implement with respect to the work machine main body;
a travel sensor that detects a state of travel of the travel unit;
a work implement posture sensor that detects a posture of the work implement;
an object sensor that detects an object around the work machine main body; and
a controller that provides a command to drive the work implement actuator based on detection values from the travel sensor, the work implement posture sensor, and the object sensor, wherein
the controller recognizes a loading target into which loads in the bucket are to be loaded, based on detection of the object, and controls the work implement actuator and the travel unit such that the bucket is in a full dump state while a feature point of the bucket is located above the loading target and such that the travel unit travels rearward with the full dump state being maintained.

8. A method of controlling a work machine, the method comprising:

recognizing a loading target into which loads in a bucket are to be loaded, based on an object detection signal;
moving a feature point of the bucket to above the loading target;
setting the bucket into a full dump state while the feature point is located above the loading target; and
controlling a travel unit to travel rearward with the full dump state being maintained.

FIG.1

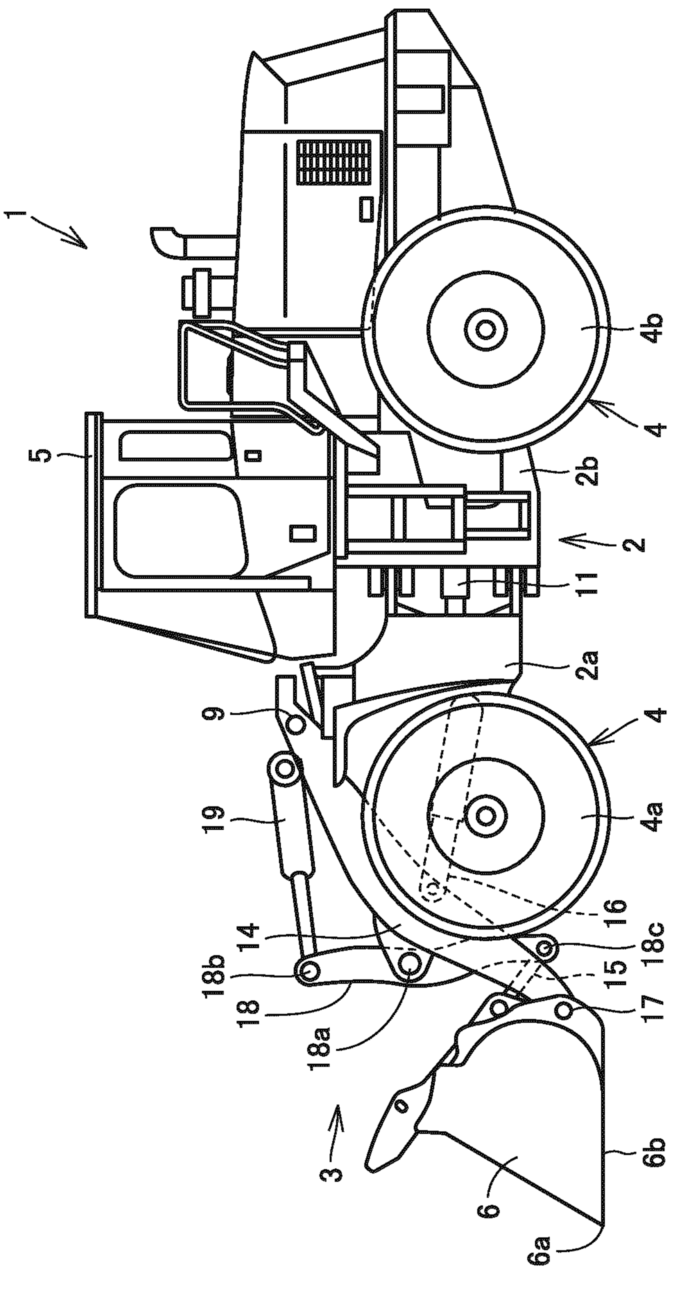
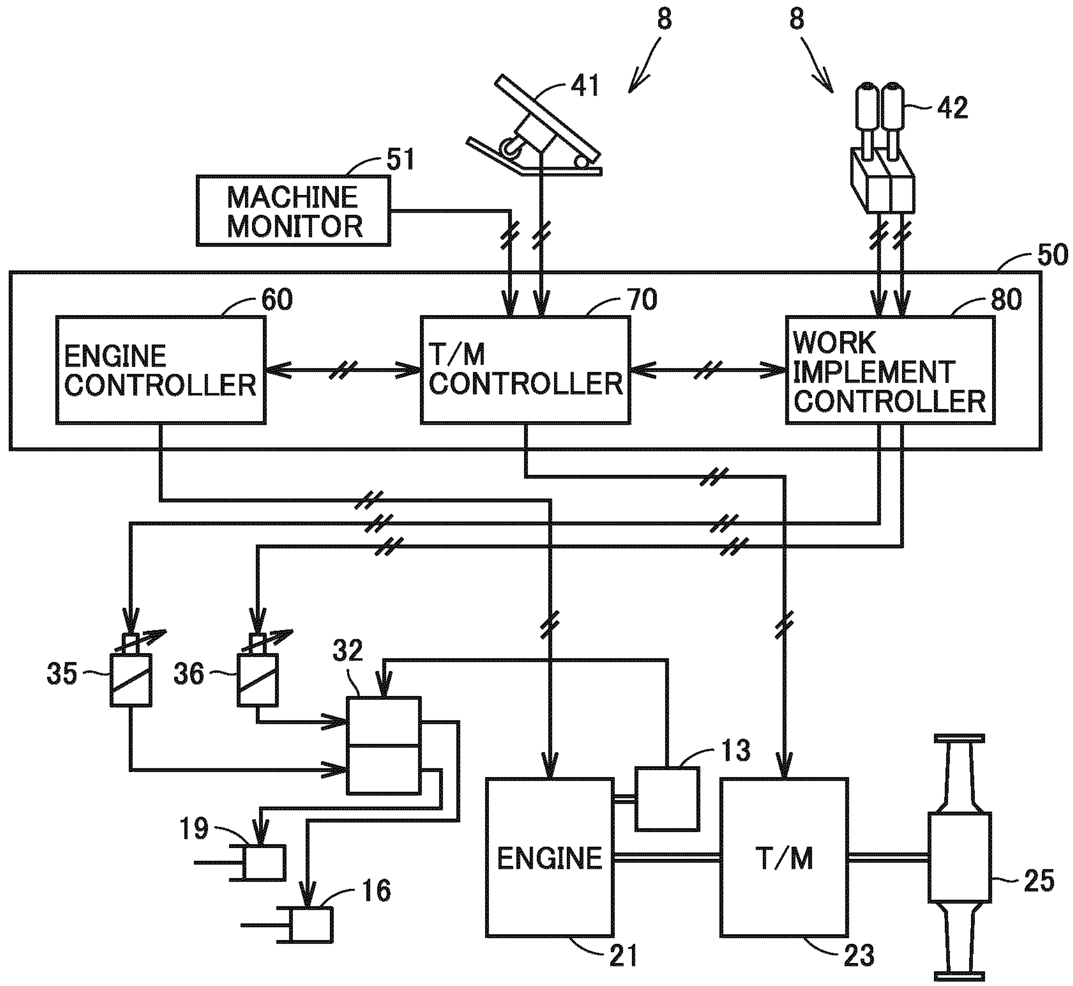


FIG.2


8
8
41
42
51
MACHINE MONITOR
50
60
70
80
ENGINE CONTROLLER
T/M CONTROLLER
WORK IMPLEMENT CONTROLLER
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ENGINE
T/M
21
23
25

FIG.3

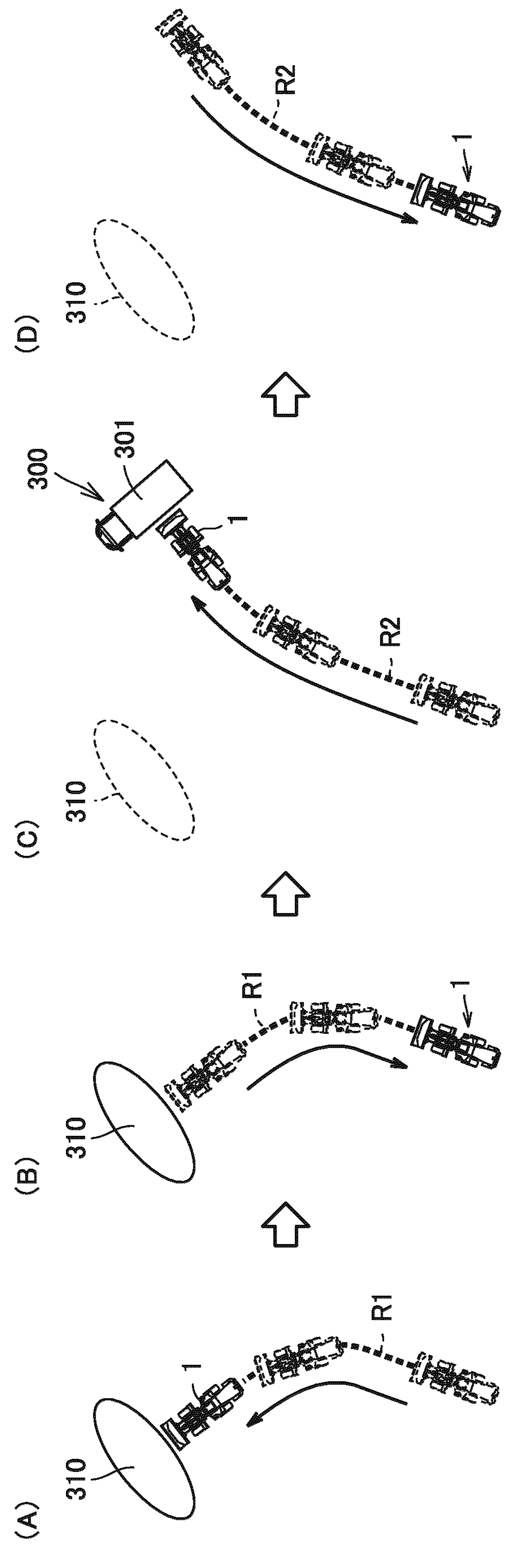


FIG.4

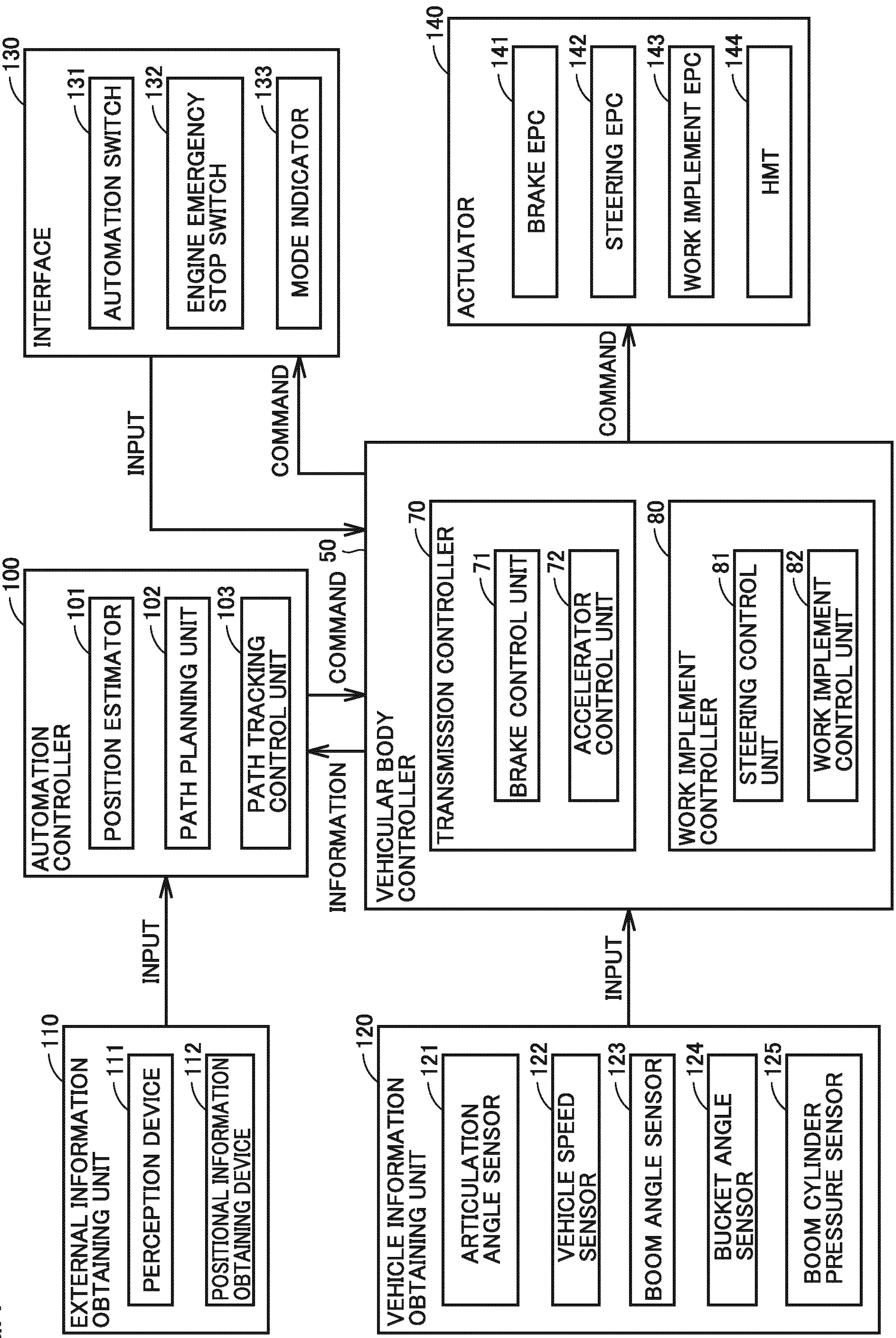

100
AUTOMATION CONTROLLER
101
POSITION ESTIMATOR
102
PATH PLANNING UNIT
103
PATH TRACKING CONTROL UNIT
110
EXTERNAL INFORMATION OBTAINING UNIT
111
PERCEPTION DEVICE
112
POSITIONAL INFORMATION OBTAINING DEVICE
INPUT
130
INTERFACE
131
AUTOMATION SWITCH
132
ENGINE EMERGENCY STOP SWITCH
133
MODE INDICATOR
INPUT
COMMAND
COMMAND
INFORMATION
50
VEHICULAR BODY CONTROLLER
70
TRANSMISSION CONTROLLER
71
BRAKE CONTROL UNIT
72
ACCELERATOR CONTROL UNIT
80
WORK IMPLEMENT CONTROLLER
81
STEERING CONTROL UNIT
82
WORK IMPLEMENT CONTROL UNIT
COMMAND
140
ACTUATOR
141
BRAKE EPC
142
STEERING EPC
143
WORK IMPLEMENT EPC
144
HMT
INPUT
120
VEHICLE INFORMATION OBTAINING UNIT
121
ARTICULATION ANGLE SENSOR
122
VEHICLE SPEED SENSOR
123
BOOM ANGLE SENSOR
124
BUCKET ANGLE SENSOR
125
BOOM CYLINDER PRESSURE SENSOR

FIG.5

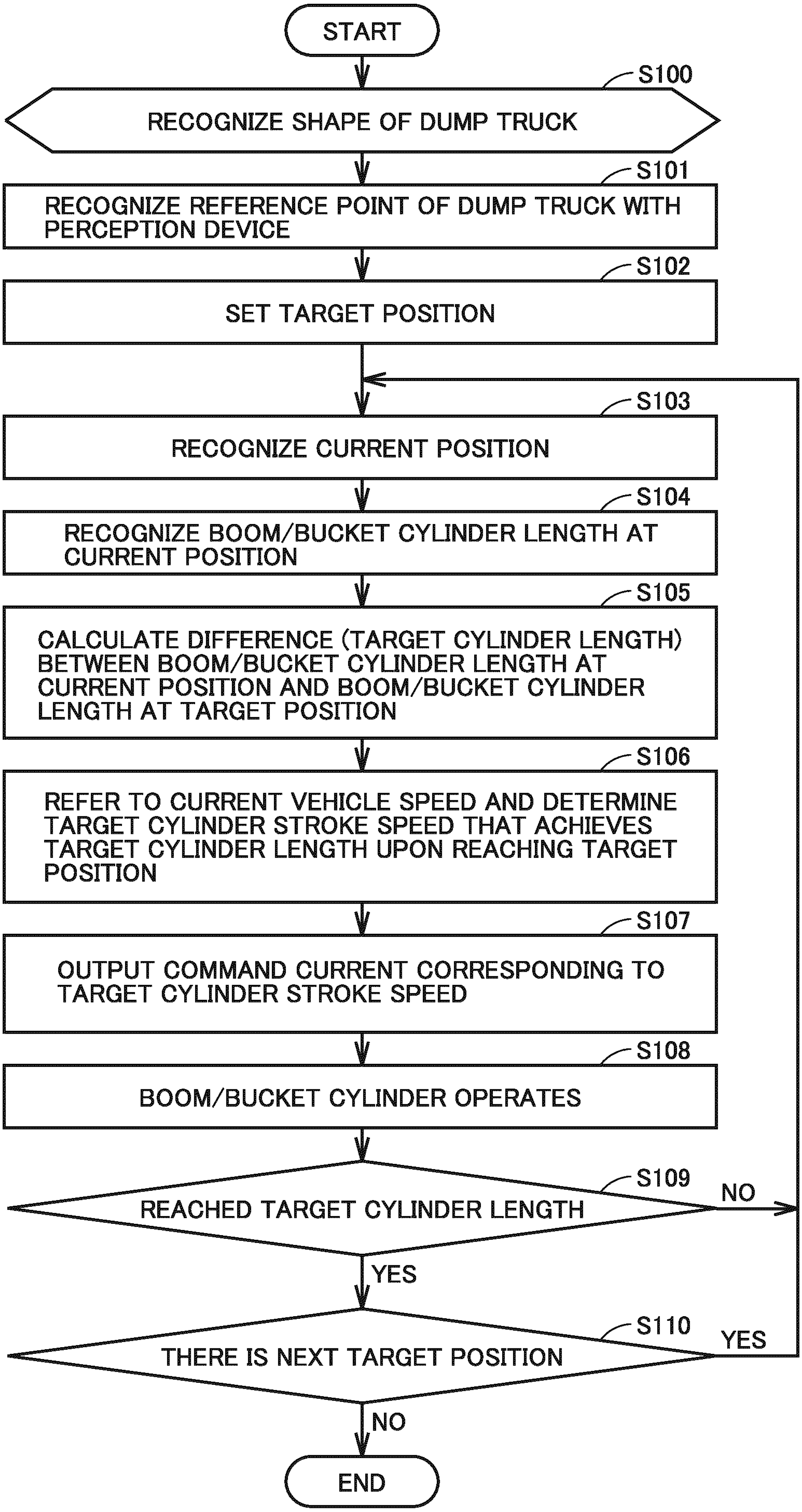

START
S100
RECOGNIZE SHAPE OF DUMP TRUCK
S101
RECOGNIZE REFERENCE POINT OF DUMP TRUCK WITH PERCEPTION DEVICE
S102
SET TARGET POSITION
S103
RECOGNIZE CURRENT POSITION
S104
RECOGNIZE BOOM/BUCKET CYLINDER LENGTH AT CURRENT POSITION
S105
CALCULATE DIFFERENCE (TARGET CYLINDER LENGTH) BETWEEN BOOM/BUCKET CYLINDER LENGTH AT CURRENT POSITION AND BOOM/BUCKET CYLINDER LENGTH AT TARGET POSITION
S106
REFER TO CURRENT VEHICLE SPEED AND DETERMINE TARGET CYLINDER STROKE SPEED THAT ACHIEVES TARGET CYLINDER LENGTH UPON REACHING TARGET POSITION
S107
OUTPUT COMMAND CURRENT CORRESPONDING TO TARGET CYLINDER STROKE SPEED
S108
BOOM/BUCKET CYLINDER OPERATES
S109
REACHED TARGET CYLINDER LENGTH
NO
YES
S110
THERE IS NEXT TARGET POSITION
YES
NO
END

FIG.6

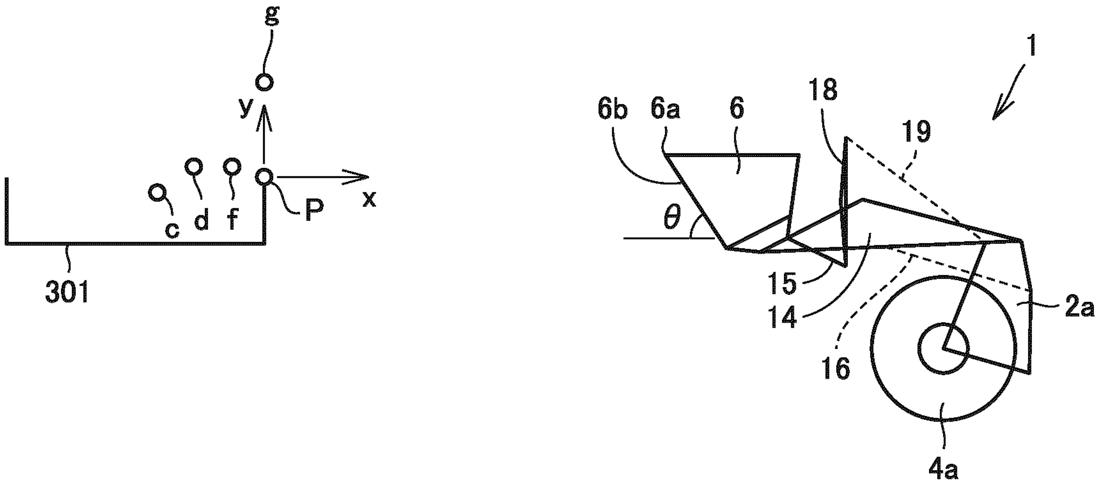
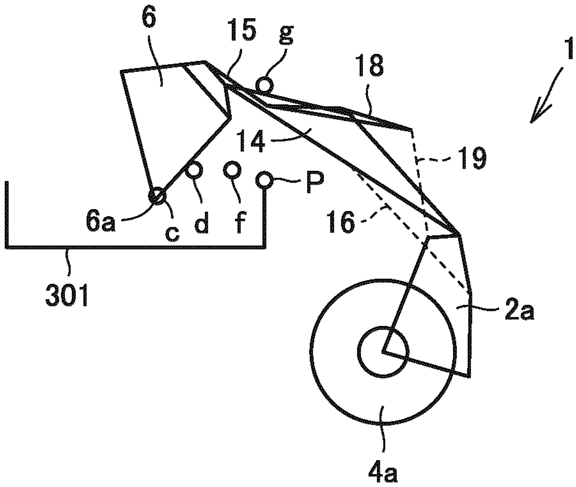

g
y
x
P
c
d
f
301
1
18
19
6b
6a
6
θ
15
14
16
2a
4a

FIG.7


6
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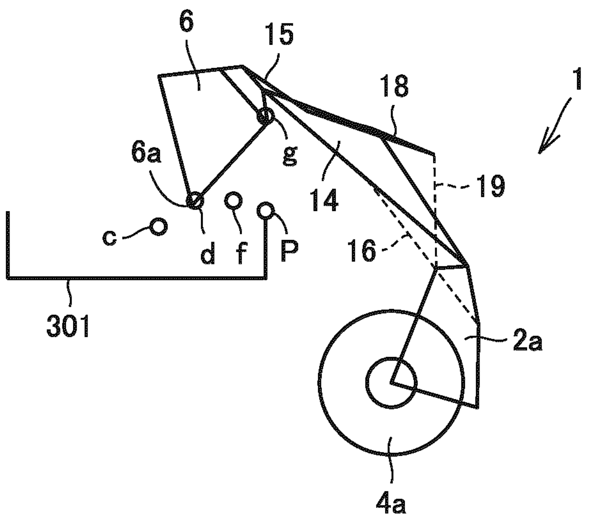
18
1
14
19
6a
c
d
f
P
16
301
2a
4a

FIG.8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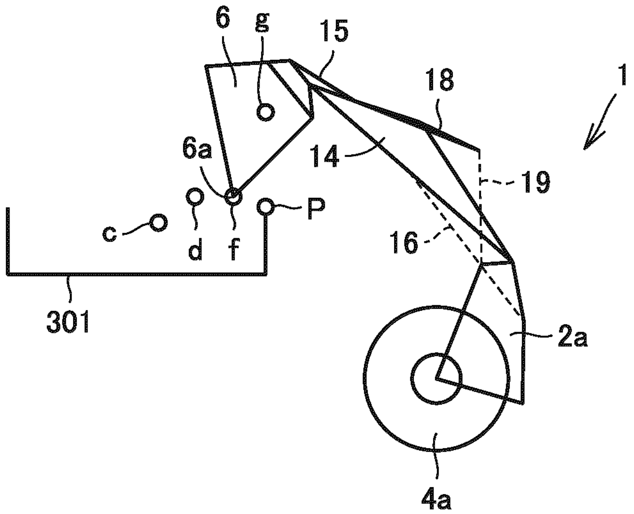
6a
g
14
19
c
d
f
P
16
301
2a
4a

FIG.9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1
6a
14
19
c
d
f
P
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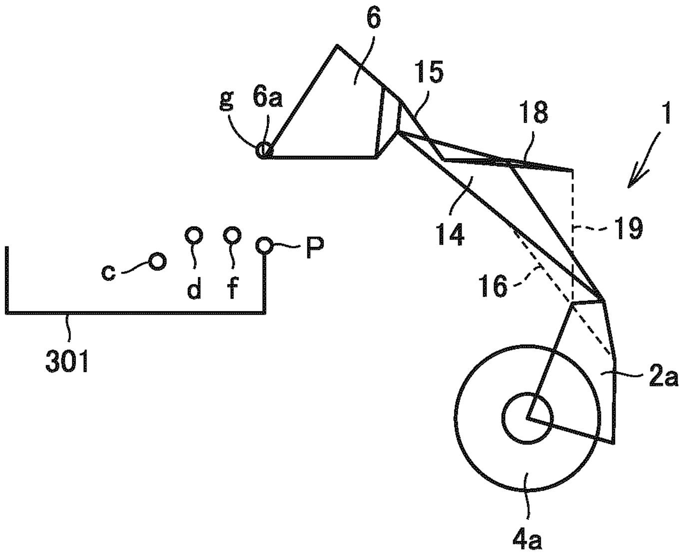
301
2a
4a

FIG.10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18
1
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14
c
d
f
P
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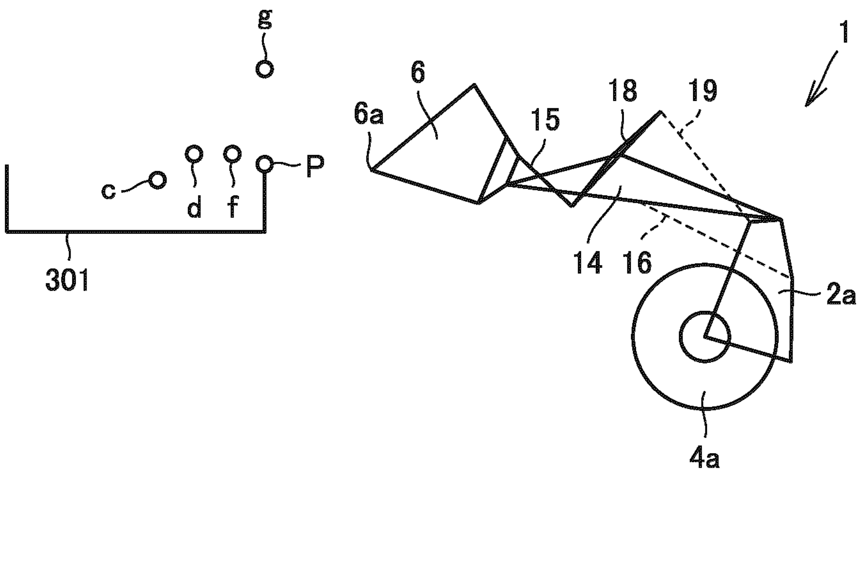
301
2a
4a

FIG.11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6
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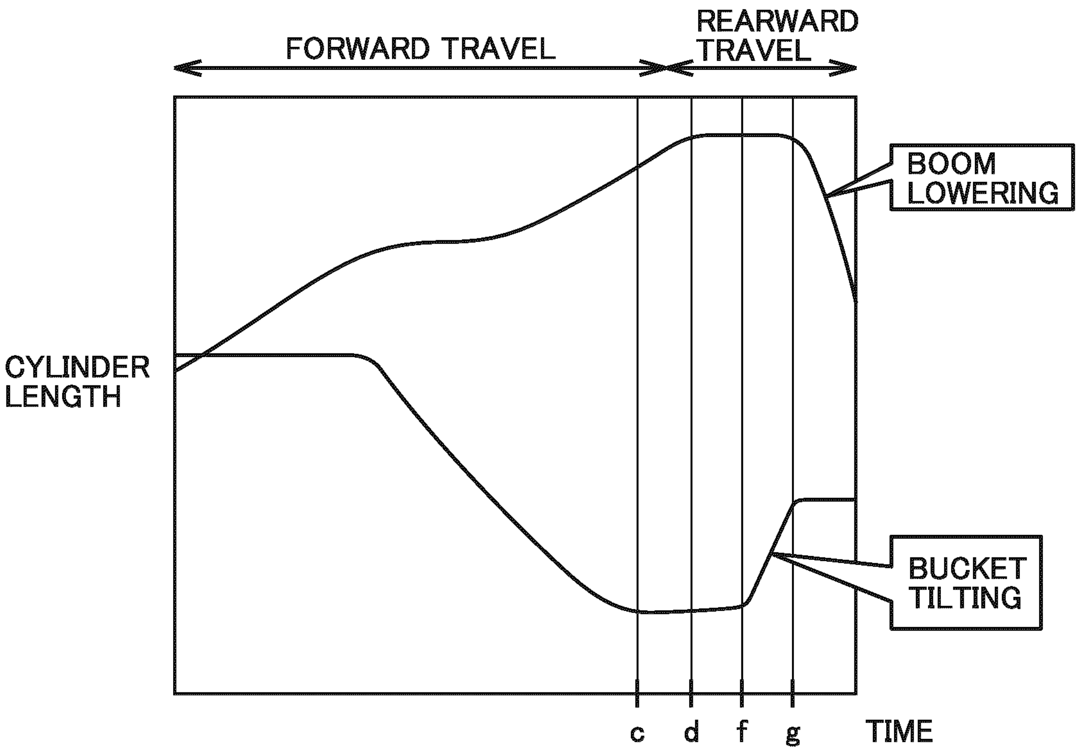
19
6a
15
c
d
f
P
14
16
301
2a
4a

FIG.12


FORWARD TRAVEL
REARWARD TRAVEL
BOOM LOWERING
CYLINDER LENGTH
BUCKET TILTING
c
d
f
g
TIME

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/028887

A. CLASSIFICATION OF SUBJECT MATTER

E02F 3/43(2006.01)i
FI: E02F3/43 A

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

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2019-190238 A (KOMATSU LTD.) 31 October 2019 (2019-10-31) entire text, all drawings	1-8
A	JP 2021-9556 A (KOMATSU LTD.) 28 January 2021 (2021-01-28) entire text, all drawings	1-8
A	WO 2015/129932 A1 (KOMATSU LTD.) 03 September 2015 (2015-09-03) entire text, all drawings	1-8
A	WO 2011/108550 A1 (KOMATSU LTD.) 09 September 2011 (2011-09-09) entire text, all drawings	1-8
A	JP 10-88625 A (KOMATSU LTD.) 07 April 1998 (1998-04-07) entire text, all drawings	1-8
A	US 2021/0223400 A1 (DOOSAN INFRACORE CO., LTD.) 22 July 2021 (2021-07-22) entire text, all drawings	1-8

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 September 2023	**19 September 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/028887

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2019-190238 A	31 October 2019	US 2021/0010225 A1	
JP 2021-9556 A	28 January 2021	US 2022/0307233 A1	
WO 2015/129932 A1	03 September 2015	US 2016/0281323 A1	
WO 2011/108550 A1	09 September 2011	US 2013/0073151 A1	
JP 10-88625 A	07 April 1998	US 6247538 B1	
US 2021/0223400 A1	22 July 2021	EP 3851590 A1	

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2016152994 A **[0002] [0003]**