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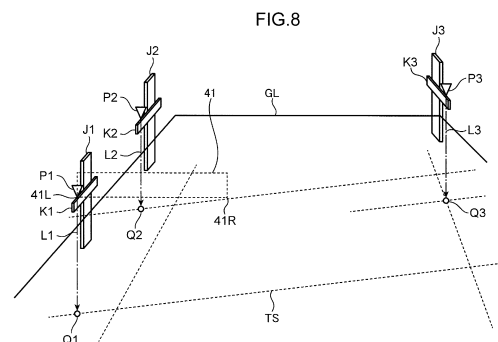
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(54) **WORK ASSIST DEVICE FOR WORK MACHINE AND METHOD FOR RECOGNIZING CONSTRUCTION SURFACE AT WORK SITE**

(57) A work assist device (1) includes a body coordinates information acquiring unit (53), a body orientation information acquiring unit (54), a work member position information acquiring unit (55), a specific part coordinates computing unit (502), a placement information receiving unit, a distance information input unit (52), a construction surface computing unit (503), a storage unit (505), and a construction information output unit (506). The specific part coordinates computing unit (502) can compute absolute coordinates of a specific part of a work member (41), from acquired information from each acquiring unit. The construction surface computing unit (503) determines an equation for a construction surface (TS) in an absolute coordinate system at a work site, from absolute coordinates of three ground reference points at which the specific part is placed in order and three pieces of distance information indicating a distance from the ground reference points to the construction surface (TS).



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Description

Technical Field

[0001] The present invention relates to a work assist device of a work machine and a method of recognizing a construction surface at a work site, the work assist device and the method assisting in performing work using a work machine.

Background Art

[0002] A work machine including a machine body and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body has been known for years. The work member is, for example, an attachment including an earth-removing blade or a bucket capable of performing excavation work or leveling work.

[0003] Patent Literature 1 discloses a target work surface setting device (work assist device) that allows a worker operating a work machine to easily recognize the position of a target work surface (construction surface) virtually set in the ground. The target work surface setting device includes a work machine side computer incorporated in the work machine and an office side computer placed in an office separated away from a work site. When the setting switch of the work machine side computer is turned on, 3D data unique to the work site, the 3D data including a plan view, a cross-sectional view, and the like, is transmitted from the office side computer to the work machine side computer through a transceiver. The work machine side computer computes position information on the target work surface, based on the received 3D data.

[0004] The work machine side computer computes also three-dimensional position information on the work machine at the work site, based on position information sent from a GPS antenna unit provided on the work machine and correction information sent from a GPS base station set in the work site. The work machine side computer then compares the computed position information on the target work surface with the three-dimensional position information on the work machine to determine whether the work machine is within a range in which the work member can reach the target work surface, and informs the worker of the result of the determination. Being informed of the result of the determination, the worker understands a relative positional relationship between the work member and the target work surface, and is therefore able to efficiently carry out the excavation work and the leveling work at the work site.

Citation List

Patent Literature

[0005] Patent Literature 1: Japanese Patent Applica-

tion Laid-Open No. 2006-265954

[0006] According to the technique described in Patent Literature 1, setting the construction surface (target work surface) requires that a communication mechanism enabling communication between the work machine side computer and the office side computer be provided and that the work machine side computer have a large-capacity storage unit for storing 3D data unique to the work site. This leads to a complicated configuration of the work assist device that assists the work machine in performing work and to an increase in the cost of the work machine, thus posing a problem that some constructors have difficulty in introducing such a work assist machine.

Summary of Invention

[0007] An object of the present invention is to provide a work assist device of a work machine and a method of recognizing a construction surface at a work site, the work assistance device and the method allowing a worker to easily recognize a construction surface without the need of receiving 3D data unique to a work site from an external device or storing the 3D data in advance.

[0008] A work assist device of a work machine according to one aspect of the present invention, the work assist device being devised in view of the above problem, is a work assist device of a work machine including: a machine body having a traveling unit capable of traveling on the ground; and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body and capable of excavating the ground. The work assist device is configured to assist in work of forming, by the work machine, a given construction surface on a work site. The work assist device includes: a body coordinates information acquiring unit that can acquire body coordinates information that is information on absolute coordinates of a body reference point at the work site, the body reference point being set on the machine main body in advance; a body orientation information acquiring unit that can acquire body orientation information that is information on an orientation of the machine body with respect to the body reference point; a work member position information acquiring unit that can acquire work member position information that is information on a relative position of the work member to the machine body; a specific part coordinates computing unit that can compute and output absolute coordinates of a specific part of the work member at the work site, based on the body coordinates information acquired by the body coordinates information acquiring unit, on the body orientation information acquired by the body orientation information acquiring unit, and on the work member position information acquired by the work member position information acquiring unit; a placement information receiving unit that can receive pieces of placement information that is information indicating that the specific part of the work member is placed at least at three ground reference points associated with the con-

struction surface according to travel of the traveling unit; a storage unit that stores absolute coordinates of the specific part as absolute coordinates the at least three ground reference points at the work site, respectively, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit in correspondence to the placement information receiving unit's receiving the placement information at the at least three ground reference points; a distance information input unit that can receive input of at least three pieces of distance information that is information indicating a distance from each of the at least three ground reference points to the construction surface in a vertical direction; a construction surface computing unit that computes an equation for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit, and a construction surface information output unit that outputs information on the equation for the construction surface computed by the construction surface computing unit.

[0009] A method of recognizing a construction surface at a work site according to another aspect of the present invention includes: preparing a work machine including a machine body having a traveling unit capable of traveling on the ground and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body, the work member being capable of excavating the ground, and preparing a work assist device of the work machine as well; placing the specific part of the work member in order at the at least three ground reference points associated with the construction surface, according to at least traveling of the traveling unit and storing absolute coordinates of the specific part in the storage unit as absolute coordinates of each of the ground reference points, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit in correspondence to each of the ground reference points; inputting at least three pieces of distance information to the distance information input unit, the distance information indicating a distance from each of the at least three ground reference points to the construction surface in a vertical direction; computing an equation for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit; and outputting information on the computed equation for the construction surface and, based on the output information, allowing a worker to recognize a position of the construction surface at the work site.

[0010] A method of recognizing a construction surface at a work site according to still another aspect of the present invention includes: preparing a work machine

including a machine body having a traveling unit capable of traveling on the ground and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body, the work member being capable of excavating the ground, and preparing a work assist device of the work machine as well; placing the specific part of the work member in order at the at least three ground reference points associated with the construction surface, according to at least traveling of the traveling unit and storing absolute coordinates of the specific part in the storage unit as absolute coordinates of each of the ground reference points, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit in correspondence to each of the ground reference points; inputting at least three pieces of distance information to the distance information input unit, the distance information indicating a distance from each of the at least three ground reference points to the construction surface in a vertical direction; computing an equation for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit; outputting information on the computed equation for the construction surface and, based on the output information, allowing a worker to recognize a position of the construction surface at the work site; providing the work site with a reference member for checking including a straight part that is parallel to the construction surface and that is perpendicular to a direction of traveling of the traveling body of the work machine in a plan view; operating the work machine to align a lower end part of an earth-removing blade, the lower end part extending in a left-to-right direction, with the straight part of the reference member for checking; and comparing a distance from a left end of the lower end part of the earth-removing blade to the construction surface with a distance from a right end of the lower end part of the same to the construction surface to check whether the computed equation for the construction surface is within a given range.

Brief Description of Drawings

[0011]

FIG. 1 is a schematic side sectional view for describing a structure of a work machine including a work assist device according to an embodiment of the present invention.

FIG. 2 is a block diagram of the work machine including the work assist device according to the embodiment of the present invention.

FIG. 3 is a side view for describing coordinate information on the work assist device and the work machine according to the embodiment of the present invention.

FIG. 4 is a plan view for describing coordinate information on the work assist device and the work machine according to the embodiment of the present invention.

FIG. 5 is a flowchart of a construction surface setting process carried out by the work assist device according to the embodiment of the present invention.

FIG. 6 is a flowchart showing a part of the construction surface setting process carried out by the work assist device according to the embodiment of the present invention.

FIG. 7 is a flowchart showing a part of construction surface setting process carried out by the work assist device according to the embodiment of the present invention.

FIG. 8 is a perspective view of a work site for the work machine including the work assist device according to the embodiment of the present invention.

FIG. 9 is a schematic view for describing a process of computation of a construction surface by the work assist device according to the embodiment of the present invention.

FIG. 10 is a side sectional view of the work site for the work machine including the work assist device according to the embodiment of the present invention.

FIG. 11 is a perspective view of the work site for the work machine including the work assist device according to the embodiment of the present invention.

Description of Embodiment

[0012] An embodiment of the present invention will hereinafter be described with reference to the drawings. FIG. 1 is a schematic side sectional view for describing a structure of an excavator 100 (work machine) including a construction surface setting device (work assist device) 1 (FIG. 2) according to the embodiment. FIG. 2 is a block diagram of the excavator 100 including the construction surface setting device 1 according to the embodiment. FIG. 3 is a side view for describing coordinate information on the construction surface setting device 1 and the excavator 100 according to the embodiment, and FIG. 4 is a plan view for describing the coordinate information on the same.

[0013] In the embodiment, the hydraulic excavator 100, which is an example of a work machine, is provided with the construction surface setting device 1. The excavator 100 includes a machine body 10, an attachment 30, and a dozer unit 40. The machine body 10 includes a lower body 11 and an upper slewing body 20. On both left and right sides of the lower body 11, crawler units 12 (traveling units) capable of traveling on the ground are attached, respectively. The upper slewing body 20 has a slewing frame 21 supported on the lower body 11 in such a way as to be capable of turning around a pivot extending in the vertical direction, a cab 22 allowing a worker to sit therein, an engine room 23 disposed behind

the cab 22, an engine 24, a first hydraulic pump 25, a second hydraulic pump 26, and a support 27.

[0014] The engine 24 is placed in the engine room 23. The first hydraulic pump 25 and the second hydraulic pump 26 are driven by the engine 24, and each deliver hydraulic oil to a hydraulic circuit (not illustrated) for driving the attachment 30 and the dozer unit 40. The support 27 is disposed at a location that is on the slewing frame 21 and that is at the right side of the cab 22 (the back of the paper surface in FIG. 1), and supports the attachment 30 in such a way as to allow it to move up and down. The attachment 30 includes a boom, an arm, and a bucket which (not illustrated) can swing up and down, and performs prescribed excavation work and the like.

[0015] The dozer unit 40 (work member) is disposed on a front part of the lower body 11. The dozer unit 40 is supported by the machine body 10 in such a way as to be capable of moving relative to the machine body 10, and can excavate the ground. The dozer unit 40 has an earth-removing blade 41 and a support frame 42 (earth-removing blade support) that supports the earth-removing blade 41. The excavator 100 further includes a lift cylinder 43, a pair of left and right angle cylinders 44, and a tilt cylinder 45. The support frame 42 is supported by the lower body 11 of the machine body 10 in such a way as to be capable of swinging about a lift rotating shaft F1 extending in the left-to-right direction. The lift cylinder 43 extends and contracts in response to supply and discharge of hydraulic oil from and to the second hydraulic pump 26, and this extension/contraction causes the support frame 42 to swing about the lift rotating shaft F1. As a result, the earth-removing blade 41 swings in a lift direction D1 shown in FIG. 1, which changes a lift angle of the earth-removing blade 41 (dozer unit 40). The pair of left and right angle cylinders 44 each extend and contract in response to supply and discharge of hydraulic oil from the second hydraulic pump 26, and this extension/contraction causes the earth-removing blade 41 to swing about an angular rotating shaft F2. As a result, the earth-removing blade 41 swings in an angular direction D2 shown in FIG. 1, which changes an angular angle of the earth-removing blade 41 (dozer unit 40). The earth-removing blade 41 is supported by the front end of the support frame 42 in such a way as to be capable of swinging about a tilt rotating shaft F3 extending in the left-to-right direction. The tilt cylinder 45 extends and contracts in response to supply and discharge of the hydraulic oil from the second hydraulic pump 26, and this extension/contraction causes the earth-removing blade 41 to swing about a tilt rotating shaft F3 in a tilt direction D3 shown FIG. 1, which changes a tilt angle of the earth-removing blade 41 (dozer unit 40).

[0016] As shown in FIG. 2, the construction surface setting device 1 included in the excavator 100 (the work assist device of the work machine) includes a controller 50, an operation unit 51, an input unit 52, a body coordinates detection unit 53, a body angle detection unit 54, an earth-removing blade angle detection unit 55, a drive

unit 56, a display unit 57, and an informing unit 58. The construction surface setting device 1 can assist in performing work of forming a prescribed construction surface TS (see FIGS. 8 and 10) at a work site.

[0017] The operation unit 51 is disposed in the cab 22, and receives operation instructions given by a worker, the operation instructions including an instruction on traveling actions of the crawler unit 12, an instruction on slewing actions of the upper slewing body 20, and an instruction on driving of the attachment 30 and the dozer unit 40.

[0018] The input unit 52 (placement information receiving unit, distance information input unit) is disposed in the cab 22, and receives various pieces of information input by the worker. According to the embodiment, in particular, the input unit 52 can receive pieces of placement information in order, the placement information being information indicating that at least according to traveling of the crawler unit 12, a specific part of the earth-removing blade 41 is placed at least at three ground reference points associated with the construction surface TS of the work site, the three ground reference points being located above the construction surface TS so that the specific part of the earth-removing blade 41 can be placed in order at the three ground reference points on the ground. The input unit 52 can also receive input of at least three pieces of distance information that is information indicating a distance from each of the at least three ground reference points to the construction surface TS in the vertical direction.

[0019] The body coordinates detection unit 53 (body coordinates information acquiring unit) can acquire body coordinates information that is information on absolute coordinates of a body reference point at the work site, the body reference point being set on the machine body 10 in advance. The body coordinates detection unit 53 includes a global navigation satellite system (GNSS) reference station 61 and a GNSS mobile station 62. The body reference point is set on the top surface of the cab 22. The GNSS reference station 61 is a reference station disposed at the work site or at a location closest to the work site. As shown in FIG. 3, the GNSS reference station 61 determines the absolute coordinates by three axes, i.e., an x0 axis, a y0 axis, and a z0 axis set with respect to an origin G0 as a point of reference. The GNSS mobile station 62 is disposed on the top surface of the cab 22 in correspondence to the body reference point. It should be noted that in addition to a known global positioning system (GPS), such a satellite positioning system as a global navigation satellite system (GLONASS), Galileo, or a quasi-zenith satellite system (QZSS) may also be adopted as the GNSS.

[0020] The body angle detection unit 54 (body orientation information acquiring unit) can acquire body orientation information that is information on an orientation of the machine body 10 with respect to the body reference point. In the embodiment, the body angle detection unit 54 is an angle sensor (body angle sensor) disposed on

the top surface portion of the cab 22 in correspondence to the body reference point. The body angle detection unit 54 detects respective rotations around x1, y1, and z1 axes with respect to a mobile station origin G1, as indicated in FIGS. 3 and 4, and is provided as a known inertial measurement unit (IMU). In other words, the body angle detection unit 54 detects and outputs a lift angle, a pitch angle, and a yaw angle of the machine body 10 with respect to the body reference point, respectively, as the body orientation information.

[0021] The earth-removing blade angle detection unit 55 (work member position information acquiring unit) can acquire work member position information that is information on a relative position of the dozer unit 40 (earth-removing blade 41) to the machine body 10. In the embodiment, the earth-removing blade angle detection unit 55 is an angle sensor (earth-removing blade angle sensor) disposed on the earth-removing blade 41. The earth-removing blade angle detection unit 55 detects respective rotations around x3, y3, and z3 axes with respect to an earth-removing blade origin G3, as indicated in FIGS. 3 and 4, and, in the embodiment, is provided as an inertial measurement unit (IMU), as the body angle detection unit 54 is. In other words, the earth-removing blade angle detection unit 55 detects and outputs a lift angle, an angular angle, and a tilt angle of the earth-removing blade 41, as the work member position information.

[0022] The drive unit 56 includes the engine 24, the first hydraulic pump 25, and the second hydraulic pump 26 that are described above, and further includes a drive/transmission mechanism, such as a hydraulic circuit and gears. The drive unit 56 receives a control signal from a drive control unit 501 of the controller 50, and drives the crawler unit 12, the slewing frame 21, the attachment 30, and the dozer unit 40.

[0023] The display unit 57 is disposed in the cab 22, and displays various pieces of information on actions of the excavator 100. In particular, the display unit 57 can display position information on the construction surface TS (information on the construction surface TS) based on an equation for the construction surface TS output from the output unit 506, which will be described later. The display unit 57 can also display information on a relative position between the construction surface TS and the specific part, based on absolute coordinates of the specific part output from the earth-removing blade coordinates computing unit 502.

[0024] The informing unit 58 is disposed in the cab 22 or outside the excavator 100, and informs the worker of various pieces of information. As an example, the informing unit 58 includes a speaker, a buzzer, a light, and the like.

[0025] The controller 50 includes a central processing unit (CPU), a read-only memory (ROM) storing a control program, a random access memory (RAM) used as a work area for the CPU, and the like. The controller 50 is connected to the operation unit 51, the input unit 52, the body coordinates detection unit 53, the body angle de-

tection unit 54, the earth-removing blade angle detection unit 55, the drive unit 56, the display unit 57, the informing unit 58, and the like. As a result of the CPU's executing the control program stored in the ROM, the controller 50 functions as the controller including the drive control unit 501, the earth-removing blade coordinates computing unit 502, a construction surface computing unit 503, a determining unit 504, a storage unit 505, and an output unit 506.

[0026] In accordance with an instruction signal input to the operation unit 51, the drive control unit 501 controls the drive unit 56 to cause it to drive the crawler unit 12, the slewing frame 21, the attachment 30, and the dozer unit 40.

[0027] The earth-removing blade coordinates computing unit 502 (specific part coordinates computing unit) computes absolute coordinates of a specific part of the earth-removing blade 41 at the work site. Specifically, the earth-removing blade coordinates computing unit 502 can compute and output absolute coordinates of a specific part of the earth-removing blade 41 at the work site, based on the body coordinates information acquired by the body coordinates detection unit 53, the body orientation information acquired by the body angle detection unit 54, and the work member position information acquired by the earth-removing blade angle detection unit 55.

[0028] The construction surface computing unit 503 computes an equation for the construction surface TS in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit 505, and the at least three pieces of distance information input to the input unit 52. More specifically, the construction surface computing unit 503 computes absolute coordinates of at least three virtual reference points located respectively below the at least three ground reference points, from the absolute coordinates of the at least three ground reference points and the at least three pieces of distance information, and computes the equation of the construction surface TS, based on the computed absolute coordinates of at least three virtual reference points. A method of computing the construction surface TS will be described in detail later.

[0029] The determining unit 504 executes various determination operations in a flow of a construction surface TS setting process. The determining unit 504 executes also a given determination process when checking the equation for the construction surface TS computed and determined by the construction surface computing unit 503.

[0030] The storage unit 505 stores various pieces of information that is referred to in the flow of the construction surface TS setting process. The storage unit 505 stores also various pieces of threshold information and the like in advance. Further, the storage unit 505 stores absolute coordinates of the specific part as absolute coordinates of the at least three ground reference points at

the work site, the absolute coordinates of the specific part being computed by the earth-removing blade coordinates computing unit 502 in correspondence to the input unit 52 receiving the placement information at the at least three ground reference points.

[0031] The output unit 506 (construction surface information output unit) outputs information on the equation for the construction surface TS computed and determined by the construction surface computing unit 503.

[0032] FIG. 5 is a flowchart of a construction surface setting process carried out by the construction surface setting device 1 according to the embodiment. FIGS. 6 and 7 are flowcharts showing a part of the construction surface setting process of FIG. 5. FIG. 8 is a perspective view of a work site for the excavator 100 including the construction surface setting device 1 according to the embodiment. FIG. 9 is a schematic view for describing a process of computation of the construction surface TS by the construction surface setting device 1 according to the embodiment.

[0033] As shown in FIG. 4, the earth-removing blade 41 of the excavator 100 has a lower end part 41S extending in the left-to-right direction. Both left and right ends of the lower end part 41S of the earth-removing blade 41 are defined as an earth-removing blade left end 41L and an earth-removing blade right end 41R, respectively. In the embodiment, to acquire position information (plane equation) on the construction surface TS in an absolute coordinate system of the work site, the earth-removing blade left end 41L of the earth-removing blade 41 functions as a specific part.

[0034] FIG. 8 shows an example of the work site where three finishing stakes are set on a ground GL. Specifically, a first horizontal plate K1 is fixed to a first vertical plate J1 driven in the ground GL. Similarly, a second horizontal plate K2 is fixed to a second vertical plate J2 and a third horizontal plate K3 is fixed to a third vertical plate J3. The first vertical plate J1, the second vertical plate J2, and the third vertical plate J3 are arranged in such a way as to extend in the vertical direction, while the first horizontal plate K1, the second horizontal plate K2, and the third horizontal plate K3 are arranged in such a way as to extend in the horizontal direction.

[0035] On the top surfaces of the horizontal plates, a first reference point P1, a second reference point P2, and a third reference point P3 (which are all ground reference points) are set in advance, respectively, the first, second, and third reference points P1, P2, and P3 corresponding to the construction surface TS scheduled to be formed by excavation and ground leveling work. A first depth L1, a second depth L2, and a third depth L3 (each serving as distance information), which represent a distance from the first reference point P1 to the construction surface TS, a distance from the second reference point P2 to the same, and a distance from the third reference point P3 to the same in the vertical direction, respectively, are given in advance as known values at the work site. These distances are noted, for example, on side surfaces of the

first horizontal plate K1, the second horizontal plate K2, and the third horizontal plate K3, respectively. Points reached by going down from the first reference point P1, the second reference point P2, and the third reference point P3 by the first depth L1, the second depth L2, and the third horizontal plate K3, respectively, are defined as a first virtual point Q1, a second virtual point Q2, and a third virtual point Q3 (which are all virtual reference points), respectively. It is a prerequisite that the first reference point P1, the second reference point P2, and the third reference point P3 be not on a straight line.

[0036] As shown in FIG. 5, when the worker starts the construction surface TS setting process at the work site, a construction surface computation step is executed first (step S1 in FIG. 5). Step S1 will be described in detail later. When the construction surface computation step is over, the determining unit 504 of the controller 50 checks a construction surface computation completion flag (step S02). The construction surface computation completion flag is a flag for determining whether the construction surface computation step in step S01 is completed. This flag can be switched between ON and OFF, and is stored and updated in the storage unit 505. When the construction surface computation completion flag is ON in step S02 (YES in step S02), the determining unit 504 proceeds to step S03. When the construction surface computation completion flag is OFF in step S02 (NO in step S02), on the other hand, the determining unit 504 returns to step S01. In step S03, the determining unit 504 checks a correction mode switch. The correction mode switch is provided in the cab 22. This switch is used to determine whether or not to correct an equation for the construction surface TS computed in step S01 through a given correction flow, and is switched ON or OFF by the worker on a necessity basis. When the correction mode switch is ON in step S03, the construction surface computing unit 503 executes a correction computation on the construction surface TS. The correction computation will also be described in detail later. When the correction mode switch is OFF in step S03 or when the correction computation is completed in step S04, the determining unit 504 checks whether an MC start switch is ON (step S05). The MC start switch is a switch for determining whether or not to execute automatic machine control (MC), that is, whether or not to cause the excavator 100 to automatically carry out construction work on the construction surface TS, and is provided in the cab 22. When the MC start switch is ON (YES in step S05), automatic MC is executed, based on the computed construction surface TS (step S06). When the MC start switch is OFF (NO in step S05), on the other hand, it is determined that the worker has an intention to carry out construct work on the construction surface TS by himself or herself, in which case the process flow returns to step S01, and the equation for the construction surface TS, position information, and the like that are computed and determined at preceding step S01 are displayed on the display unit 57. By checking these pieces of information displayed, the work-

er is able to carry out the work by himself or herself while recognizing the position of the construction surface TS.

[0037] The construction surface computation step in step S01 of FIG. 5 will be described more specifically, with reference to FIG. 6. When the construction surface computation step S01 is started, the earth-removing blade coordinates computing unit 502 executes a blade edge coordinates computation (step S11). At this step, the earth-removing blade coordinates computing unit 502 computes absolute coordinates (global coordinates) of the blade edge, i.e., the earth-removing blade left end 41L of the earth-removing blade 41 at the work site, from detection results from the body coordinates detection unit 53 (GNSS reference station 61, GNSS mobile station 62), the body angle detection unit 54, and the earth-removing blade angle detection unit 55. It should be noted that this computation is carried out substantially as real-time computation at given time intervals (e.g., one-second intervals) during execution of the construction surface computation step S01. At this time, the earth-removing blade coordinates computing unit 502 acquires a coordinate vector of the GNSS mobile station 62, from known coordinate of the GNSS reference station 61 and GNSS. The earth-removing blade coordinates computing unit 502 also computes a vector heading from the GNSS mobile station 62 (mobile station origin G1) to a frame origin G2 located at a base end of the support frame 42 of the dozer unit 40 and a vector heading from the GNSS mobile station 62 to the earth-removing blade origin G3 of the earth-removing blade 41, from the specification-defined length of the machine body 10 and rotation angles detected by angle sensors. As a result, this allows the earth-removing blade coordinates computing unit 502 to compute the absolute coordinates of the earth-removing blade left end 41L of the earth-removing blade 41, thus allowing the earth-removing blade coordinates computing unit 502 to acquire absolute coordinates of each reference point when the reference point is input at a step to be executed later.

[0038] When the earth-removing blade coordinates computing unit 502 becomes able to compute the absolute coordinates of the earth-removing blade left end 41L of the earth-removing blade 41, a reference information receiving step is started (step S12 of FIG. 6). As shown in FIG. 7, when the reference information receiving step is started, a request for inputting a number-of-reference-points N is displayed on the display unit 57, and the worker inputs a value for the number-of-reference-points N on the input unit 52 (step S21). The number-of-reference-points N represents the number of reference points (ground reference points) set on the ground. In the case of FIG. 8, N=3 is input because the first reference point P1, the second reference point P2, and the third reference point P3 are prepared in this case.

[0039] Subsequently, an instruction request for setting the first reference point P1 (n=1) is displayed on the display unit 57. Responding to the instruction request, the worker operates the crawler unit 12 and the dozer unit

40 of the excavator 100 to place the earth-removing blade left end 41L of the earth-removing blade 41 at the first reference point P1 of FIG. 8. In other words, the earth-removing blade left end 41L (blade edge) of the earth-removing blade 41 is moved to the first reference point P1 ($n=1$). At this point of time, the worker presses a setting instruction switch (not illustrated) provided on the input unit 52. As a result, a setting instruction to store absolute coordinates of the first reference point P1 is received by the input unit 52 (step S22), and therefore the coordinates of the first reference point P1 are stored in the storage unit 505. At this time, the absolute coordinates of the earth-removing blade left end 41L, the absolute coordinates being computed by the earth-removing blade coordinates computing unit 502, are stored in the storage unit 505 as the absolute coordinates of the first reference point P1 (step S23). Subsequently, a request for inputting depth information (distance information) on the first virtual point Q1 ($n=1$) is displayed on the display unit 57. Responding to the request, the worker confirms the first depth L1 indicated in the vicinity of the first reference point P1, for example, indicated on the first horizontal plate K1, and inputs the value of the first depth L1 to the input unit 52 (step S24). As a result, the depth information on the first virtual point Q1 (first depth L1) is stored in the storage unit 505 (step S25). Subsequently, the determining unit 504 checks the correspondence between the current value of n ($=1$) and the value of the number-of-reference-points N received in step S21 (step S26). In step S26, when $n < N$, that is, $n \neq N$ holds (NO in step S26), 1 is added to the current value of n (step S27), and step S22 and other steps to follow are repeated.

[0040] Specifically, an instruction request for setting the second reference point P2 ($n=2$) is displayed on the display unit 57. Responding to the instruction request, the worker operates the crawler unit 12 and the dozer unit 40 of the excavator 100 to place the earth-removing blade left end 41L of the earth-removing blade 41 at the second reference point P2 of FIG. 8. In other words, the earth-removing blade left end 41L (blade edge) of the earth-removing blade 41 is moved to the second reference point P2 ($n=2$). Steps to follow from this point are the same as those in the case of $n=1$.

[0041] Eventually, $n=N$ holds in step S26 in a case of $n=3$ (YES in step S26), from which the process flow proceeds to step S13 of FIG. 6. Through the above flow of steps, the absolute coordinates of the first reference point P1, second reference point P2, and third reference point P3 at the work site and the values of the first depth L1, second depth L2, and third depth L3 are stored in the storage unit 505.

[0042] In step S13 of FIG. 6, the determining unit 504 determines whether respective absolute coordinates and depth information of the reference points are stored in the storage unit 505. When respective absolute coordinates and depth information of a set of N reference points are stored (YES in step S13), the construction surface computing unit 503 computes the position of a target con-

struction surface (plane equation) (step S14). When the absolute coordinates and depth information of the set of N reference points are not stored in step S13 (NO in step S13), the construction surface computing unit 503 updates the construction surface computation completion flag stored in the storage unit 505 to OFF, and repeats step S11 and other steps to follow.

[0043] In step S14, the construction surface computing unit 503 computes absolute coordinates of the first virtual point Q1, the second virtual point Q2, and the third virtual point Q3 (three specific virtual reference points) that are located respectively below the three specific ground reference points, from the absolute coordinates of the first reference point P1, the second reference point P2, and the third reference point P3 (three specific ground reference points) and the first depth L1, the second depth L2, and the third depth L3 (three pieces of specific distance information). At this time, the depth indicated by the depth information corresponding to the absolute coordinates of each reference point is subtracted from the Z coordinate of each reference point to compute the absolute coordinates of the virtual point corresponding to the reference point. The construction surface computing unit 503 then computes an equation for a plane passing through the computed three specific virtual reference points, as an equation for the construction surface TS.

[0044] A process by which the construction surface computing unit 503 computes the equation for the construction surface TS in step S14 of FIG. 6, based on the first virtual point Q1, the second virtual point Q2, and the third virtual point Q3, will be described with reference to FIG. 9. It should be noted that in the case of $N=3$, the equation for the construction surface TS is equivalent to the equation for the plane passing through all of the first virtual point Q1, the second virtual point Q2, and the third virtual point Q3.

[0045] As shown in FIG. 9, when a construction surface TS passing through Q1, Q2, and Q3 is assumed, taking the outer product of a vector $Q1 \cdot Q2$ and a vector $Q1 \cdot Q3$ yields a normal vector (α, β, γ) normal to each of these two vectors $Q1 \cdot Q2$ and $Q1 \cdot Q3$. When an equation for the construction surface TS is defined as $AX+BY+CZ+D=0$, the above vector elements α , β , and γ correspond to A, B, and C, respectively. Substituting α , β , and γ in A, B, and C of the equation for the construction surface TS, respectively, and substituting one of respective coordinates of Q1, Q2, and Q3 in X, Y, and Z, therefore, gives a coefficient D. Hence A, B, C, and D are all given as known values, and the equation for the construction surface TS is obtained. It should be noted that a method of computing the equation for the construction surface TS is not limited to the above method and that other known methods, such as a method using simultaneous equations, can also be used.

[0046] When the construction surface computing unit 503 computes and determines the equation for the construction surface TS in step S14 of FIG. 6, the earth-removing blade coordinates computing unit 502 com-

putes the current absolute coordinates of the earth-removing blade left end 41L of the earth-removing blade 41 (step S15). In other words, the earth-removing blade coordinates computing unit 502 computes a relative position of the earth-removing blade left end 41L (blade edge) to the construction surface TS. Then, the construction surface computing unit 503 updates the construction surface computation completion flag in the storage unit 505 to ON (step S16). Thereafter, the process flow proceeds to step S02 of FIG. 5, from which steps S03 to S06 are executed in the manner described above.

[0047] Next, a correction computation process executed in step S04 of FIG. 5 will be described. The worker is able to check whether the position information on the construction surface TS (plane equation) computed in step S01 is correct. In other words, the worker is able to check whether the computed construction surface TS is within a given error range. As an example, a case is assumed where a finishing stake for checking that is similar to those shown in FIG. 8 is additionally set at the work site. In this case, the horizontal plate of the finishing stake for checking is provided with a fourth reference point (ground reference point for checking) associated with the construction surface TS, and depth information indicating the distance from the fourth reference point to the construction surface TS (distance in the vertical direction) is noted on the horizontal plate as a known value.

[0048] Through the same flow of steps as shown in FIG. 7, absolute coordinates and depth information (distance information) of the ground reference point for checking are stored in the storage unit 505. From these absolute coordinates and depth information, the construction surface computing unit 503 computes absolute coordinates of a virtual reference point for checking located below the ground reference point for checking. Then, the determining unit 504 determines whether the equation for the construction surface TS is within the given **allowable range**, based on the computed absolute coordinates of the virtual reference point for checking and on the equation for the construction surface TS computed by the construction surface computing unit 503 in step S01. At this time, the determining unit 504 determines that the equation for the construction surface TS is within the given allowable range when the distance between the virtual reference point for checking and the construction surface TS is smaller than a preset threshold, and determines that the equation for the construction surface TS is not within the given allowable range when the distance between the virtual reference point for checking and the construction surface TS is larger than the preset threshold. In the latter case, the output unit 506 may present information indicating a problem with the equation for the construction surface TS, to the worker, using the display unit 57 or the informing unit 58. When coordinates of the virtual reference point for checking are (XP, YP, ZP), the distance ΔL between the construction surface TS and the virtual reference point for checking is given as $\Delta L = (A \times XP + B \times YP + C \times ZP + D) / \sqrt{A^2 + B^2 + C^2}$.

[0049] When it is determined that the equation for the construction surface TS is within the given allowable range, correcting the equation for the construction surface TS is unnecessary, in which case the process flow proceeds from step S04 to step S05 of FIG. 5. When it is determined that the equation for the construction surface TS is not within the given allowable range, on the other hand, the equation for the construction surface TS is corrected by the prescribed computation. In an exemplary case, the equation for the construction surface TS is computed again, based on four virtual points set by adding the above virtual reference point for checking to the first virtual point Q1, the second virtual point Q2, and the third virtual point Q3. In this case, the construction surface computing unit 503 determines a known mean square plane, based on the absolute coordinates of the four virtual points, and defines the mean square plane as the corrected construction surface TS.

[0050] One example of a method of calculating the mean square plane is the following method. The equation for the construction surface TS is computed in such a way as to minimize the sum of squares of respective distances from the four virtual points to the construction surface TS. When it is assumed, as described above, that the coefficients of X, Y, and Z in the equation expressing the construction surface TS are A, B, and C, respectively, parameter values for A, B, and C are computed in such a way as to minimize the sum of squares of respective distances from the four virtual points. When the sum of squares of respective distances L_i from the four virtual points is defined as F, F is expressed as $F = \sum (L_i)^2$. Partially differentiating both sides of $F = \sum (L_i)^2$ yields three-dimensional simultaneous equations, from which A, B, and C can be determined. To obtain each of A, B, and C as a unit vector, a precondition $A^2 + B^2 + C^2 = 1$ needs to be met. As solutions to the above equations, the LU decomposition using known matrices, the Lagrange undetermined constant method, or the like may be adopted.

[0051] It should be noted that the above method of determining the equation for the construction surface TS based on the four virtual points is not limited to the correction computation step but may be adopted at the construction surface computation step in step S01. Specifically, step S01 is not limited to the step of computing and determining the construction surface TS based on the three ground reference points and distance information but may be a step of computing and determining the construction surface TS based on four or more ground reference points and distance information. In this case, by increasing the number of reference points, a delicate setting error that is made at the time of blade edge setting can be canceled.

[0052] In the embodiment, after the construction surface TS is computed and determined, the worker is able to check a positional relationship between the construction surface TS and the earth-removing blade 41 before excavating the ground with the earth-removing blade 41 of the excavator 100. FIG. 10 is a side sectional view of

the work site for the excavator 100 including the construction surface setting device 1 according to the embodiment. FIG. 11 is a perspective view of the work site for the excavator 100 including the construction surface setting device 1 according to the embodiment.

[0053] As an example, a finishing stake for checking is placed on the rear side (this side) in the direction of traveling of the excavator 100 at the work site, as shown in FIG. 10. The finishing stake has a fourth vertical plate J4 and a fifth vertical plate J5 that are set in a vertically standing position at an interval in the front-to-rear direction, and a fourth horizontal plate K4 and a slant plate K5 that are set in such a way as to bridge the two vertical plates. The fourth horizontal plate K4 is set horizontally, and the slant plate K5 is set in such a way as to slant toward the rear end of the construction surface TS. A fourth depth L4, which is the distance from the fourth horizontal plate K4 to the construction surface TS in the vertical direction, is known, and is noted, for example, on a side surface of the fourth horizontal plate K4. Such a finishing stake is set at a work site as a conventional practice. The worker performs excavation work on the construction surface TS, using the slant of the worker and the slant plate K5 as a yardstick for determining how to proceed with the work. As described above, in a conventional work site to which the present invention is not applied, the worker does not recognize the position of the construction surface TS.

[0054] In the embodiment, as shown in FIG. 11, a plurality of construction surface virtual strings FL (reference members for checking) are stretched between a plurality of vertical plates J arranged to surround the construction surface TS at the work site. Unlike a conventional leveling string stretched horizontally, the construction surface virtual strings FL are stretched parallel with the construction surface TS, and the distance from each construction surface virtual string FL to the construction surface TS is determined to be a known fifth depth L5. Among the construction surface virtual strings FL shown in FIG. 11, a construction surface virtual string FL located on the rear end side is stretched in such a way as to be perpendicular to the traveling direction DS of the excavator 100 in a plan view. The finishing stake shown in FIG. 10 is shown in FIG. 11 as the finishing stake located on the right side of the rear end of the work site.

[0055] In a state where the construction surface TS is computed and determined in advance based on the above flow of steps, the worker operates the excavator 100 to match the lower end part 41S of the earth-removing blade 41 to the construction surface virtual string FL on this side in the traveling direction DS, as shown in FIG. 11. In other words, the earth-removing blade left end 41L and earth-removing blade right end 41R of the earth-removing blade 41 are placed on the construction surface virtual string FL. In this state, when the worker presses a switch for confirming the construction surface TS (not illustrated), the switch being disposed in the cab 22, the determining unit 504 computes distances be-

tween the earth-removing blade left end 41L/the earth-removing blade right end 41R of the earth-removing blade 41 and the construction surface TS, respectively, and compares computed two distances to check their size relationship. When a difference between the two distances is equal to or less than a preset threshold, a positional relationship between the construction surface TS and the earth-removing blade 41, the positional relationship being computed through the above flow of steps, is set correctly, in which case, in the state shown in FIG. 11, the worker operates the excavator 100 to cause the earth-removing blade 41 to dig into the ground, thus accurately performing excavation work on the construction surface TS. When the difference between the compared two distances is larger than the threshold, on the other hand, placement of the earth-removing blade 41 or the position of the construction surface TS (equation) is problematic. In this case, therefore, the output unit 506 outputs information on the problem, which is presented to the worker through the display unit 57 and the informing unit 58. This allows checking the traveling direction of the machine body 10 and offsetting an error of each angle sensor by detecting the horizontal.

[0056] According to the embodiment, when the worker starts operating the excavator 100 from the state shown in FIG. 11 and performs excavation work by the earth-removing blade 41, an excavation angle θ of the earth-removing blade 41 against the construction surface TS is computed and displayed on the display unit 57, as shown in FIG. 10. Because the absolute coordinates (plane equation) of the construction surface TS are known in step S01 and the earth-removing blade coordinates computing unit 502 can calculate the absolute coordinates of the earth-removing blade right end 41R and the earth-removing blade left end 41L of the earth-removing blade 41, the excavation angle θ of FIG. 10 can be computed, based on a positional relationship between the construction surface TS and the earth-removing blade 41. It should be noted that placing the earth-removing blade left end 41L and the earth-removing blade right end 41R of the earth-removing blade 41 along the construction surface virtual string FL in the above manner may be used as a method of correcting a yaw angle that is apt to be affected by a drifting motion.

[0057] As described above, according to the embodiment, the earth-removing blade coordinates computing unit 502 can compute and output the absolute coordinates of the earth-removing blade left end 41L (specific part) of the earth-removing blade 41 at the work site, based on the coordinates information (body coordinates information) on the machine body 10 acquired by the body coordinates detection unit 53, on the orientation information (body orientation information) of the machine body 10 acquired by the body angle detection unit 54, and on the position information (work member position information) on the earth-removing blade 41 acquired by the earth-removing blade angle detection unit 55. When the earth-removing blade left end 41L is placed at each

ground reference point in order and the input unit 52 receives placement information on the earth-removing blade left end 41L, the storage unit 505 can store the absolute coordinates of the earth-removing blade left end 41L, the absolute coordinates being computed by the earth-removing blade coordinates computing unit 502, as the absolute coordinates of each ground reference point. The input unit 52 (distance information input unit) receives depth information (distance information) on each ground reference point, the depth information indicating the distance from each ground reference point to the construction surface TS. As a result, the construction surface computing unit 503 can compute an equation for the construction surface TS in an absolute coordinate system of the work site, from the absolute coordinates of each ground reference point and the distance information corresponding to the absolute coordinates. The worker thus sets each ground reference point, using finishing stakes, leveling strings, and the like usually provided in the work site, places the earth-removing blade left end 41L of the excavator 100 at each ground reference point in order, and inputs the distance information on the distance from each ground reference point to the construction surface TS, to the input unit 52. By merely carrying out these operations, the worker is able to easily obtain the equation for the construction surface TS at the work site and to easily recognize the position of the construction surface TS, based on the information output by the output unit 506. In addition, receiving information including enormous data, such as 3D data of the work site, from external equipment or storing the above-mentioned information in the storage unit 505 in advance is unnecessary, which prevents complication in configuration of the construction surface setting device 1 and suppresses an increase in the cost of the construction surface setting device 1.

[0058] In the embodiment, the construction surface computing unit 503 computes absolute coordinates of the virtual reference points located respectively below the ground reference points, from the absolute coordinates of the ground reference points and the distance information, and computes the equation for the construction surface TS, based on the computed absolute coordinates of the virtual reference points. According to such a configuration, based on the absolute coordinates of the virtual reference points set virtually in the ground, the construction surface computing unit 503 can easily compute the equation for the construction surface TS according to a plane equation computing method.

[0059] In the embodiment, the construction surface computing unit 503 computes the absolute coordinates of three virtual reference points (specific virtual reference points) located respectively below three ground reference points (specific ground reference points), and computes an equation for a plane passing through the computed three virtual reference points, as the equation for the construction surface TS. Based on the three virtual reference points, therefore, the equation for the construc-

tion surface TS can be computed easily in a short time.

[0060] However, as described above, the construction surface computing unit 503 may compute the absolute coordinates of four virtual reference points (specific virtual reference points) and compute an equation for a least square plane based on the computed four virtual reference points, as the equation for the construction surface TS. According to such a configuration, the equation for the construction surface TS can be computed with higher accuracy, based on the four virtual reference points. It should be noted that the position information (plane equation) of the construction surface TS may be computed and determined based on five or more ground reference points (virtual reference points).

[0061] In the embodiment, the construction surface computing unit can compute absolute coordinates of at least one virtual reference point for checking located below at least one ground reference point for checking, from absolute coordinates of the at least one ground reference point for checking and at least one piece of distance information for checking. The determining unit 504 determines whether the equation for the construction surface TS is within the given allowable range, based on the computed absolute coordinates of the virtual reference point for checking and on the equation for the construction surface TS, the equation being computed by the construction surface computing unit 503. According to such a configuration, the worker places the earth-removing blade left end 41L of the excavator 100 at the ground reference point for checking and inputs the distance information for checking to the input unit 52. The worker's merely carrying out these operations allows the determining unit 504 to determine the accuracy of the equation for the construction surface TS, based on the equation for the construction surface TS having been computed and on the absolute coordinates of the virtual reference point for checking. This, therefore, prevents a case where an error in excavation and ground leveling work occurs at the work site because of the erroneously computed equation for the construction surface TS. In addition, the worker is able to start the work after sufficiently confirming the accuracy of the computed equation for the construction surface.

[0062] In the embodiment, the body angle detection unit 54 includes a body angle sensor that detects and outputs a lift angle, a pitch angle, and a yaw angle of the machine body 10 with respect to the body reference point on the cab 22, as orientation information on the machine body 10. The body coordinates detection unit 53 acquires coordinate information on the machine body 10, using the global positioning satellite system. According to such a configuration, even in an environment in which a shielding object is present around the excavator 100, position information and the orientation information on the machine body 10 can be detected.

[0063] In the embodiment, information displayed on the display unit 57 allows the worker to easily recognize the position of the construction surface TS and to accu-

rately perform work while recognizing the relative positional relationship between the construction surface TS and the earth-removing blade 41 from the information displayed on the display unit.

[0064] In the embodiment, the earth-removing blade 41 of the dozer unit 40 of the excavator 100 is used as a reference for computing the absolute coordinates of each ground reference point. According to such a configuration, the worker can easily recognize the equation and position information of the construction surface TS by operating the excavator 100 to place the earth-removing blade 41 at each ground reference point. In particular, when the earth-removing blade 41 of the dozer unit 40 located in advance at a position lower than the attachment 30 is used, the ground reference point (finishing stake, etc.) set at the work site can also be located at a lower position, in which case the height of a member provided to set the ground reference point can be kept low.

[0065] In the embodiment, the earth-removing blade angle detection unit 55 includes the earth-removing blade angle sensor capable of detecting and outputting a lift angle about the lift rotating shaft F1 of the earth-removing blade 41, as position information (work member position information) on the earth-removing blade 41. According to such a configuration, by adjusting the lift angle of the earth-removing blade 41 in addition to adjusting traveling of the crawler unit 12, the worker can easily place the earth-removing blade 41 of the excavator 100 at each ground reference point.

[0066] In the embodiment, the above earth-removing blade angle sensor can detect and output also a tilt angle about the tilt rotating shaft F3 of the earth-removing blade 41, as the position information on the earth-removing blade 41. According to such a configuration, because the earth-removing blade angle sensor can detect the tilt angle of the earth-removing blade 41, the worker can easily place the earth-removing blade 41 of the excavator 100 at the ground reference point by adjusting the lift angle of the earth-removing blade 41, in addition to adjusting the traveling of the crawler unit 12 and the lift angle as well. The earth-removing blade angle sensor can detect and output also an angular angle about the angular rotating shaft F2 of the earth-removing blade 41. This allows the worker to tilt the earth-removing blade 41 against the horizontal direction. It is therefore possible that, as shown in FIG. 11, the earth-removing blade 41 is placed along the construction surface virtual string FL stretched slantly above the ground to perform work of checking the construction surface TS.

[0067] In the embodiment, through the above flow of steps, the worker is able to recognize the position of the construction surface TS at the work site. A method of recognizing a construction surface at a work site according to the embodiment is a method of recognizing a construction surface at a work site, the method including: preparing a work machine including a machine body having a traveling unit capable of traveling on the ground

and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body, the work member being capable of excavating the ground, and preparing the above work assist device of the work machine as well; placing the specific part of the work member in order at the at least three ground reference points associated with the construction surface, according to at least traveling of the traveling unit and storing absolute coordinates of the specific part in the storage unit as absolute coordinates of each of the ground reference points, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit in correspondence to each of the ground reference points; inputting at least three pieces of distance information to the distance information input unit, the distance information indicating a distance from each of the at least three ground reference points to the construction surface in the vertical direction; computing an equation for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit; and outputting information on the equation for the construction surface computed by the construction surface computing unit, and, based on the output information, allowing a worker to recognize a position of the construction surface at the work site.

[0068] According to this method, the worker sets each ground reference point, using finishing stakes, leveling strings, and the like usually provided in the work site, places the specific part of the work machine at each ground reference point in order, and inputs the distance information on the distance from each ground reference point to the construction surface, to the input unit, and by merely carrying out these operations, the worker is able to easily obtain the equation for the construction surface at the work site and to easily recognize the position of the construction surface, based on the information output by the construction surface information output unit. In addition, receiving information including enormous data, such as 3D data of the work site, from external equipment or storing the above-mentioned information in the storage unit in advance is unnecessary, which prevents complication in configuration of the work assist device and suppresses an increase in the cost of the work assist device.

[0069] A method of recognizing a construction surface at a work site according to the embodiment is a method of recognizing a construction surface at a work site, the method including: preparing a work machine including a machine body having a traveling unit capable of traveling on the ground and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body, the work member being capable of excavating the ground, and preparing the above work assist device of the work machine as well;

placing the specific part of the work member in order at the at least three ground reference points associated with the construction surface, according to at least traveling of the traveling unit and storing absolute coordinates of the specific part in the storage unit as absolute coordinates of each of the ground reference points, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit in correspondence to each of the ground reference points; inputting at least three pieces of distance information to the distance information input unit, the distance information indicating a distance from each of the at least three ground reference points to the construction surface in the vertical direction; computing an equation for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit; outputting information on the equation for the construction surface computed by the construction surface computing unit and, based on the output information, allowing a worker to recognize a position of the construction surface at the work site; providing the work site with a reference member for checking including a straight part that is parallel to the construction surface and that is perpendicular to a direction of traveling of the traveling body of the work machine in a plan view; operating the work machine to align a lower end part of an earth-removing blade, the lower end part extending in a left-to-right direction, with the straight part of the reference member for checking; and comparing a distance from a left end of the lower end part of the earth-removing blade to the construction surface with a distance from a right end of the lower end part of the same to the construction surface to check whether the computed equation for the construction surface is within a given range.

[0070] According to this method, when the worker aligns the earth-removing blade with the reference member for checking and finds that respective distances from the left and right ends of the earth-removing blade to the construction surface are equal to each other with a margin of error within a given error range, the earth-removing blade and the construction surface are parallel to each other. The worker thus causes the earth-removing blade to dig into the ground without making any adjustment, and is able to perform excavation work on the construction surface in stable manner.

[0071] The construction surface setting device 1 according to the present invention, the excavator 100 including the construction surface setting device 1, and the method of recognizing the construction surface at the work site have been described above. The present invention is not limited to these device, excavator, and method, and may be implemented as the following modifications.

[0072] (1) According to the above embodiment, the earth-removing blade left end 41L of the earth-removing

blade 41 is defined as the specific part. The specific part, however, may be the earth-removing blade right end 41R or a central part of the earth-removing blade 41. In addition, the absolute coordinates of each reference point may be computed based not on the earth-removing blade 41 but on a specific part of the attachment 30 (e.g., a part of the bucket at the front end of the attachment 30).

[0073] (2) Instead of specifying the ground reference position by the specific part of the machine body 10, the worker may input coordinates of the ground reference position directly to the input unit 52 in a state where the GNSS mobile station 62 is disposed at a position that should be stored. In this case, the worker presses a storage instruction switch (not illustrated) disposed in the cab 22 to send coordinates of the position of the GNSS mobile station 62 to the controller 50.

[0074] (3) A place where the ground reference point is set may be any place whose height from the construction surface TS (virtual reference point) is known at the work site, such as the top of the vertical plate of the finishing stake, the top surface or bottom surface of the horizontal plate, a reference line drawn on the horizontal plate, and the leveling string stretched between the finishing stakes. By matching the specific part of the earth-removing blade 41 to the ground reference point set in such a place, the worker is able to carry out more understandable positioning of the earth-removing blade 41. It is desirable, in particular, that the ground reference point be set at a position that the worker in the cab 22 can visually recognize easily.

[0075] (4) The locations of the ground reference points are not limited to the periphery of a space above the construction surface TS, and may be outside the construction area. Using finishing stakes placed outside the construction area as the reference points allows computing and determining the construction surface TS using only the same finishing stakes as conventional finishing stakes, in which case enormous 3D shape data indicating the topography of the work site or the like is no longer necessary.

[0076] (5) In the above embodiment, the body coordinates detection unit 53 includes the GNSS reference station 61 and the GNSS mobile station 62. The body coordinates detection unit 53, however, may acquire body coordinates information that is information on absolute coordinates of the body reference point at the work site, the body reference point being set in advance on the machine body 10, using a total station. As an example, a master unit equipped with a camera capable of measuring a distance and an angle is installed at a work site in place of the GNSS reference station 61, and a slave unit including a prism of which an image is captured by the camera is attached to the excavator 100 in place of the GNSS mobile station 62. According to such a configuration, the body coordinates information can be detected accurately, and can be detected even at a work site with its above space blocked, such as a work site in a tunnel.

[0077] (6) In the above embodiment, as shown in FIG.

3, the work member position information that is the information on the relative position of the dozer unit 40 (earth-removing blade 41) to the machine body 10 is acquired through the relative position information on the earth-removing blade 41, the relative position information being based on the origin G3, x3 axis, y3 axis, and z3 axis detected by the earth-removing blade angle detection unit 55, with respect to the coordinates of the machine body 10, the coordinates being referenced to the origin G1, x1 axis, y1 axis, and z1 axis set by the GNSS mobile station 62. However, the form of acquisition of the work member position information is not limited to this in the present invention. As shown in FIG. 3, a relay point based on the origin G2, x2 axis, y2 axis, and z2 axis may be set on the base end of the dozer unit 40, and the work member position information, which is the information on the relative position of the dozer unit 40 (earth-removing blade 41) to the machine body 10, may be acquired via the relay point. The GNSS mobile station 62 may be disposed directly on the base end of the dozer unit 40.

[0078] A work assist device of a work machine according to one aspect of the present invention, the work assist device being devised in view of the above problem, is a work assist device of a work machine including: a machine body having a traveling unit capable of traveling on the ground; and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body, the work member being capable of excavating the ground. The work assist device is configured to assist in work of forming, by the work machine, a given construction surface on a work site. The work assist device includes: a body coordinates information acquiring unit that can acquire body coordinates information that is information on absolute coordinates of a body reference point at the work site, the body reference point being set on the machine main body in advance; a body orientation information acquiring unit that can acquire body orientation information that is information on an orientation of the machine body with respect to the body reference point; a work member position information acquiring unit that can acquire work member position information that is information on a relative position of the work member to the machine body; a specific part coordinates computing unit that can compute and output absolute coordinates of a specific part of the work member at the work site, based on the body coordinates information acquired by the body coordinates information acquiring unit, on the body orientation information acquired by the body orientation position information acquiring unit, and on the work member position information acquired by the work member position information acquiring unit; a placement information receiving unit that can receive pieces of placement information that is information indicating that the specific part of the work member is placed at least at three ground reference points associated with the construction surface; a storage unit that stores absolute coordinates of the specific part as absolute coordinates of the at least

three ground reference points at the work site, respectively, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit in correspondence to the placement information receiving unit's receiving the placement information at the at least three ground reference points; a distance information input unit that can receive input of at least three pieces of distance information that is information indicating a distance from each of the at least three ground reference points to the construction surface in a vertical direction; a construction surface computing unit that computes an equation for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit, and a construction surface information output unit that outputs information on the equation for the construction surface computed by the construction surface computing unit.

[0079] According to this configuration, the construction surface computing unit can compute the equation for the construction surface in the absolute coordinate system of the work site, from the absolute coordinates of each ground reference point and the distance information corresponding to the absolute coordinates. The worker thus sets each ground reference point, places the specific part at each ground reference point in order, and inputs the distance information on the distance from each ground reference point to the construction surface, to the input unit. By merely carrying out these operations, the worker is able to easily obtain the equation for the construction surface at the work site and to easily recognize the position of the construction surface, based on the information output by the construction surface information output unit. In addition, receiving information including enormous data, such as 3D data of the work site, from external equipment or storing the above-mentioned information in the storage unit in advance is unnecessary, which prevents complication in configuration of the work assist device and suppresses an increase in the cost of the work assist device. The worker may set the ground reference points using finishing stakes, leveling strings, and the like conventionally used at the work site.

[0080] In the above configuration, it is desirable that the construction surface computing unit compute absolute coordinates of at least three virtual reference points located respectively below the at least three ground reference points, from the absolute coordinates of the at least three ground reference points and the at least three pieces of distance information and compute the equation for the construction surface, based on the computed absolute coordinates of the at least three virtual reference points.

[0081] According to this configuration, based on the absolute coordinates of three or more virtual reference points set virtually in the ground, the construction surface computing unit can easily compute the equation for the

construction surface according to a plane equation computing method.

[0082] In the above configuration, it is preferable that the at least three ground reference points include three specific ground reference points, that the distance information input unit receive input of three pieces of specific distance information indicating a distance from each of the three specific ground reference points to the construction surface in the vertical direction, and that the construction surface computing unit compute absolute coordinates of three specific virtual reference points located respectively below the three specific ground reference points, from the absolute coordinates of the three specific ground reference points and the three pieces of specific distance information and compute an equation for a plane passing through the computed three specific virtual reference points, as the equation for the construction surface.

[0083] According to this configuration, the equation for the construction surface can be computed easily in a short time, based on the three specific virtual reference points.

[0084] In the above configuration, the at least three ground reference points may include at least four specific ground reference points, that the distance information input unit receive input of at least four pieces of specific distance information indicating a distance from each of the at least four specific ground reference points to the construction surface in the vertical direction, and that the construction surface computing unit compute absolute coordinates of at least four specific virtual reference points located respectively below the at least four specific ground reference points, from the absolute coordinates of the at least four specific ground reference points and the at least four pieces of specific distance information and compute an equation for a least-square plane based on the computed at least four specific virtual reference points, as the equation for the construction surface.

[0085] According to this configuration, the equation for the construction surface can be computed with higher accuracy, based on the four or more specific virtual reference points.

[0086] In the above configuration, it is desirable that the placement information receiving unit be able to further receive placement information for checking indicating that the specific part is placed on the at least one ground reference point for checking associated with the construction surface according to traveling of the traveling unit, that the storage unit be able to store absolute coordinates of the specific part as absolute coordinates of the at least one ground reference point for checking at the work site, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit, in correspondence to the placement information receiving unit's receiving the placement information for checking, that the distance information input unit be able to receive input of at least one piece of distance information for checking that is information indicating a distance

from the at least one ground reference point for checking to the construction surface in the vertical direction, that the construction surface computing unit be able to compute absolute coordinates of at least one virtual reference point for checking located below the at least one ground reference point for checking, from the absolute coordinates of the at least one ground reference point for checking and the at least one piece of distance information for checking, and that the work assist device further includes a determining unit that determines whether the equation for the construction surface is within a given allowable range, based on the computed absolute coordinates of the virtual reference point for checking and on the equation for the construction surface computed in advance by the construction surface computing unit.

[0087] According to this configuration, the worker places the specific part of the work machine at the ground reference point for checking and inputs the distance information for checking to the distance information input unit, and the worker's merely carrying out these operations allows the determining unit to determine the accuracy of the equation for the construction surface, based on the equation for the construction surface having been computed and on the absolute coordinates of the virtual reference point for checking. This allows the worker to start the work after sufficiently confirming the accuracy of the computed equation for the construction surface.

[0088] In the above configuration, it is desirable that the body orientation information acquiring unit includes a body angle sensor that detects and outputs a lift angle, a pitch angle, and a yaw angle of the machine body with respect to the body reference point, as the body orientation information. It is also desirable that the body coordinates information acquiring unit acquire the body coordinates information, using the global positioning satellite system or the total station.

[0089] In the above configuration, it is desirable that the work assist device further includes a display unit capable of displaying information on the equation for the construction surface, the information being output from the construction surface information output unit.

[0090] According to this configuration, the worker can easily recognize the position of the construction surface by the information displayed on the display unit.

[0091] In the above configuration, it is desirable that the display unit be able to display also information on a relative position between the construction surface and the specific part, based on the absolute coordinates of the specific part output from the specific part coordinates computing unit.

[0092] According to this configuration, the worker is able to accurately perform the work while recognizing a relative positional relationship between the construction surface and a work member by referring to the information displayed on the display unit.

[0093] In the above configuration, it is preferable that the work member of the work machine includes an earth-removing blade and an earth-removing blade support

supporting the earth-removing blade, the earth-removing blade support being supported by the machine body in such a way as to be capable of swinging about a lift rotating shaft extending in the left-to-right direction, and that the specific part coordinates computing unit be able to compute and output absolute coordinates of a specific part of the earth-removing blade, as a specific part of the work member at the work site.

[0094] According to this configuration, the worker can easily recognize the position of the construction surface by operating the work machine to place the earth-removing blade at each ground reference point.

[0095] In the above configuration, it is desirable that the work member position information acquiring unit includes an earth-removing blade angle sensor capable of detecting and outputting a lift angle about the lift rotating shaft of the earth-removing blade, as the work member position information.

[0096] According to this configuration, because the work member position information acquiring unit includes the earth-removing blade angle sensor, the worker can easily place the earth-removing blade of the work machine at the ground reference point by adjusting the lift angle of the earth-removing blade, in addition to adjusting traveling of the traveling unit.

[0097] In the above configuration, it is preferable that the earth-removing blade of the work member be supported by the earth-removing blade support in such a way as to be capable of swinging about a tilt rotating shaft extending in the left-to-right direction, and that the earth-removing blade angle sensor be able to detect and output also a tilt angle about the tilt rotating shaft of the earth-removing blade, as the work member position information.

[0098] According to this configuration, because the earth-removing blade angle sensor can detect the tilt angle of the earth-removing blade, the worker can easily place the earth-removing blade of the work machine at the ground reference point by adjusting the lift angle of the earth-removing blade, in addition to adjusting traveling of the traveling unit and the lift angle as well.

[0099] A method of recognizing a construction surface at a work site according to another aspect of the present invention is a method of recognizing a construction surface at a work site, the method including: preparing a work machine including a machine body having a traveling unit capable of traveling on the ground and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body, the work member being capable of excavating the ground, and preparing the work assist device of the work machine as well; placing the specific part of the work member in order at the at least three ground reference points associated with the construction surface, according to at least traveling of the traveling unit and storing absolute coordinates of the specific part in the storage unit as absolute coordinates of each of the ground reference points, the absolute coordinates of the specific part

being computed by the specific part coordinates computing unit in correspondence to each of the ground reference points; inputting at least three pieces of distance information to the distance information input unit, the distance information indicating a distance from each of the at least three ground reference points to the construction surface in the vertical direction; computing an equation for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit; and outputting information on the computed equation for the construction surface and, based on the output information, allowing a worker to recognize a position of the construction surface at the work site.

[0100] According to this method, the worker sets each ground reference point, places the specific part of the work machine at each ground reference point in order, and inputs the distance information on the distance from each ground reference point to the construction surface, to the input unit, and by merely carrying out these operations, the worker is able to easily obtain the equation for the construction surface at the work site and to easily recognize the position of the construction surface, based on the information output by the construction surface information output unit. In addition, receiving information including enormous data, such as 3D data of the work site, from external equipment or storing the above-mentioned information in the storage unit in advance is unnecessary, which prevents complication in configuration of the work assist device and suppresses an increase in the cost of the work assist device.

[0101] A method of recognizing a construction surface at a work site according to still another aspect of the present invention is a method of recognizing a construction surface at a work site, the method including: preparing a work machine including a machine body having a traveling unit capable of traveling on the ground and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body, the work member being capable of excavating the ground, and preparing the above work assist device of the work machine as well; placing the specific part of the work member in order at the at least three ground reference points associated with the construction surface, according to at least traveling of the traveling unit and storing absolute coordinates of the specific part in the storage unit as absolute coordinates of each of the ground reference points, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit in correspondence to each of the ground reference points; inputting at least three pieces of distance information to the distance information input unit, the distance information indicating a distance from each of the at least three ground reference points to the construction surface in the vertical direction; computing an equation

for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit; outputting information on the equation for the construction surface computed by the construction surface computing unit and, based on the output information, allowing a worker to recognize a position of the construction surface at the work site; providing the work site with a reference member for checking including a straight part that is parallel to the construction surface and that is perpendicular to a direction of traveling of the traveling body of the work machine in a plan view; operating the work machine to align a lower end part of the earth-removing blade, the lower end part extending in the left-to-right direction, with the straight part of the reference member for checking; and comparing a distance from a left end of the lower end part of the earth-removing blade to the construction surface with a distance from a right end of the lower end part of the same to the construction surface to check whether the computed equation for the construction surface is within a given range.

[0102] According to this method, by merely aligning the earth-removing blade with the reference member for checking, the worker is able to check the accuracy of the equation for the construction surface, from a relative positional relationship between the earth-removing blade and the construction surface. When the worker finds that respective distances from the left and right ends of the earth-removing blade to the construction surface are equal to each other with a margin of error within a given error range, the worker causes the earth-removing blade to dig into the ground without making any adjustment, and is able to perform excavation work on the construction surface in stable manner.

[0103] The present invention provides a work assist device of a work machine and a method of recognizing a construction surface at a work site, the work assistance device and the method allowing a worker to easily recognize a construction surface without the need of receiving 3D data unique to a work site from an external device or storing the 3D data in advance.

Claims

1. A work assist device of a work machine including: a machine body having a traveling unit capable of traveling on a ground; and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body and configured to excavate the ground, the work assist device being configured to assist in work of forming, by the work machine, a given construction surface on a work site, and the work assist device comprising:

a body coordinates information acquiring unit configured to acquire body coordinates information that is information on absolute coordinates of a body reference point at the work site, the body reference point being set on the machine body in advance;

a body orientation information acquiring unit configured to acquire body orientation information that is information on an orientation of the machine body with respect to the body reference point;

a work member position information acquiring unit configured to acquire work member position information that is information on a relative position of the work member to the machine body; a specific part coordinates computing unit configured to compute and output absolute coordinates of a specific part of the work member at the work site, based on the body coordinates information acquired by the body coordinates information acquiring unit, on the body orientation information acquired by the body orientation information acquiring unit, and on the work member position information acquired by the work member position information acquiring unit;

a placement information receiving unit configured to receive pieces of placement information that is information indicating that the specific part of the work member is placed at least at three ground reference points associated with the construction surface according to at least traveling of the traveling unit;

a storage unit that stores absolute coordinates of the specific part as absolute coordinates of the at least three ground reference points at the work site, respectively, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit in correspondence to the placement information receiving unit's receiving the placement information at the at least three ground reference points;

a distance information input unit configured to receive input of at least three pieces of distance information that is information indicating a distance from each of the at least three ground reference points to the construction surface in a vertical direction;

a construction surface computing unit that computes an equation for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit; and a construction surface information output unit that outputs information on the equation for the construction surface computed by the construc-

tion surface computing unit.

2. The work assist device of the work machine, according to claim 1, wherein the construction surface computing unit computes absolute coordinates of at least three virtual reference points located respectively below the at least three ground reference points, from the absolute coordinates of the at least three ground reference points and the at least three pieces of distance information, and computes the equation for the construction surface, based on the computed absolute coordinates of the at least three virtual reference points.

3. The work assist device of the work machine, according to claim 2, wherein

the at least three ground reference points include three specific ground reference points, the distance information input unit receives input of three pieces of specific distance information indicating a distance from each of the three specific ground reference points to the construction surface in a vertical direction, and the construction surface computing unit computes absolute coordinates of three specific virtual reference points located respectively below the three specific ground reference points, from the absolute coordinates of the three specific ground reference points and the three pieces of specific distance information, and computes an equation for a plane passing through the computed three specific virtual reference points, as the equation for the construction surface.

4. The work assist device of the work machine, according to claim 2, wherein

the at least three ground reference points include at least four specific ground reference points, the distance information input unit receives input of at least four pieces of specific distance information indicating a distance from each of the at least four specific ground reference points to the construction surface in a vertical direction, and the construction surface computing unit computes absolute coordinates of at least four specific virtual reference points located respectively below the at least four specific ground reference points, from the absolute coordinates of the at least four specific ground reference points and the at least four pieces of specific distance information, and computes an equation for a least-square plane based on the computed at least four specific virtual reference points, as the equation for the construction surface.

5. The work assist device of the work machine, according to any one of claims 1 to 4, wherein

the placement information receiving unit is configured to further receive placement information for checking indicating that the specific part is placed on the at least one ground reference point for checking associated with the construction surface according to traveling of the traveling unit,

the storage unit is configured to store absolute coordinates of the specific part as absolute coordinates of the at least one ground reference point for checking at the work site, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit, in correspondence to the placement information receiving unit's receiving the placement information for checking,

the distance information input unit is configured to receive input of at least one piece of distance information for checking that is information indicating a distance from the at least one ground reference point for checking to the construction surface in a vertical direction,

the construction surface computing unit is configured to compute absolute coordinates of at least one virtual reference point for checking located below the at least one ground reference point for checking, from the absolute coordinates of the at least one ground reference point for checking and the at least one piece of distance information for checking, and

the work assist device further comprises a determining unit that determines whether the equation for the construction surface is within a given allowable range, based on the computed absolute coordinates of the virtual reference point for checking and on the equation for the construction surface computed in advance by the construction surface computing unit.

6. The work assist device of the work machine, according to claim 1, wherein

the body orientation information acquiring unit includes a body angle sensor that detects and outputs a lift angle, a pitch angle, and a yaw angle of the machine body with respect to the body reference point, as the body orientation information.

7. The work assist device of the work machine, according to claim 1, wherein

the body coordinates information acquiring unit acquires the body coordinates information, using a global positioning satellite system or a total station.

8. The work assist device of the work machine, according to claim 1, wherein

the work assist device further comprises a display unit configured to display information on the equation for the construction surface, the information being output from the construction surface information output unit.

9. The work assist device of the work machine, according to claim 8, wherein the display unit is configured to display also information on a relative position between the construction surface and the specific part, based on absolute coordinates of the specific part output from the specific part coordinates computing unit.

10. The work assist device of the work machine, according to claim 1, wherein

the work member of the work machine includes an earth-removing blade and an earth-removing blade support supporting the earth-removing blade, the earth-removing blade support being supported by the machine body in such a way as to be capable of swinging about a lift rotating shaft extending in a left-to-right direction, and the specific part coordinates computing unit is configured to compute and output absolute coordinates of a specific part of the earth-removing blade, as a specific part of the work member at the work site.

11. The work assist device of the work machine, according to claim 10, wherein the work member position information acquiring unit includes an earth-removing blade angle sensor configured to detect and output a lift angle about a lift rotating shaft of the earth-removing blade, as the work member position information.

12. The work assist device of the work machine, according to claim 11,

the earth-removing blade of the work member is supported by the earth-removing blade support in such a way as to be capable of swinging about a tilt rotating shaft extending in a left-to-right direction, and the earth-removing blade angle sensor is configured to detect and output also a tilt angle about a tilt rotating shaft of the earth-removing blade, as the work member position information.

13. A method of recognizing a construction surface at a work site, the method comprising:

preparing a work machine including a machine body having a traveling unit configured to travel on a ground and a work member supported by the machine body in such a way as to be capable

of moving relative to the machine body, the work member being configured to excavate the ground, and preparing the work assist device of the work machine according to any one of claims 1 to 12 as well;

placing the specific part of the work member in order at the at least three ground reference points associated with the construction surface, according to at least traveling of the traveling unit and storing absolute coordinates of the specific part in the storage unit as absolute coordinates of each of the ground reference points, the absolute coordinates of the specific part being computed by the specific part coordinates computing unit in correspondence to each of the ground reference points;

inputting at least three pieces of distance information to the distance information input unit, the distance information indicating a distance from each of the at least three ground reference points to the construction surface in a vertical direction;

computing an equation for the construction surface in an absolute coordinate system of the work site, from the absolute coordinates of the at least three ground reference points, the absolute coordinates being stored in the storage unit, and the at least three pieces of distance information input to the distance information input unit; and

outputting information on the equation for the construction surface computed by the construction surface computing unit and, based on the output information, allowing a worker to recognize a position of the construction surface at the work site.

14. A method of recognizing a construction surface at a work site, the method comprising:

preparing a work machine including a machine body having a traveling unit configured to travel on a ground and a work member supported by the machine body in such a way as to be capable of moving relative to the machine body, the work member being configured to excavate the ground, and preparing the work assist device of the work machine according to any one of claims 10 to 12 as well;

placing the specific part of the work member in order at the at least three ground reference points associated with the construction surface, according to at least traveling of the traveling unit and storing absolute coordinates of the specific part in the storage unit as absolute coordinates of each of the ground reference points, the absolute coordinates of the specific part being computed by the specific part coordinates

computing unit in correspondence to each of the
 ground reference points;
 inputting at least three pieces of distance infor-
 mation to the distance information input unit, the
 distance information indicating a distance from 5
 each of the at least three ground reference
 points to the construction surface in the vertical
 direction;
 computing an equation for the construction sur-
 face in an absolute coordinate system of the 10
 work site, from the absolute coordinates of the
 at least three ground reference points, the ab-
 solute coordinates being stored in the storage
 unit, and the at least three pieces of distance
 information input to the distance information in- 15
 put unit;
 outputting information on the equation for the
 construction surface computed by the construc-
 tion surface computing unit and, based on the
 output information, allowing a worker to recog- 20
 nize a position of the construction surface at the
 work site;
 providing the work site with a reference member
 for checking including a straight part that is par- 25
 allel to the construction surface and that is per-
 pendicular to a direction of traveling of the
 traveling body of the work machine in a plan
 view;
 operating the work machine to align a lower end
 part of the earth-removing blade, the lower end 30
 part extending in a left-to-right direction, with the
 straight part of the reference member for check-
 ing; and
 comparing a distance from a left end of the lower
 end part of the earth-removing blade to the con- 35
 struction surface with a distance from a right end
 of the lower end part of the same to the con-
 struction surface to check whether the comput-
 ed equation for the construction surface is within
 a given range. 40

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FIG.1

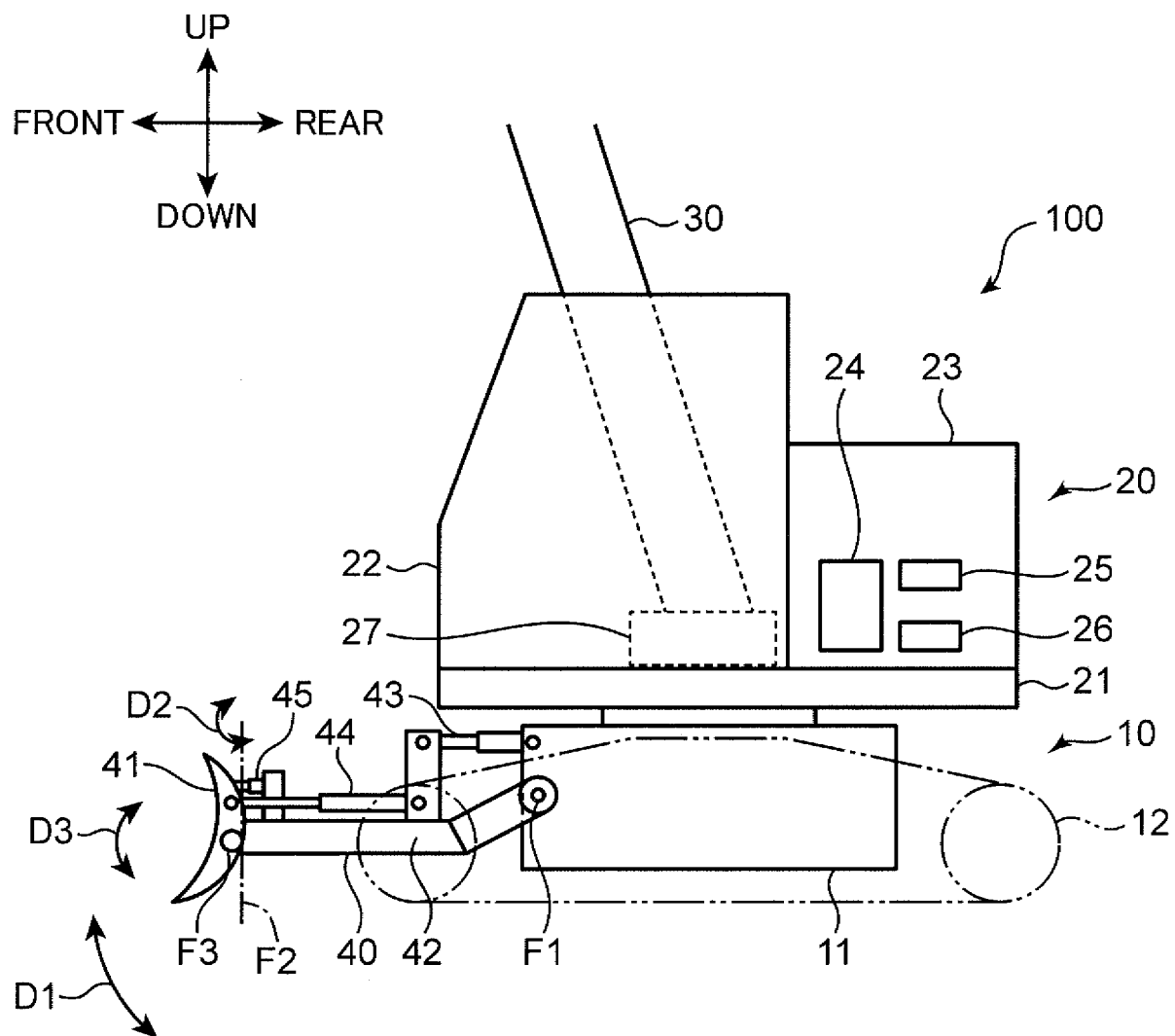


FIG. 2

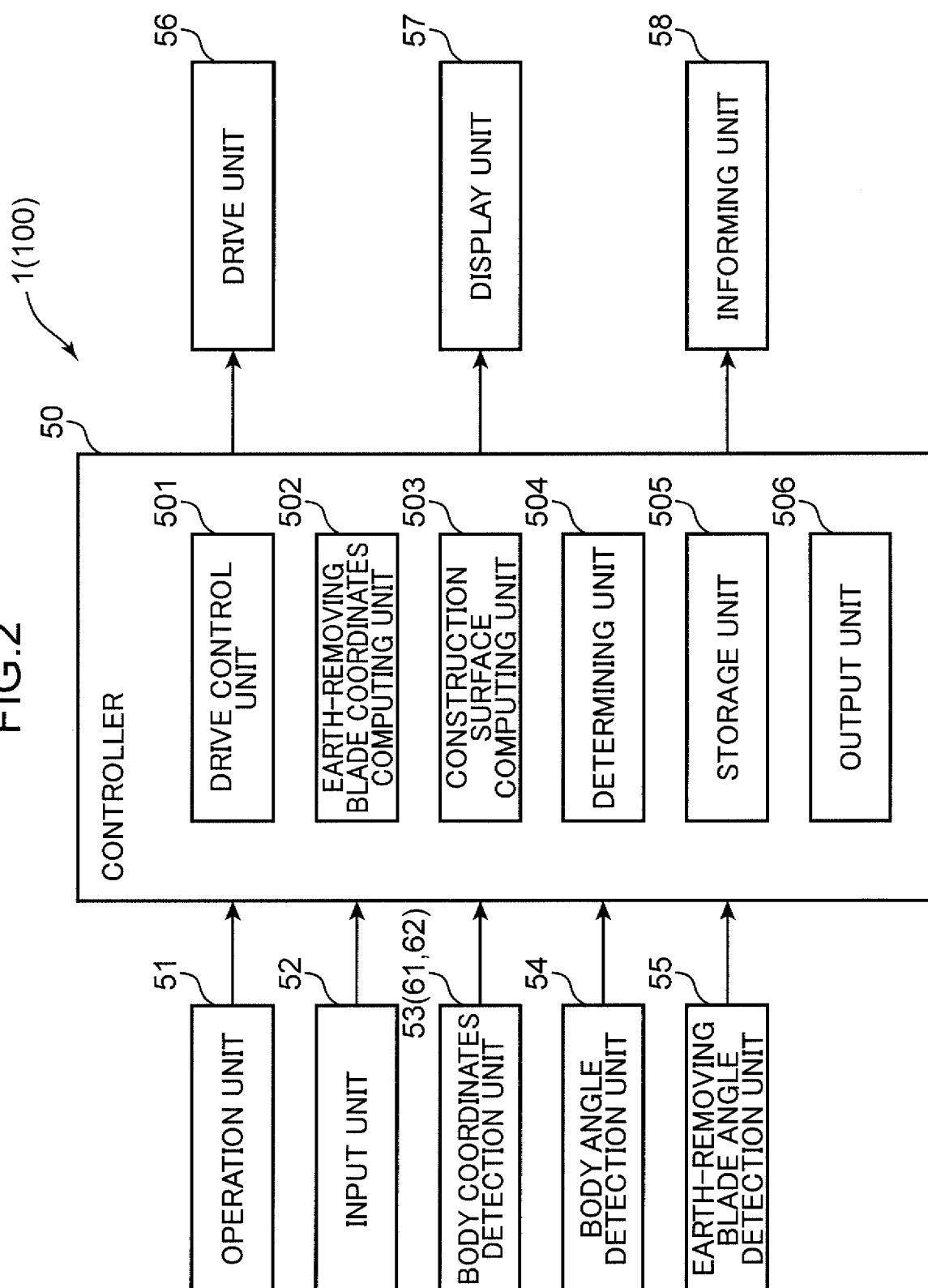


FIG.3

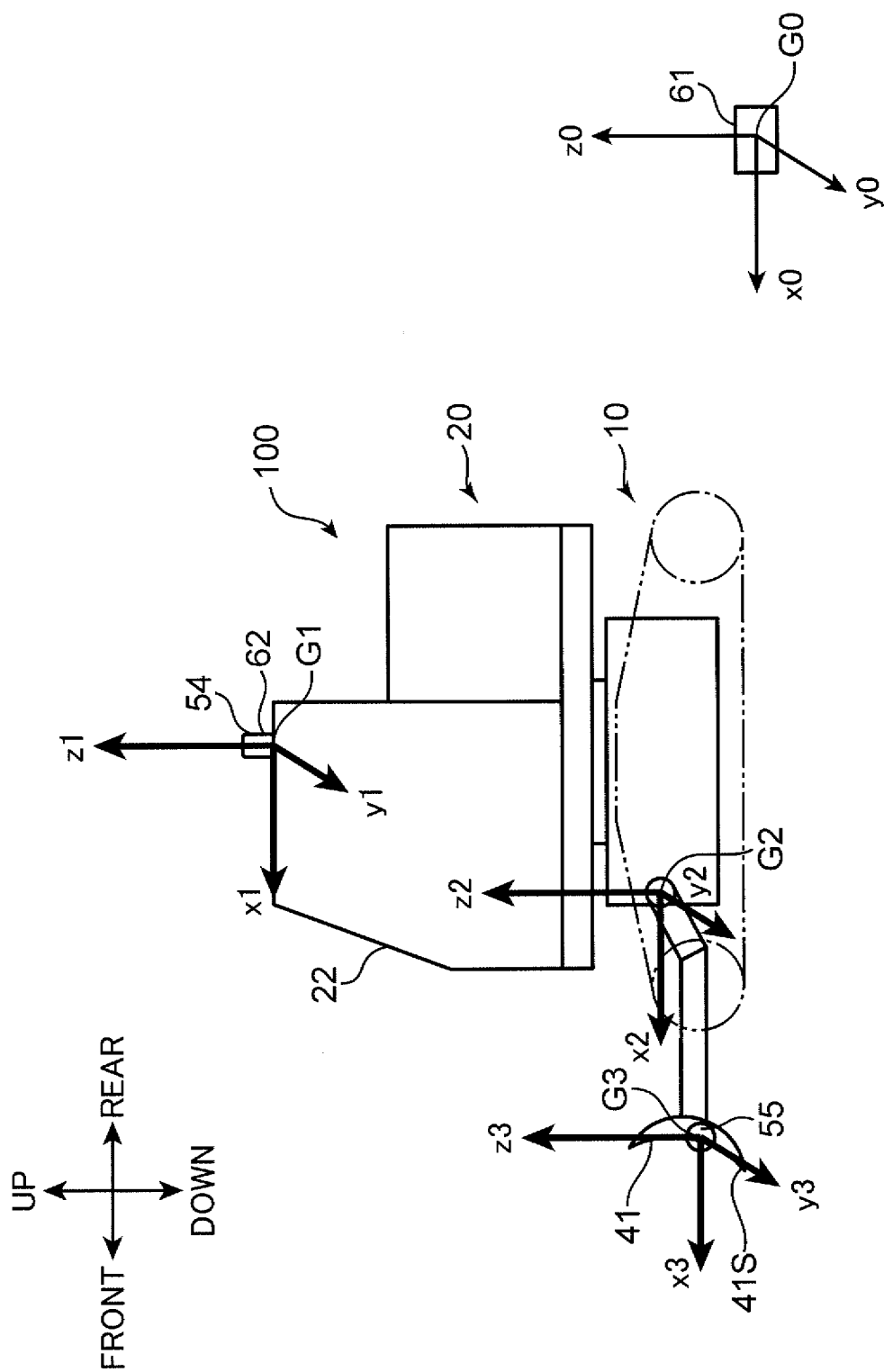


FIG. 4

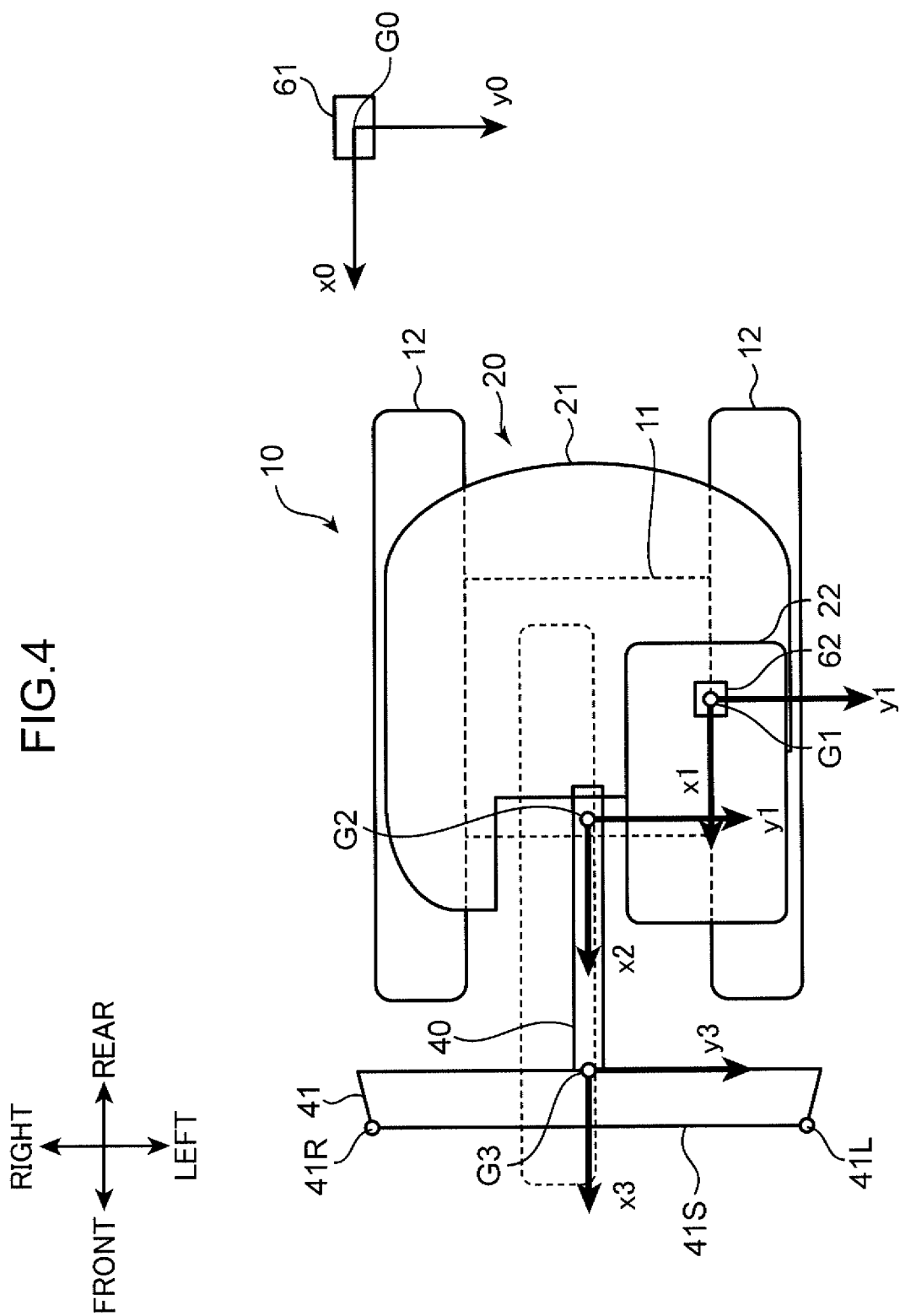


FIG.5

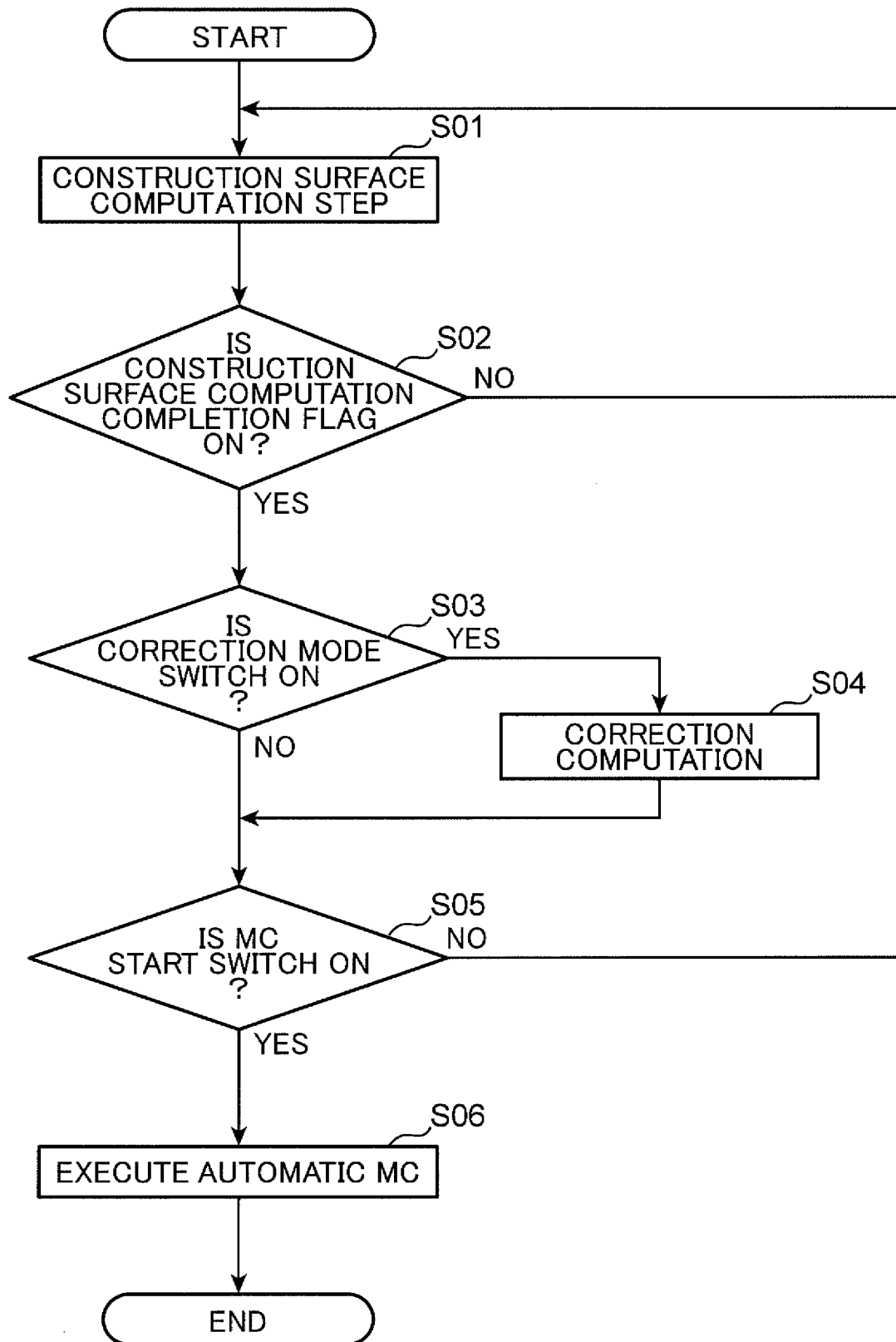


FIG.6

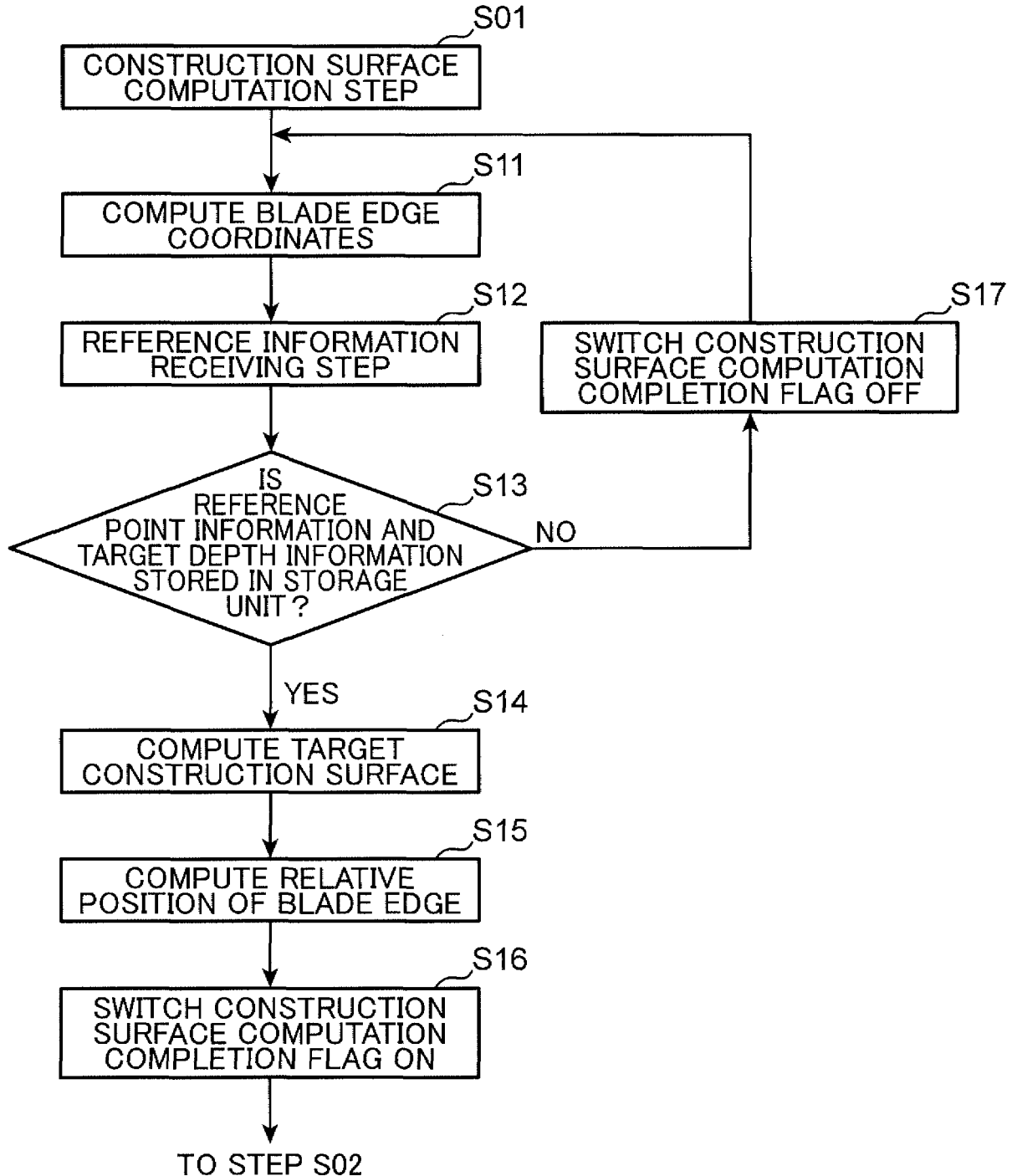


FIG.7

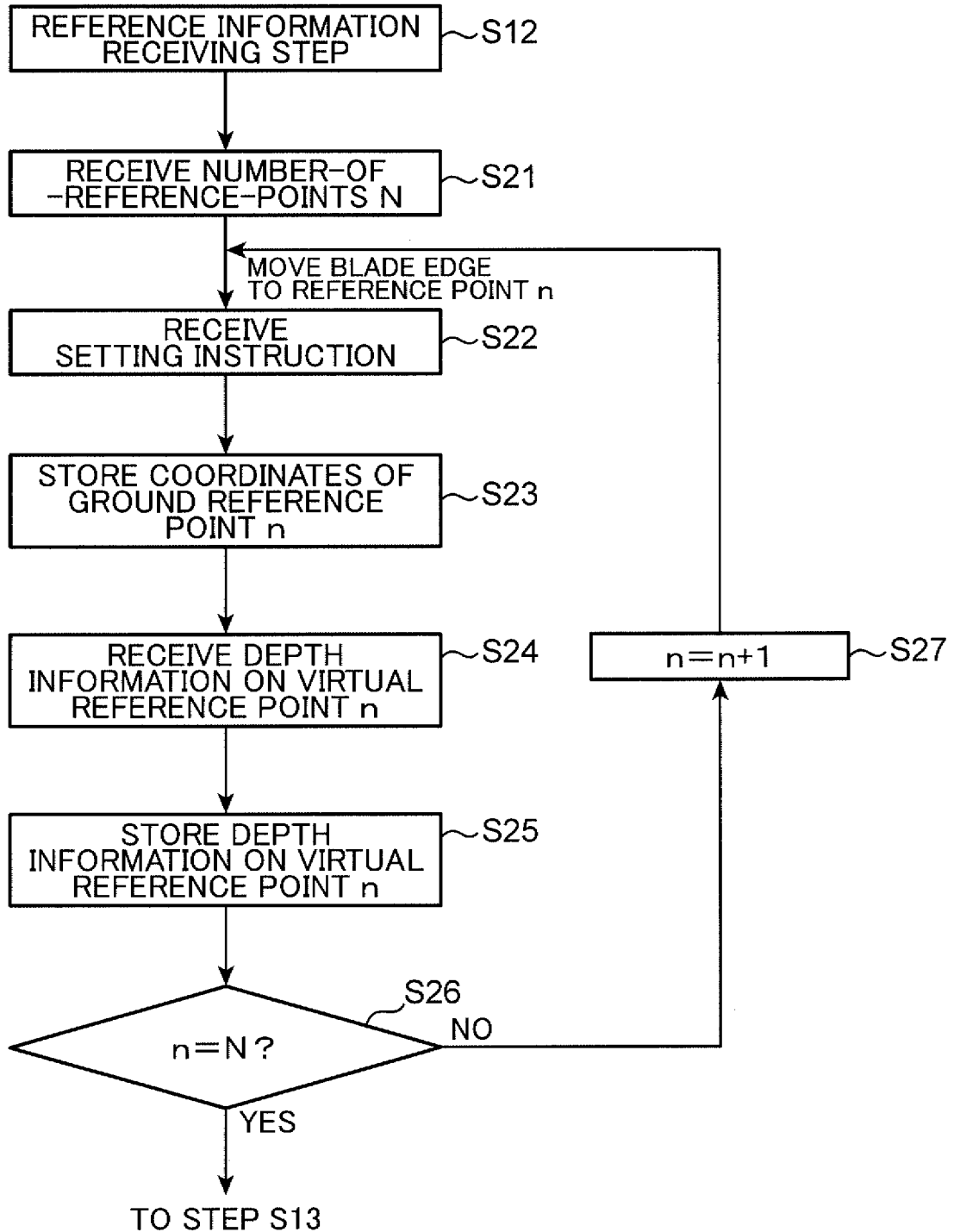


FIG. 8.

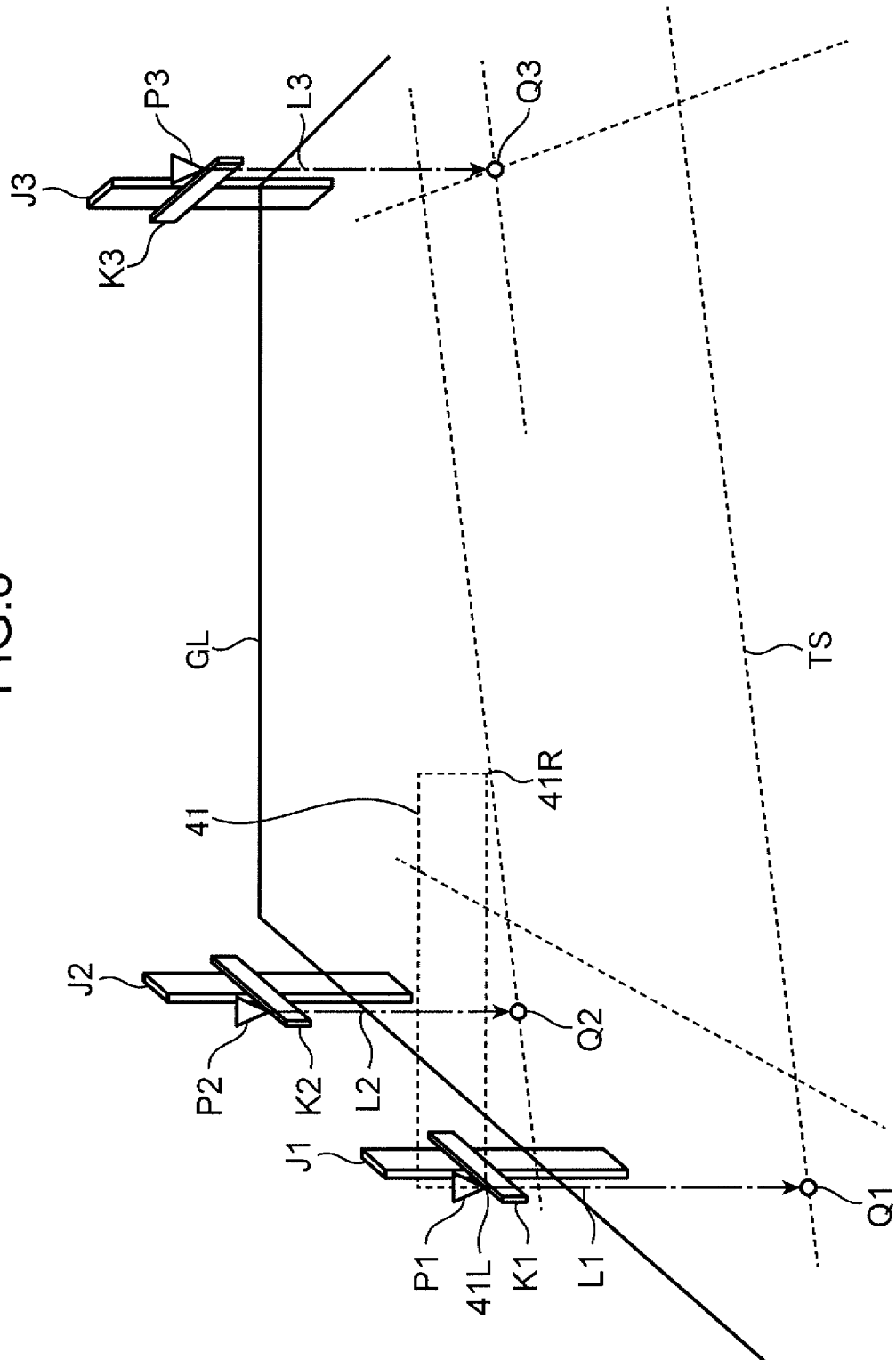


FIG.9

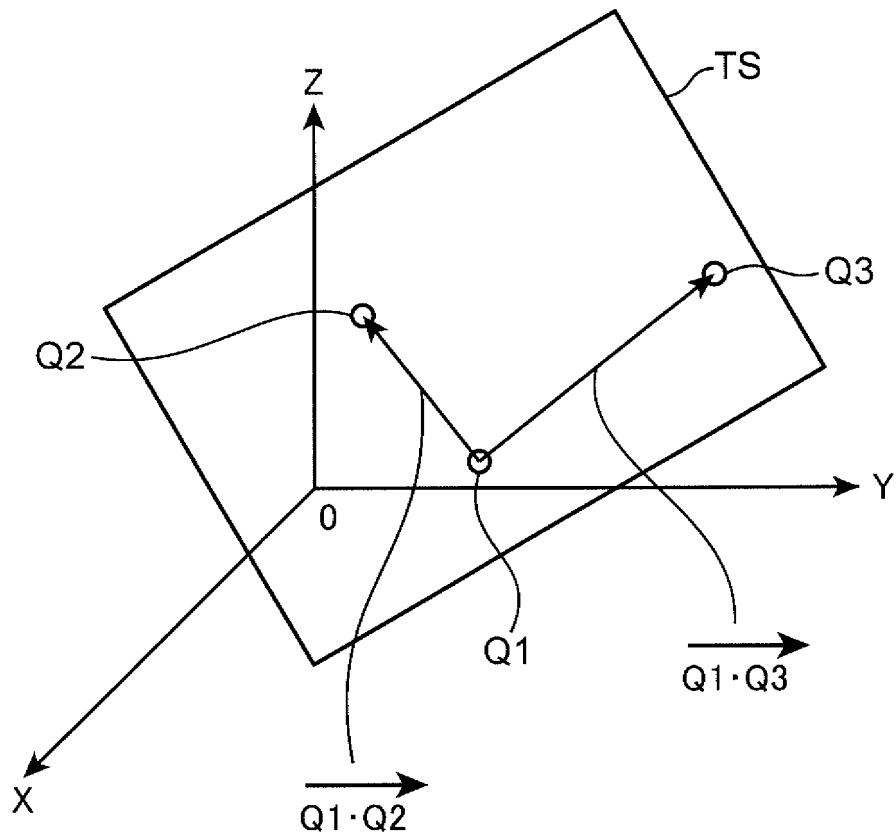


FIG.10

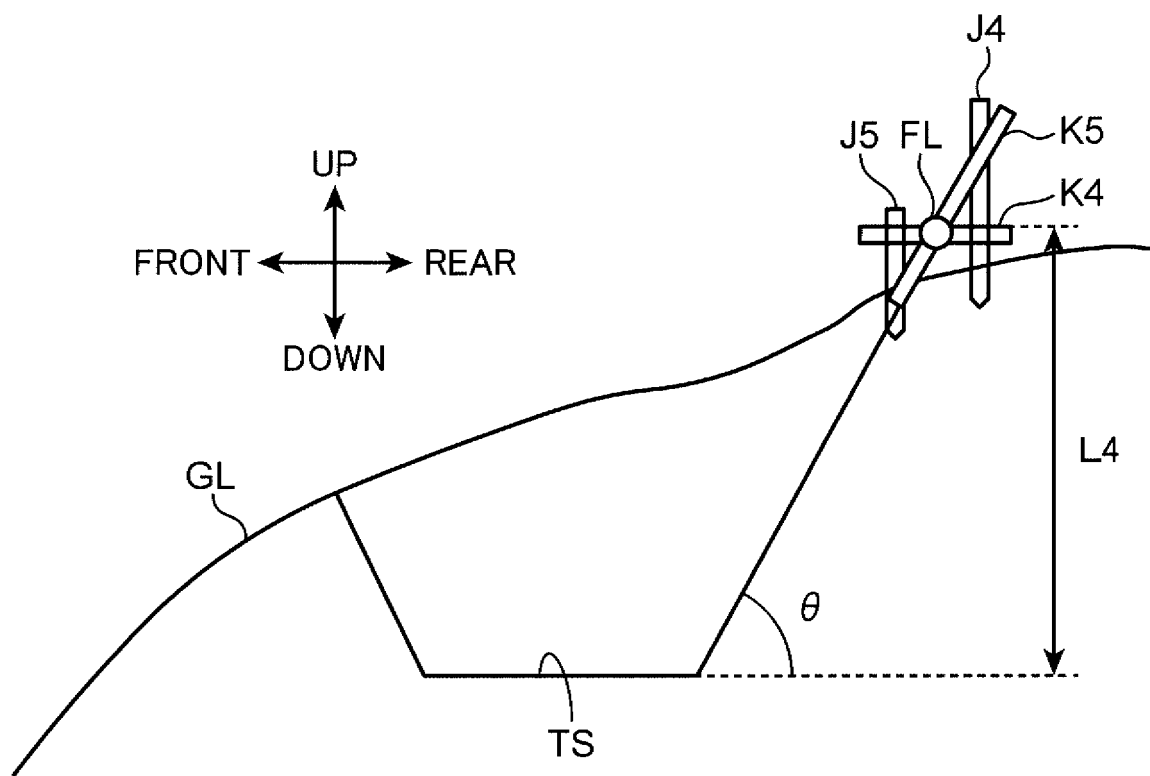
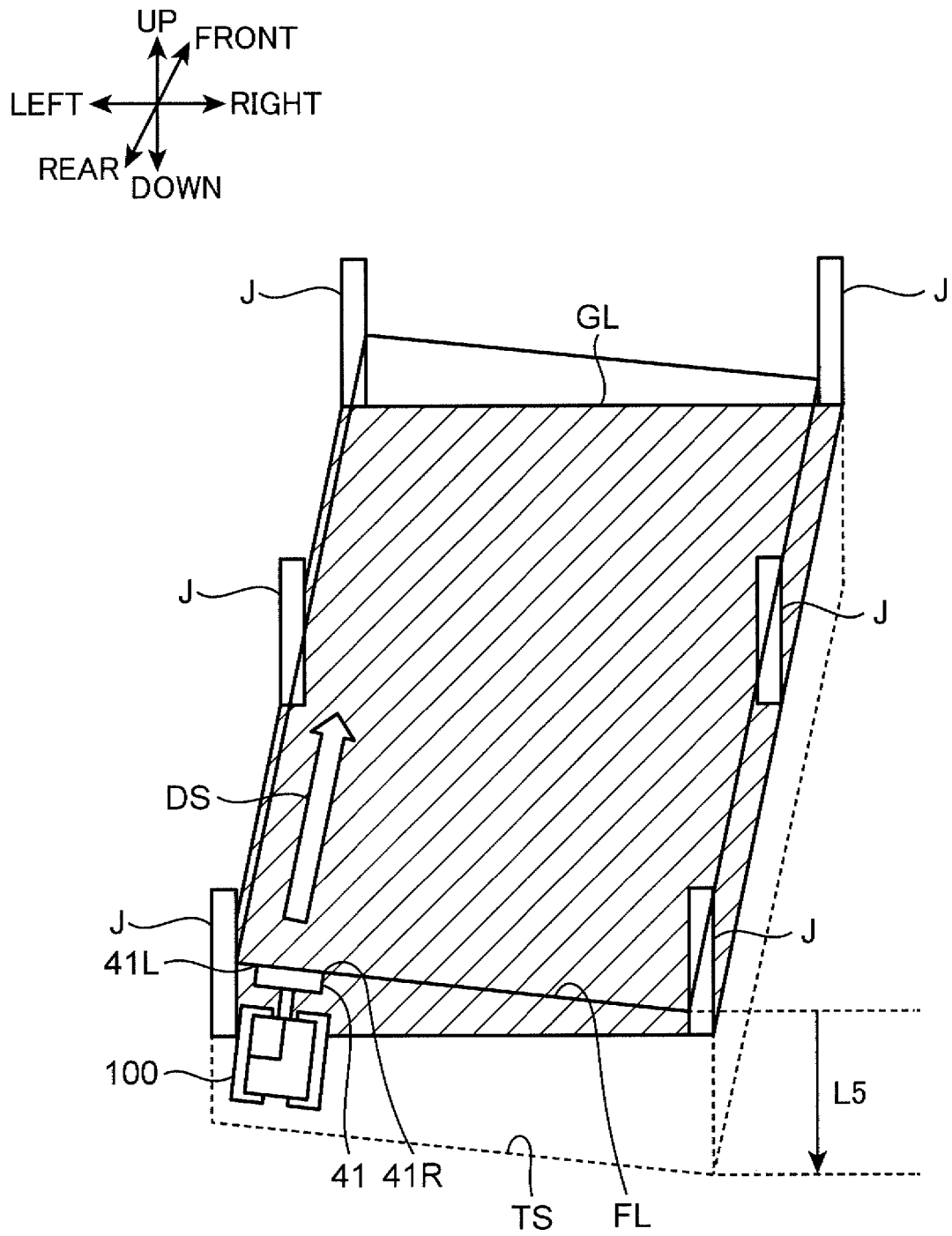


FIG.11



5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/039417

10

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. E02F9/26 (2006.01) i

FI: E02F9/26 A

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

15

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl. E02F9/26, E02F9/20-E02F9/22, E02F3/42-E02F3/43, E02F3/84-E02F3/85, E02F9/00, G08G1/00-G08G99/00

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 1971-2020
 Registered utility model specifications of Japan 1996-2020
 Published registered utility model applications of Japan 1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

25

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2002-340556 A (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 27 November 2002	1-14
A	JP 2017-180712 A (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 05 October 2017	1-14
A	JP 2019-039208 A (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 14 March 2019	1-14
A	JP 2018-155027 A (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 04 October 2018	1-14
A	JP 2010-117230 A (TOPCON CORP.) 27 May 2010	1-14
A	JP 2017-071916 A (KOMATSU LTD.) 13 April 2017	1-14

40



Further documents are listed in the continuation of Box C.



See patent family annex.

45

* 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

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

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

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Date of the actual completion of the international search
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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2020/039417
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International application No.
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REFERENCES CITED IN THE DESCRIPTION

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