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(54) **TERRAIN RECOGNITION SYSTEM AND TERRAIN RECOGNITION METHOD**

(57) Processing circuitry of a terrain recognition system is configured to: acquire ground surface height data indicating ground surface heights of sub-areas included in an excavation target region; each time excavation by a construction machine is executed a set number of times, execute first update processing in which the ground surface heights of the sub-areas in the ground surface height data are updated based on point cloud data acquired from a distance measuring sensor; and execute second update processing in which the ground surface heights of the sub-areas through which a bucket has passed in the ground surface height data are updated based on trajectory information indicating a movement trajectory of the bucket.

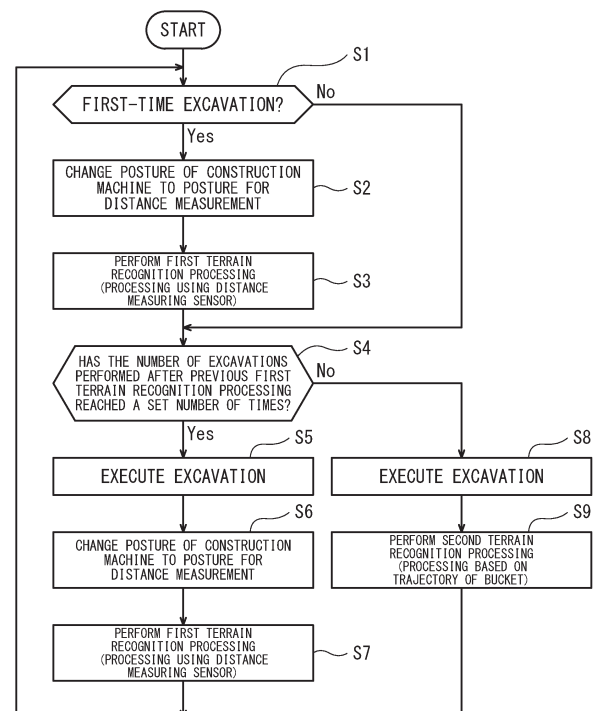


FIG. 4

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Description

Technical Field

[0001] The present disclosure relates to a terrain recognition system and a terrain recognition method for a construction machine.

Background Art

[0002] PTL 1 discloses an excavator capable of recognizing a current shape of a ground surface as a work target. A controller of the excavator includes a terrain database updater and a ground surface shape information acquirer. The terrain database updater may update a terrain database using an output of an image pickup apparatus that acquires an image of surroundings of the excavator. The ground surface shape information acquirer acquires information regarding a current shape of an excavation target ground surface based on terrain information updated by the terrain database updater, a past transition of the posture of an excavation attachment, and the like.

Citation List

Patent Literature

[0003] PTL 1: Japanese Patent No. 7178885

Summary of Invention

Technical Problem

[0004] In a construction machine, there is a demand to proceed with excavating work while accurately recognizing terrain of an excavation target region.

[0005] An object of the present disclosure is to provide a terrain recognition system and a terrain recognition method capable of accurately recognizing terrain of an excavation target region of a construction machine.

Solution to Problem

[0006] A terrain recognition system according to one aspect of the present disclosure is a terrain recognition system for a construction machine, the construction machine including: a bucket that excavates soil in an excavation target region; and a distance measuring sensor, the terrain recognition system being a system for recognizing terrain of the excavation target region, the terrain recognition system including processing circuitry configured to: acquire ground surface height data indicating ground surface heights of sub-areas included in the excavation target region; each time excavation by the construction machine is executed a set number of times, execute first update processing in which the ground surface heights of the sub-areas in the ground

surface height data are updated based on point cloud data acquired from the distance measuring sensor; and execute second update processing in which the ground surface heights of the sub-areas through which the bucket has passed in the ground surface height data are updated based on trajectory information indicating a movement trajectory of the bucket.

[0007] A terrain recognition method according to one aspect of the present disclosure is a terrain recognition method for a construction machine, the construction machine including: a bucket that excavates soil in an excavation target region; and a distance measuring sensor, the terrain recognition method being a method of recognizing terrain of the excavation target region, the terrain recognition method including: acquiring ground surface height data indicating ground surface heights of sub-areas included in the excavation target region; each time excavation by the construction machine is executed a set number of times, executing first update processing in which the ground surface heights of the sub-areas in the ground surface height data are updated based on point cloud data acquired from the distance measuring sensor; and executing second update processing in which the ground surface heights of the sub-areas through which the bucket has passed in the ground surface height data are updated based on trajectory information indicating a movement trajectory of the bucket.

Advantageous Effects of Invention

[0008] According to one aspect of the present disclosure, the terrain of the excavation target region of the construction machine can be accurately recognized.

Brief Description of Drawings

[0009]

FIG. 1 is a schematic side view of a hydraulic excavator that is one example of a construction machine.

FIG. 2 is a diagram showing a liquid-pressure circuit incorporated in the construction machine shown in FIG. 1.

FIG. 3 is a schematic configuration diagram of a control system for the construction machine which includes a terrain recognition system according to Embodiment 1.

FIG. 4 is a flowchart showing the flow of processing performed by the control system.

FIG. 5 is one example of a ground surface height map showing a ground surface height of an excavation target region.

FIG. 6 is a flowchart showing the flow of processing according to Modified Example performed by the control system.

FIG. 7 is a diagram for explaining the terrain recog-

dition system according to Embodiment 2.

Description of Embodiments

[0010] Hereinafter, embodiments will be described with reference to the drawings.

Embodiment 1

[0011] FIG. 1 shows a construction machine 1 in which a terrain recognition system of Embodiment 1 is used. FIG. 3 shows a control system 4 for the construction machine 1 which includes the terrain recognition system. The construction machine 1 performs excavating work with respect to an excavation target region. The excavation target region is a region of a ground surface that is a work target. In the present embodiment, the construction machine 1 is a hydraulic excavator 10. However, the control system 4 may be used in the construction machine 1 other than the hydraulic excavator 10, such as a wheel loader, provided that the construction machine 1 includes a bucket 16 that excavates soil.

[0012] The construction machine 1 includes a traveling body 11 and movable structures 12 constituting an articulated body rotatably supported by the traveling body 11. To be specific, the movable structures 12 are rotatably coupled to each other, and the movable structure 12 that is located closest to the traveling body 11 is rotatably coupled to the traveling body 11. In the present embodiment, the traveling body 11 includes a pair of crawlers.

[0013] The above-described bucket 16 is located at a tip of the articulated body. To be specific, a side opposite to the bucket 16, i.e., a side adjacent to the traveling body 11 is defined as a base end side, and a side adjacent to the bucket 16 is a tip side.

[0014] Moreover, as shown in FIG. 2, the construction machine 1 includes: traveling motors 31 and 32 that respectively drive the pair of crawlers; and liquid-pressure actuators 33 that respectively rotate the movable structures 12. The traveling motors 31 and 32 and the liquid-pressure actuators 33 constitute a liquid-pressure circuit 2 together with a pump apparatus 21. More specifically, the pump apparatus 21 is connected to a valve unit 22 including control valve devices 40, and the traveling motors 31 and 32 and the liquid-pressure actuators 33 are connected to the valve unit 22.

[0015] In the present embodiment, the pump apparatus 21 includes: a variable displacement pump (a swash plate pump or a bent axis pump) 21a whose tilt angle is changeable; and a regulator 21b that changes the tilt angle of the pump 21a. Moreover, in the present embodiment, a discharge flow rate of the pump apparatus 21 is controlled by an electric positive control method. However, the discharge flow rate of the pump apparatus 21 may be controlled by another method, such as a hydraulic negative control method.

[0016] In the present embodiment, since the construction machine 1 is the hydraulic excavator 10, the movable structures 12 include a swing body 13, a boom 14, an arm 15, and the above-described bucket 16 as shown in FIG. 1. The liquid-pressure actuators 33 include a swing motor 34, a boom cylinder 35, an arm cylinder 36, and a bucket cylinder 37 as shown in FIG. 2.

[0017] The swing motor 34 rotates the swing body 13 relative to the traveling body 11 about a rotation axis Jsw extending at a center of the traveling body 11 in a direction orthogonal to a front-rear direction and a width direction of the traveling body 11. The boom cylinder 35 rotates the boom 14 relative to the swing body 13 about a rotation axis Jbm extending at a base end portion of the boom 14 in the width direction of the swing body 13. The arm cylinder 36 rotates the arm 15 relative to the boom 14 about a rotation axis Jam extending at a tip portion of the boom 14 in the width direction of the swing body 13. The bucket cylinder 37 rotates the bucket 16 relative to the arm 15 about a rotation axis Jbt extending at a tip portion of the arm 15 in the width direction of the swing body 13.

[0018] The control valve devices 40 includes two control valve devices 41 for the traveling motors, a swing control valve device 42, a boom control valve device 43, an arm control valve device 44, and a bucket control valve device 45. The two control valve devices 41 for the traveling motors control the flow of operating oil supplied from the pump apparatus 21 to the traveling motors 31 and 32. The swing control valve device 42 controls the flow of the operating oil supplied from the pump apparatus 21 to the swing motor 34. The boom control valve device 43 controls the flow of the operating oil supplied from the pump apparatus 21 to the boom cylinder 35. The arm control valve device 44 controls the flow of the operating oil supplied from the pump apparatus 21 to the arm cylinder 36. The bucket control valve device 45 controls the flow of the operating oil supplied from the pump apparatus 21 to the bucket cylinder 37.

[0019] In the example shown in FIG. 2, the control valve devices 40 are incorporated in the valve unit 22. However, the valve unit 22 may be constituted by units, and the control valve devices 40 may be incorporated in the respective independent units. Moreover, the control valve devices 40 only need to be capable of controlling the flow of the operating oil supplied to and discharged from corresponding actuators, and the configurations of the control valve devices 40 are not particularly limited. For example, the control valve devices 40 may be electromagnetic spool valves. Or, each control valve device 40 may include a pilot-operated spool valve and an electromagnetic proportional valve that outputs pilot pressure to the pilot-operated spool valve.

[0020] As shown in FIG. 3, the control system 4 for the construction machine 1 includes posture angle sensors 5, a distance measuring sensor 6, a controller 7,

and the control valve devices 40 and the pump apparatus 21 which are control targets of the controller 7. The posture angle sensors 5, the distance measuring sensor 6, the control valve devices 40, and the pump apparatus 21 are connected to the controller 7 by wired or wireless communication.

[0021] When the pump apparatus 21 is controlled by another method other than the electric positive control method, the pump apparatus 21 does not have to be the control target of the controller 7, and the pump apparatus 21 does not have to be connected to the controller 7.

[0022] Each of the posture angle sensors 5 detects the posture of the construction machine 1 as posture information. In the present embodiment, the posture angle sensors 5 include a vehicle body posture angle sensor 51, a swing posture angle sensor 52, a boom posture angle sensor 53, an arm posture angle sensor 54, and a bucket posture angle sensor 55. The vehicle body posture angle sensor 51 detects a vehicle body posture angle that is an inclination angle of the traveling body 11 relative to a horizontal plane. The swing posture angle sensor 52 detects a swing posture angle that is an angle of the swing body 13 relative to the front-rear direction of the traveling body 11 on a plane orthogonal to the rotation axis Jsw. The boom posture angle sensor 53 detects a boom posture angle that is an inclination angle of the boom 14 relative to the horizontal plane. The arm posture angle sensor 54 detects an arm posture angle that is an inclination angle of the arm 15 relative to the horizontal plane. The bucket posture angle sensor 55 detects a bucket posture angle that is an inclination angle of the bucket 16 relative to the horizontal plane.

[0023] The distance measuring sensor 6 measures terrain of the excavation target region. The distance measuring sensor 6 measures distances from the distance measuring sensor 6 to respective points in the excavation target region and acquires three-dimensional point cloud data of a surface of the excavation target region. The point cloud data is a set of point data indicating three-dimensional coordinates of respective positions of the terrain included within a measurement range (which may also be referred to as a field of view) of the distance measuring sensor 6. The distance measuring sensor 6 is, for example, a LiDAR (Light Detection And Ranging), a stereo camera, or the like.

[0024] The distance measuring sensor 6 is located so as to measure the terrain in front of the swing body 13 of the construction machine 1. In the present embodiment, since the construction machine 1 is the hydraulic excavator 10, a cabin 17 including an operator's seat on which an operator is seated, and the like is mounted on a left side of a front portion of the swing body 13. The distance measuring sensor 6 is attached to a front side of a roof portion of the cabin 17. When the excavation target region is located in front of the swing body 13, the excavation target region is included in the mea-

surement range of the distance measuring sensor 6.

[0025] The controller 7 includes processing circuitry 70. The processing circuitry 70 generates control commands to be output to the control targets, based on the posture information received from the posture angle sensors 5, the point cloud data received from the distance measuring sensor 6, and the like.

[0026] The processing circuitry 70 includes a processor 71, a system memory 72, and a storage memory 73. The processor 71 may include a CPU. The system memory 72 may include a RAM. The storage memory 73 may include a hard disk, a flash memory, or a combination thereof. The storage memory 73 stores a program 73a.

[0027] The controller 7 may include at least one user interface 74. The user interface 74 may be located at the operator's seat. For example, the user interface 74 includes an input interface and an output interface. For example, the input interface may be a touch panel, a handle, a lever, a switch, or the like. For example, the output interface may be a display.

[0028] The controller 7 may include at least one communication interface 75. The communication interface 75 includes an interface that communicably connects an external device and the controller 7 through wired or wireless communication. The communication interface 75 may include an interface that is communicably connected to a communication network, such as the Internet, through wired or wireless communication.

[0029] In the present embodiment, an automatic excavation program is included in the program 73a stored in the storage memory 73. The automatic excavation program is a program for causing the construction machine 1 to perform excavating work with respect to the excavation target region by autonomous operation. The processing circuitry 70 executes automatic excavation processing in such a manner that the processor 71 executes the automatic excavation program read from the storage memory 73.

[0030] In the automatic excavation processing of the present embodiment, the excavating work of the construction machine 1 with respect to the excavation target region proceeds while timely recognizing the terrain of the excavation target region which may change due to excavation. To be specific, in the present embodiment, the automatic excavation program includes a terrain recognition program for recognizing the terrain of the excavation target region, and the controller 7 serves as a terrain recognition device.

[0031] FIG. 4 is a flowchart showing the flow of the automatic excavation processing performed by the control system 4. The automatic excavation processing is started in a state in which: the excavation target region is determined; and a positional relation of the excavation target region relative to the construction machine 1 is grasped by the processing circuitry 70.

[0032] For example, the excavation target region may be predetermined in an absolute coordinate sys-

tem (XY coordinate system) of a construction site. In this case, the construction machine 1 may include: a position sensor that detects the position of the construction machine 1 in the absolute coordinate system; and an orientation sensor that detects an orientation of the construction machine 1 in the absolute coordinate system. For example, the construction machine 1 may include a GNSS compass. To be specific, by grasping the position and orientation of the construction machine 1 in the absolute coordinate system, the positional relation of the construction machine 1 relative to the excavation target region in the absolute coordinate system can be grasped.

[0033] Or, for example, the excavation target region may be set as a region that can be excavated without the movement of the construction machine 1. To be specific, the excavation target region may be determined in a relative coordinate system with respect to the construction machine 1.

[0034] When the automatic excavation processing is started, first, the processing circuitry 70 determines whether or not the excavation to be performed is a first-time excavation with respect to the excavation target region (Step S1).

[0035] When it is determined that the excavation to be performed is the first-time excavation (Yes in Step S1), the processing circuitry 70 controls the control targets (such as the swing control valve device 42, the boom control valve device 43, the arm control valve device 44, the bucket control valve device 45, and the pump apparatus 21) such that the posture of the construction machine 1 is changed to a predetermined posture for distance measurement (Step S2).

[0036] Specifically, the posture for distance measurement is such a posture that a part of the construction machine 1 enters the measurement range of the distance measuring sensor 6 (for example, a scan range of the LiDAR when the distance measuring sensor 6 is the LiDAR) as little as possible. To be specific, Step S2 is a step for reducing a region that becomes a blind spot from the distance measuring sensor 6 in the excavation target region due to the boom 14, the arm 15, and the bucket 16. For example, the posture for distance measurement may be predetermined by the swing posture angle, the boom posture angle, the arm posture angle, and the bucket posture angle. For example, when the construction machine 1 is in the posture for distance measurement, the bucket 16 may be located higher than the distance measuring sensor 6.

[0037] After the posture of the construction machine 1 is changed to the posture for distance measurement, the processing circuitry 70 executes first terrain recognition processing (Step S3). The first terrain recognition processing is processing for recognizing the terrain of the excavation target region using the distance measuring sensor 6. In the present embodiment, in the first terrain recognition processing and below-described second terrain recognition processing, recognizing the

terrain of the excavation target region denotes storing ground surface height data indicating ground surface heights of sub-areas constituting the excavation target region or updating the ground surface height data. The ground surface height data is stored in, for example, the storage memory 73.

[0038] The ground surface heights of the sub-areas will be described with reference to FIG. 5. FIG. 5 shows one example of a ground surface height map showing the ground surface height of an excavation target region R1. In FIG. 5, the range of the excavation target region R1 is defined on an XY plane parallel to the horizontal plane. As shown in FIG. 5, the excavation target region R1 is divided into sub-areas R2. Hatching patterns of the sub-areas R2 indicate the ground surface heights of the sub-areas R2. The ground surface height data of the sub-area R2 is stored in association with positional information of the corresponding sub-area R2.

[0039] In the ground surface height map of FIG. 5, the excavation target region R1 is shown as a rectangular plane parallel to the horizontal plane, and the sub-area R2 is defined as a square. However, the shapes of the excavation target region R1 and the sub-area R2 are not limited to these. For example, the excavation target region R1 may have a trapezoidal shape or a sector shape. The number of sub-areas R2 included in the excavation target region R1, a ratio of the size of the sub-area R2 to the size of the excavation target region R1, and the like may be suitably set.

[0040] In the first terrain recognition processing of the present embodiment, first, the processing circuitry 70 transmits a command to the distance measuring sensor 6 to start measurement. After the measurement by the distance measuring sensor 6 is completed, the processing circuitry 70 receives the three-dimensional point cloud data from the distance measuring sensor 6. The processing circuitry 70 determines to which sub-area R2 the XY coordinate of each point data of the acquired three-dimensional point cloud data belongs. Then, the processing circuitry 70 calculates the ground surface height of the sub-area R2 from the Z coordinate of the point data included in the sub-area R2.

[0041] For example, when only one piece of point data is included in the sub-area R2, the processing circuitry 70 sets the Z coordinate of this point data as the ground surface height of the sub-area R2. For example, when pieces of point data are included in the sub-area R2, the processing circuitry 70 calculates one ground surface height from the Z coordinates of the pieces of point data by a predetermined calculation. For example, the processing circuitry 70 may calculate an average value of the Z coordinates of the pieces of point data as the ground surface height or may calculate the ground surface height from the Z coordinates remaining after excluding outliers from the Z coordinates of the pieces of point data.

[0042] There may be a case in which no point data is

included in the sub-area R2. For example, the sub-area R2 that has become a blind spot from the distance measuring sensor 6 due to at least one of the boom 14, the arm 15, and the bucket 16 may include no point data. Moreover, when a soil raised portion is present in the excavation target region R1, the sub-area R2 that has become a blind spot from the distance measuring sensor 6 due to this soil raised portion may include no point data. In a case in which there is the sub-area R2 for which the distance measurement by the distance measuring sensor 6 could not be performed (hereinafter referred to as a "distance measurement impossible area"), the processing circuitry 70 may estimate the ground surface height of the distance measurement impossible area from the ground surface heights of the sub-areas R2 located around the distance measurement impossible area. For example, the ground surface height of the distance measurement impossible area may be estimated using the ground surface heights of the sub-areas R2 located around the distance measurement impossible area by a known interpolation method or may be estimated by averaging the ground surface heights of the sub-areas R2 surrounding the distance measurement impossible area.

[0043] Thus, the processing circuitry 70 acquires the ground surface height data indicating the ground surface height of each sub-area R2 of the excavation target region R1 and stores the ground surface height data in the memory 73.

[0044] Next, the processing circuitry 70 determines whether or not the number of excavations performed after the previous first terrain recognition processing has reached a set number of times (Step S4). More specifically, during the automatic excavation processing, the processing circuitry 70 counts the number k of excavations performed in Steps S5 and S8 described later. In Step S4, the processing circuitry 70 determines whether or not the number k has reached the set number of times. When the first terrain recognition processing is executed in Step S7 described later, the processing circuitry 70 returns the number k to zero, which is an initial value.

[0045] When it is determined that the number of excavations performed after the previous first terrain recognition processing has reached the set number of times (Yes in Step S4), the processing circuitry 70 controls the control targets (such as the swing control valve device 42, the boom control valve device 43, the arm control valve device 44, the bucket control valve device 45, and the pump apparatus 21) so as to excavate the soil in the excavation target region R1 (Step S5). In Step S5, for example, the processing circuitry 70 determines, based on the ground surface height data, which portion of the soil in the excavation target region R1 is to be excavated, and controls the control targets so as to excavate the determined portion of the soil.

[0046] After that, the processing circuitry 70 controls the control valve devices 40 and the pump apparatus

21 so as to change the posture of the construction machine 1 to the posture for distance measurement (Step S6), and then, the processing circuitry 70 executes the first terrain recognition processing (Step S7). Since Steps S6 and S7 are similar to Steps S2 and S3, respectively, explanations thereof are omitted.

[0047] When it is determined in Step S4 that the number of excavations performed after the previous first terrain recognition processing has not reached the set number of times (No in Step S4), the processing circuitry 70 controls the control targets so as to excavate the soil in the excavation target region R1 (Step S8).

[0048] In at least Step S8, the processing circuitry 70 stores information necessary to calculate the trajectory of a tip of the bucket 16 that is operating. For example, the processing circuitry 70 stores time-series data of detected values of the posture angle sensors 5 during the movement of the bucket 16 for excavation.

[0049] After Step S8, the processing circuitry 70 executes the second terrain recognition processing (Step S9). The second terrain recognition processing is processing of recognizing the terrain of the excavation target region based on the trajectory of the tip of the bucket 16 in the excavation of Step S8.

[0050] Specifically, in the second terrain recognition processing, the processing circuitry 70 calculates the movement trajectory of the tip of the bucket 16 from the time-series data of the detected values of the posture angle sensors 5 during the movement of the bucket 16 at the time of excavation, and stores the movement trajectory as trajectory information. For example, the movement trajectory of the tip of the bucket 16 may be time-series data of position coordinates of two points, i.e., a right end and a left end of a tip-side end edge of the bucket 16 during the operation of the construction machine 1 in Step S8. After that, the processing circuitry 70 identifies, based on the trajectory information and the ground surface height data stored in the memory 73, the sub-areas R2 through which the bucket 16 has passed during the excavation in Step S8. Then, the processing circuitry 70 updates the ground surface height of each identified sub-area R2 to the height of the tip of the bucket 16 at the time when the bucket 16 passes through the sub-area R2.

[0051] One example of the second terrain recognition processing will be described below. However, the method of calculating the movement trajectory of the tip of the bucket 16, the method of identifying the sub-areas R2 through which the bucket 16 has passed, and the method of updating the ground surface heights of the identified sub-areas R2 are not limited to the second terrain recognition processing described below.

[0052] First, from the time-series data of the detected values of the posture angle sensors 5 during the movement of the bucket 16 at the time of excavation, the processing circuitry 70 calculates, as the trajectory information, the time-series data of the position coordi-

nates of points that are a first point of the right end of the tip of the bucket 16, a second point of the left end of the tip of the bucket 16, and a third point on an opening plane of the bucket 16. For example, the third point is a point located at a middle of an end edge of a base end side of the bucket 16. After that, the processing circuitry 70 treats the first point, the second point, and the third point as one set and performs the following processing for each set.

[0053] The processing circuitry 70 defines a virtual triangle having the first point, the second point, and the third point as its vertices and projects the virtual triangle onto the XY plane. The processing circuitry 70 identifies the sub-areas R2 that overlap with the projected triangle on the XY plane by a certain amount or more. For example, the processing circuitry 70 compares the center of gravity of the projected triangle with the centers of gravity of the sub-areas R2 and identifies the sub-areas R2 whose centers of gravity are located within the projected triangle. The processing circuitry 70 extracts the height (Z coordinate) of a point on the virtual triangle, which has the first point, the second point, and the third point as its vertices, at the XY coordinates of the center of gravity of the specified sub-area R2. Then, the processing circuitry 70 compares the extracted height with the ground surface height of this sub-area R2 stored in the memory 73. When the processing circuitry 70 determines that the extracted height is lower than the stored ground surface height of the sub-area R2, the processing circuitry 70 updates the stored ground surface height of the sub-area R2 to the extracted height. When the processing circuitry 70 determines that the extracted height is equal to or higher than the ground surface height of the sub-area R2 stored in the memory 73, the processing circuitry 70 maintains the ground surface height of the sub-area R2 stored in the memory 73 without updating it.

[0054] The processing circuitry 70 sequentially performs the above processing, which has been performed with respect to the above virtual triangle extracted from the time-series data during the excavation operation, with respect to virtual triangles extracted from the time-series data corresponding to the excavation operation. Then, the processing circuitry 70 terminates the second terrain recognition processing.

[0055] After Steps S7 and S9, the process returns to Step S1. As above, each time the excavation is performed, one of the first terrain recognition processing of Step S7 and the second terrain recognition processing of Step S9 is executed, and the ground surface height data stored in the memory 73 is updated. The first terrain recognition processing of Step S7 corresponds to first update processing, and the second terrain recognition processing of Step S9 corresponds to second update processing.

[0056] The above automatic excavation processing is one example. For example, the processing circuitry 70 may control the control targets so as to excavate the

soil in the excavation target region R1 before the determination in Step S4 instead of executing Steps S5 and S8 after the determination in Step S4.

[0057] As described above, in the present embodiment, the second terrain recognition processing updates the ground surface height of the sub-area R2 in the ground surface height data based on the movement trajectory of the bucket 16. Therefore, the ground surface height of the excavation target region R1 which changes each time the excavation is performed can be recognized in real time.

[0058] Moreover, in the present embodiment, each time the excavation by the construction machine 1 is performed the set number of times, the first terrain recognition processing is executed to update the ground surface height of each sub-area R2 based on the point cloud data acquired from the distance measuring sensor 6. Therefore, the discrepancy between the ground surface height of the sub-area R2 recognized in the second terrain recognition processing and the actual ground surface height of the sub-area can be eliminated at an appropriate timing. Thus, the excavating work can proceed while accurately recognizing the ground surface height of the excavation target region.

[0059] Moreover, in order to perform the first terrain recognition processing, it is necessary to change the posture of the construction machine 1 to the posture for distance measurement, and the measurement by the distance measuring sensor 6 also requires time. However, in the present embodiment, since the first terrain recognition processing is limited to being performed each time the excavation by the construction machine 1 is carried out the set number of times, the excavating work can proceed efficiently.

Processing according to Modified Example

[0060] FIG. 6 is a flowchart showing the flow of processing according to Modified Example performed by the control system 4. In the processing shown in FIG. 4, each time the excavation is performed, one of the first terrain recognition processing and the second terrain recognition processing is executed. However, in the processing shown in FIG. 6, each time the excavation is performed, the second terrain recognition processing is always executed.

[0061] Since Steps T1, T2, and T3 shown in FIG. 6 are similar to Steps S1, S2, and S3 shown in FIG. 4, respectively, explanations thereof are omitted. After Step T3, the processing circuitry 70 controls the control targets so as to excavate the soil in the excavation target region (Step T4). Then, the processing circuitry 70 executes the second terrain recognition processing (Step T5). Since Steps T4 and T5 shown in FIG. 6 are similar to Steps S8 and S9 shown in FIG. 4, respectively, explanations thereof are omitted.

[0062] After Step T5, the processing circuitry 70 determines whether or not the number of excavations per-

formed after the previous first terrain recognition processing has reached the set number of times (Step T6). When it is determined that the number of excavations performed after the previous first terrain recognition processing has reached the set number of times (Yes in Step T6), the processing circuitry 70 controls the control targets so as to change the posture of the construction machine 1 to the posture for distance measurement (Step T7). Then, the processing circuitry 70 executes the first terrain recognition processing (Step T8). After Step T8, or when it is determined in Step T6 that the number of excavations performed after the previous first terrain recognition processing has not reached the set number of times (No in Step T6), the process returns to Step T1. Since Steps T6, T7, and T8 shown in FIG. 6 are similar to Steps S4, S6, and S7 shown in FIG. 4, respectively, explanations thereof are omitted. The first terrain recognition processing of Step T8 corresponds to the first update processing, and the second terrain recognition processing of Step T5 corresponds to the second update processing.

Embodiment 2

[0063] FIG. 7 is a diagram for explaining a terrain recognition system 100 according to Embodiment 2. The terrain recognition system 100 includes: the posture angle sensors 5 and the distance measuring sensor 6 included in the construction machine 1; and a terrain recognition device 8 that is an external device of the construction machine 1. Since the construction machine 1 is the same as that described in Embodiment 1, an explanation thereof is omitted. In Embodiment 1, the first terrain recognition processing and the second terrain recognition processing are executed by the controller 7 of the construction machine 1. However, in Embodiment 2, the first terrain recognition processing and the second terrain recognition processing are executed by the terrain recognition device 8.

[0064] The terrain recognition device 8 is located outside the construction machine 1. The terrain recognition device 8 is configured to be communicable with the controller 7 of the construction machine 1. For example, the terrain recognition device 8 may be a cloud server.

[0065] The terrain recognition device 8 includes processing circuitry 80. The processing circuitry 80 executes processing for recognizing the terrain of the excavation target region based on information received from the construction machine 1.

[0066] The processing circuitry 80 includes a processor 81, a system memory 82, and a storage memory 83. The processor 81 may include a CPU. The system memory 82 may include a RAM. The storage memory 83 may include a hard disk, a flash memory, or a combination thereof. The storage memory 83 stores a program 83a. In the present embodiment, the program 83a includes a terrain recognition program for recognizing

the terrain of the excavation target region.

[0067] The terrain recognition device 8 may include at least one user interface 84. For example, the user interface 84 includes an input interface and an output interface. For example, the input interface may be a touch panel, a keyboard, a mouse, a microphone, or the like. For example, the output interface may be a display.

[0068] The terrain recognition device 8 includes at least one communication interface 85. The communication interface 85 is an interface that is communicably connected to the controller 7 of the construction machine 1. The communication interface 85 may be directly communicably connected to the controller 7 or may be communicably connected to the controller 7 through a communication network, such as the Internet.

[0069] The terrain recognition device 8 receives, from the construction machine 1, the posture information obtained by the posture angle sensors 5, the point cloud data obtained by the distance measuring sensor 6, and excavation information indicating whether or not excavation has been performed with respect to the excavation target region. The excavation information may be information indicating the number of excavations.

[0070] Together with the start of the excavating work by the construction machine 1 with respect to the excavation target region, the processing circuitry 80 executes the following processing in the same manner as the processing described in Embodiment 1 and shown in FIG. 4.

[0071] For example, the processing circuitry 80 determines based on the excavation information received from the construction machine 1 whether or not the excavation to be performed is the first-time excavation with respect to the excavation target region (Step S1). When it is determined that the excavation to be performed is the first-time excavation (Yes in Step S1), the processing circuitry 80 transmits a command to the controller 7 to change the posture of the construction machine 1 to a predetermined posture for distance measurement (Step S2). Moreover, the processing circuitry 80 transmits, to the controller 7, a command that requests the point cloud data obtained by the distance measuring sensor 6, and then, executes the first terrain recognition processing based on the point cloud data received from the controller 7 (Step S3). Thus, the processing circuitry 80 acquires the ground surface height data indicating the ground surface heights of the subareas R2 of the excavation target region R1 and stores the ground surface height data in a memory 83.

[0072] Next, the processing circuitry 80 determines whether or not the number of excavations performed after the previous first terrain recognition processing has reached the set number of times (Step S4).

[0073] When it is determined that the number of excavations performed after the previous first terrain recognition processing has reached the set number of

times (Yes in Step S4), the processing circuitry 80 receives the excavation information indicating that the excavation has been performed with respect to the excavation target region (Step S5), and then, performs steps similar to Steps S2 and S3 described above (Steps S6 and S7).

[0074] When it is determined in Step S4 that the number of excavations performed after the previous first terrain recognition processing has not reached the set number of times (No in Step S4), the processing circuitry 80 receives the trajectory information indicating the movement trajectory of the tip of the bucket 16 or information (such as the posture information) necessary to calculate the movement trajectory, together with the excavation information indicating that the excavation has been performed with respect to the excavation target region (Step S8). Then, the processing circuitry 80 executes the second terrain recognition processing based on the movement trajectory (Step S9).

[0075] After Steps S7 and S9, the process returns to Step S1. Thus, each time the excavation is performed, the ground surface height data stored in the memory 83 is updated. When updating the ground surface height data in Steps S7 and S9, the ground surface height data before update does not have to be deleted, and may be accumulated as past ground surface height data. To be specific, the ground surface height data that changes during the excavating work may be accumulated in, for example, a database on a cloud server. Each time the ground surface height data is updated, the terrain recognition device 8 may transmit the ground surface height data to the controller 7 of the construction machine 1. Moreover, processing similar to the processing shown in FIG. 6 according to Modified Example is applicable to the present embodiment.

[0076] According to the present embodiment, the terrain recognition processing is executed by an external device of the construction machine 1. Therefore, the amount of calculation performed by the controller 7 of the construction machine 1 can be reduced.

[0077] The terrain recognition device 8 may be constituted by devices that are independent from each other. The terrain recognition device 8 may include a server and a user terminal that is communicably connected to the server.

Other Embodiments

[0078] The present disclosure is not limited to the above embodiments, and modifications, additions, and eliminations may be made with respect to the configurations of the embodiments.

[0079] For example, the traveling body 11 may include wheels instead of a pair of crawlers. In this case, the liquid-pressure circuit 2 may not include the traveling motors 31 and 32, and the wheels may be driven by an engine or an electric motor.

[0080] Moreover, in Embodiments 1 and 2, the pro-

gram executed by the processing circuitry is the automatic excavation program for causing the construction machine 1 to perform the excavating work with respect to the excavation target region by the autonomous operation. However, the processing circuitry may execute only the terrain recognition program for recognizing the terrain of the excavation target region, and the excavation operation by the construction machine 1 may be performed in accordance with manual operation by the operator. The operator may perform operations by boarding the construction machine 1 or by remote control from outside the construction machine 1.

[0081] For example, the operations of the construction machine 1 in Steps S2, S5, S6, and S8 of FIG. 4 and Steps T2, T4, and T8 of FIG. 6 may be controlled in accordance with the manual operation by the operator. When changing the posture of the construction machine 1 to the posture for distance measurement by the operation of the operator, the posture for distance measurement does not have to be a predetermined posture and may be a posture determined at the discretion of the operator.

[0082] Moreover, the processing circuitry may output the ground surface height data to the display included in the user interface 74 or the user interface 84. In this case, the display may display the ground surface height map shown in FIG. 5. For example, when the excavation operation by the construction machine 1 is executed by the operation of the operator, the operator can operate the construction machine 1 while grasping the terrain of the excavation target region in detail from the ground surface height data displayed on the display.

[0083] The set number of times may be a variable value. In this case, the processing circuitry may be configured to set the set number of times based on set-number-of-times information input by the user through the user interface 74, the user interface 84, or the like.

[0084] Or, the processing circuitry may be configured to acquire excavation status information indicating an excavation status of the construction machine 1 and set the set number of times based on the acquired excavation status information. The excavation status information may be, for example, ground information indicating the type or state of the ground in the excavation target region. In this case, the construction machine 1 may include a sensor that detects the ground information, and the processing circuitry may acquire the ground information from this sensor. Or, the ground information may be information input by the user through the user interface.

[0085] The excavation status information may be, for example, weather information indicating weather during excavation or weather before excavation. In this case, the construction machine 1 may receive the weather information from a weather center. Or, the weather information may be information input by the user through the user interface.

[0086] Moreover, the processing circuitry may be configured to: after the first update processing is executed, determine whether or not a deviation between the ground surface height indicated by the ground surface height data before the update and the ground surface height indicated by the ground surface height data after the update is a predetermined value or more; and when it is determined that the deviation is the predetermined value or more, change the set number of times such that the set number of times becomes smaller than the set number of times before update. In this case, the processing circuitry may sum up the deviations of all the sub-areas of the excavation target region and determine whether or not the sum of the deviations is a predetermined value or more. Or, the processing circuitry may determine whether or not a largest one of the deviations of all the sub-areas of the excavation target region is a predetermined value or more.

[0087] The foregoing has described the embodiments as examples of the technology disclosed in the present application. However, the technology in the present disclosure is not limited to these and is applicable to embodiments in which modifications, replacements, additions, omissions, and the like have been suitably made. Moreover, a new embodiment may be prepared by combining the components described in the above embodiments. For example, some of components or methods in one embodiment may be applied to another embodiment. Some components in an embodiment may be separated from the other components in the embodiment and arbitrarily extracted. Furthermore, the components shown in the attached drawings and the detailed explanations include not only components essential to solve the problems but also components for exemplifying the above technology and not essential to solve the problems. Two blocks shown sequentially in the flowchart may be executed simultaneously or may be executed in reverse order depending on the case.

[0088] The functionality of the elements disclosed herein may be implemented using circuitry or processing circuitry which includes general purpose processors, special purpose processors, integrated circuits, ASICs ("Application Specific Integrated Circuits"), FPGAs ("Field Programmable Gate Arrays"), conventional circuitry and/or combinations thereof which are configured or programmed to perform the disclosed functionality. Processors are considered processing circuitry or circuitry as they include transistors and other circuitry therein. In the disclosure, the circuitry, units, or means are hardware that carry out or are programmed to perform the recited functionality. The hardware may be any hardware disclosed herein or otherwise known which is programmed or configured to carry out the recited functionality. When the hardware is a processor which may be considered a type of circuitry, the circuitry, means, or units are a combination of hardware and software, the software being used to configure the

hardware and/or processor.

[0089] The programs disclosed in the present specification may be stored in a computerreadable storage medium. The storage medium is a non-transitory, tangible medium. The storage medium may be built into or externally attached to a computer (such as a mobile information terminal, a personal computer, or a server). The storage medium includes RAM, ROM, EEPROM, storage, and the like and may be, for example, a hard disk, a flash memory, an optical disk, or the like. The program stored in the storage medium may be executed in a computer to which the storage medium is directly connected, or may be executed in a computer to which the storage medium is connected through a communication network (such as the Internet).

[0090] The following aspects disclose preferred embodiments.

First Aspect

[0091] A terrain recognition system for a construction machine,
the construction machine including:

a bucket that excavates soil in an excavation target region; and
a distance measuring sensor,
the terrain recognition system being a system for recognizing terrain of the excavation target region,
the terrain recognition system including processing circuitry configured to:

acquire ground surface height data indicating ground surface heights of sub-areas included in the excavation target region;
each time excavation by the construction machine is executed a set number of times, execute first update processing in which the ground surface heights of the sub-areas in the ground surface height data are updated based on point cloud data acquired from the distance measuring sensor; and
execute second update processing in which the ground surface heights of the sub-areas through which the bucket has passed in the ground surface height data are updated based on trajectory information indicating a movement trajectory of the bucket.

[0092] According to the above configuration, the second update processing updates the ground surface height of the sub-area in the ground surface height data based on the movement trajectory of the bucket. Therefore, the ground surface height of the excavation target region which changes each time the excavation is performed can be recognized in real time. Moreover, according to the above configuration, each time the excavation by the construction machine is performed the set

number of times, the first update processing is executed to update the ground surface height of each sub-area based on the point cloud data acquired from the distance measuring sensor. Therefore, the discrepancy between the ground surface height of the sub-area recognized in the second update processing and the actual ground surface height of the sub-area can be eliminated at an appropriate timing. Thus, the excavating work can proceed while accurately recognizing the ground surface height of the excavation target region.

Second Aspect

[0093] The terrain recognition system according to the first aspect, wherein the processing circuitry is configured to:

each time the excavation by the construction machine is performed, determine whether or not the number of excavations performed by the construction machine after the previous first update processing has reached the set number of times;
when it is determined that the number of excavations has reached the set number of times, execute the first update processing; and
when it is determined that the number of excavations has not reached the set number of times, execute the second update processing.

Third Aspect

[0094] The terrain recognition system according to the first aspect, wherein the processing circuitry is configured to execute the second update processing each time the excavation by the construction machine is performed.

Fourth Aspect

[0095] The terrain recognition system according to any one of the first to third aspects, wherein the processing circuitry is configured to set the set number of times based on set-number-of-times information input by a user through a user interface.

[0096] According to the above configuration, the timing at which the first update processing is executed can be adjusted at the discretion of the user depending on the situation.

Fifth Aspect

[0097] The terrain recognition system according to any one of the first to fourth aspects, wherein the processing circuitry is configured to acquire excavation status information indicating an excavation status of the construction machine and set the set number of times based on the acquired excavation status information.

[0098] According to the above configuration, the set number of times can be adjusted to a value suitable for the excavation status.

Sixth Aspect

[0099] The terrain recognition system according to any one of the first to fifth aspects, wherein the processing circuitry is configured to:

after the first update processing is executed, determine whether or not a deviation between the ground surface height indicated by the ground surface height data before the update and the ground surface height indicated by the ground surface height data after the update is a predetermined value or more; and
when it is determined that the deviation is the predetermined value or more, change the set number of times such that the set number of times becomes smaller than the set number of times before the update.

According to the above configuration, the deviation between the ground surface height data before the update by the first update processing and the ground surface height data after the update by the first update processing can be kept small. Therefore, the ground surface height data can be maintained in a highly accurate state.

Seventh Aspect

[0100] A terrain recognition method for a construction machine, the construction machine including:

a bucket that excavates soil in an excavation target region; and
a distance measuring sensor,
the terrain recognition method being a method of recognizing terrain of the excavation target region, the terrain recognition method including:

acquiring ground surface height data indicating ground surface heights of sub-areas included in the excavation target region;
each time excavation by the construction machine is executed a set number of times, executing first update processing in which the ground surface heights of the sub-areas in the ground surface height data are updated based on point cloud data acquired from the distance measuring sensor; and
executing second update processing in which the ground surface heights of the sub-areas through which the bucket has passed in the ground surface height data are updated based on trajectory information indicating a move-

ment trajectory of the bucket.

[0101] According to the above method, the second update processing updates the ground surface height of the sub-area in the ground surface height data based on the movement trajectory of the bucket. Therefore, the ground surface height of the excavation target region which changes each time the excavation is performed can be recognized in real time. Moreover, according to the above method, each time the excavation by the construction machine is performed the set number of times, the first update processing is executed to update the ground surface height of each sub-area based on the point cloud data acquired from the distance measuring sensor. Therefore, the discrepancy between the ground surface height of the sub-area recognized in the second update processing and the actual ground surface height of the sub-area can be eliminated at an appropriate timing. Thus, the excavating work can proceed while accurately recognizing the ground surface height of the excavation target region.

Reference Signs List

[0102]

1	construction machine	
4	control system	
5	posture angle sensor	
6	distance measuring sensor	
10	hydraulic excavator	
13	swing body	
14	boom	
15	arm	
16	bucket	
21	pump apparatus	
40	control valve device	
70, 80	processing circuitry	
74, 84	user interface	
100	terrain recognition system	

Claims

1. A terrain recognition system for a construction machine,
the construction machine including:

a bucket that excavates soil in an excavation target region; and
a distance measuring sensor,
the terrain recognition system being a system for recognizing terrain of the excavation target region,
the terrain recognition system comprising processing circuitry configured to:

acquire ground surface height data indicating ground surface heights of sub-

areas included in the excavation target region;
each time excavation by the construction machine is executed a set number of times, execute first update processing in which the ground surface heights of the sub-areas in the ground surface height data are updated based on point cloud data acquired from the distance measuring sensor; and
execute second update processing in which the ground surface heights of the sub-areas through which the bucket has passed in the ground surface height data are updated based on trajectory information indicating a movement trajectory of the bucket.

2. The terrain recognition system according to claim 1, wherein the processing circuitry is configured to:

each time the excavation by the construction machine is performed, determine whether or not the number of excavations performed by the construction machine after the previous first update processing has reached the set number of times;
when it is determined that the number of excavations has reached the set number of times, execute the first update processing; and
when it is determined that the number of excavations has not reached the set number of times, execute the second update processing.

3. The terrain recognition system according to claim 1, wherein the processing circuitry is configured to execute the second update processing each time the excavation by the construction machine is performed.
4. The terrain recognition system according to any one of claims 1 to 3, wherein the processing circuitry is configured to set the set number of times based on set-number-of-times information input by a user through a user interface.
5. The terrain recognition system according to any one of claims 1 to 3, wherein the processing circuitry is configured to acquire excavation status information indicating an excavation status of the construction machine and set the set number of times based on the acquired excavation status information.
6. The terrain recognition system according to any one of claims 1 to 3, wherein the processing circuitry is configured to:

after the first update processing is executed,
 determine whether or not a deviation between
 the ground surface height indicated by the
 ground surface height data before the update
 and the ground surface height indicated by the
 ground surface height data after the update is
 a predetermined value or more; and
 when it is determined that the deviation is the
 predetermined value or more, change the set
 number of times such that the set number of
 times becomes smaller than the set number of
 times before the update.

7. A terrain recognition method for a construction machine,
 the construction machine including:

a bucket that excavates soil in an excavation
 target region; and
 a distance measuring sensor,
 the terrain recognition method being a method
 of recognizing terrain of the excavation target
 region,
 the terrain recognition method comprising:

acquiring ground surface height data indi-
 cating ground surface heights of sub-
 areas included in the excavation target re-
 gion;
 each time excavation by the construction
 machine is executed a set number of
 times, executing first update processing in
 which the ground surface heights of the
 sub-areas in the ground surface height
 data are updated based on point cloud
 data acquired from the distance measur-
 ing sensor; and
 executing second update processing in
 which the ground surface heights of the
 sub-areas through which the bucket has
 passed in the ground surface height data
 are updated based on trajectory informa-
 tion indicating a movement trajectory of
 the bucket.

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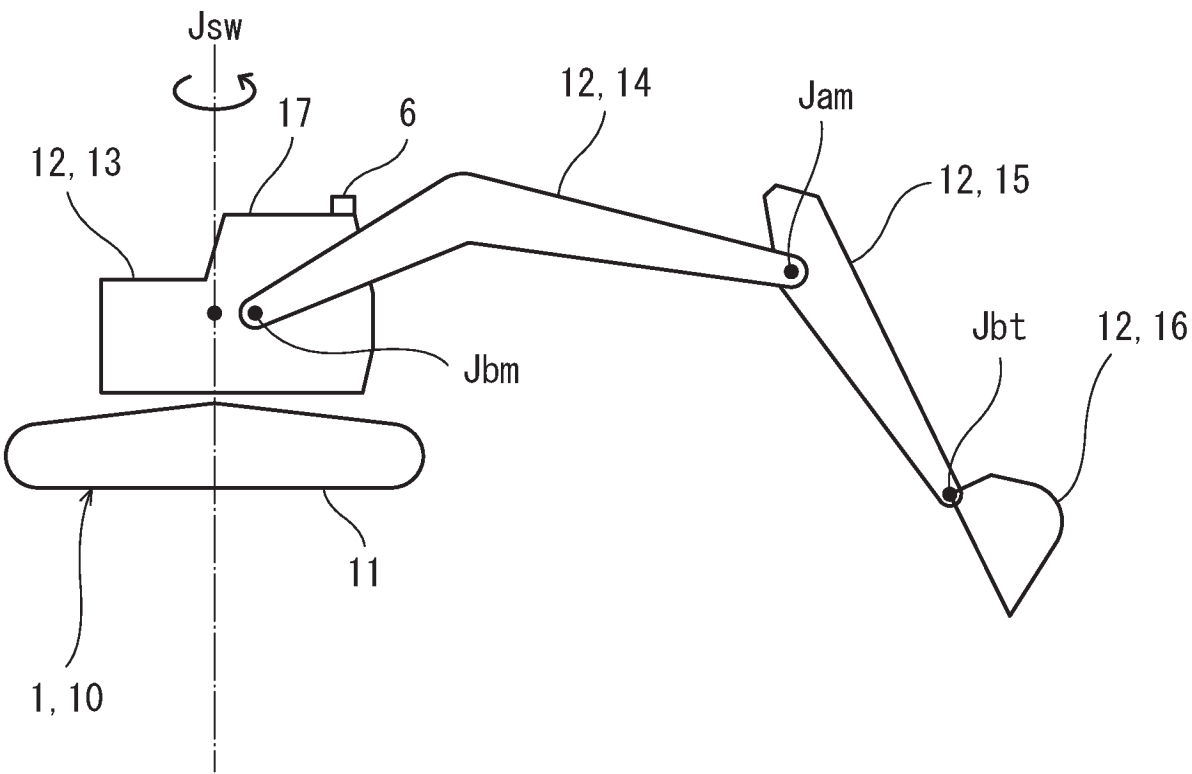


FIG. 1

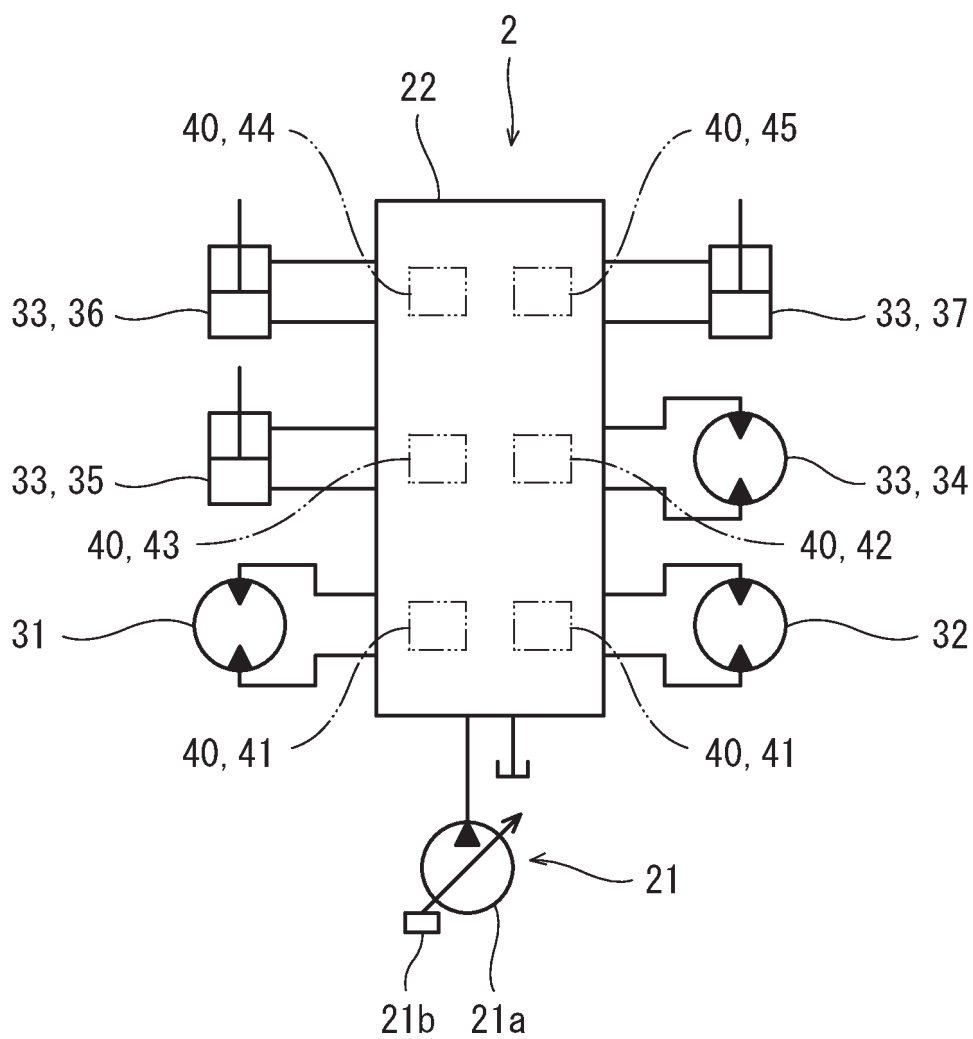


FIG. 2

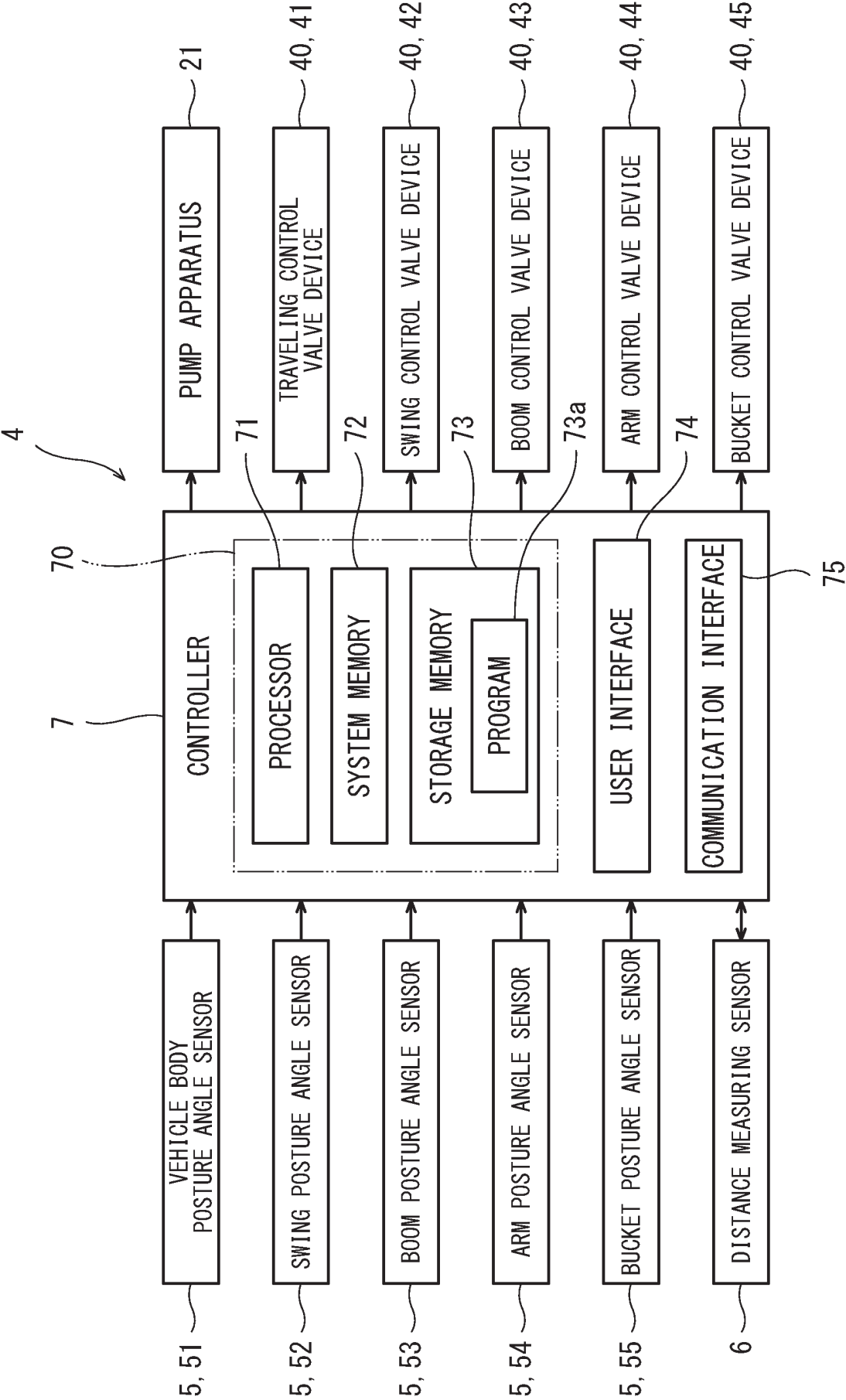


FIG. 3

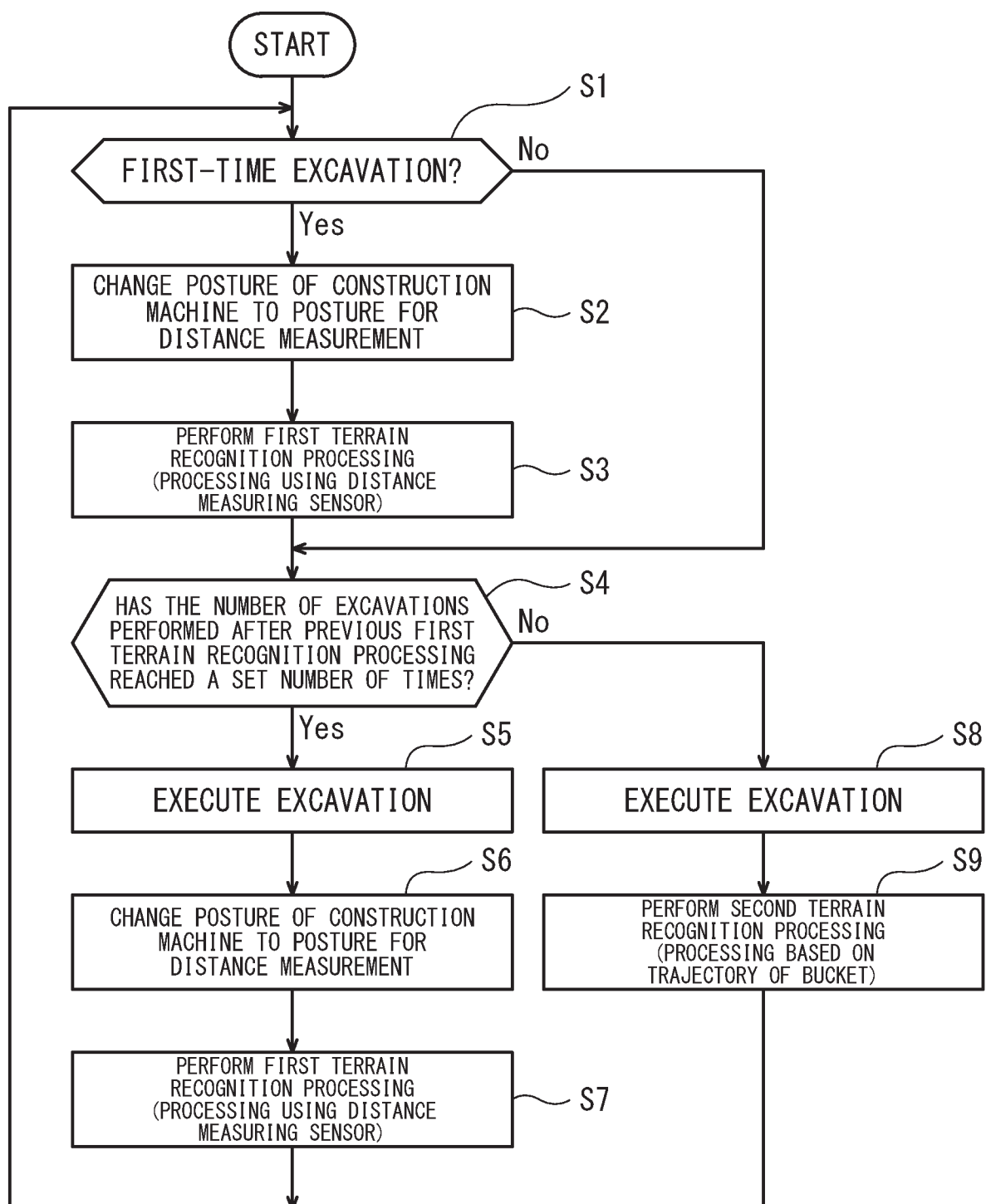


FIG. 4

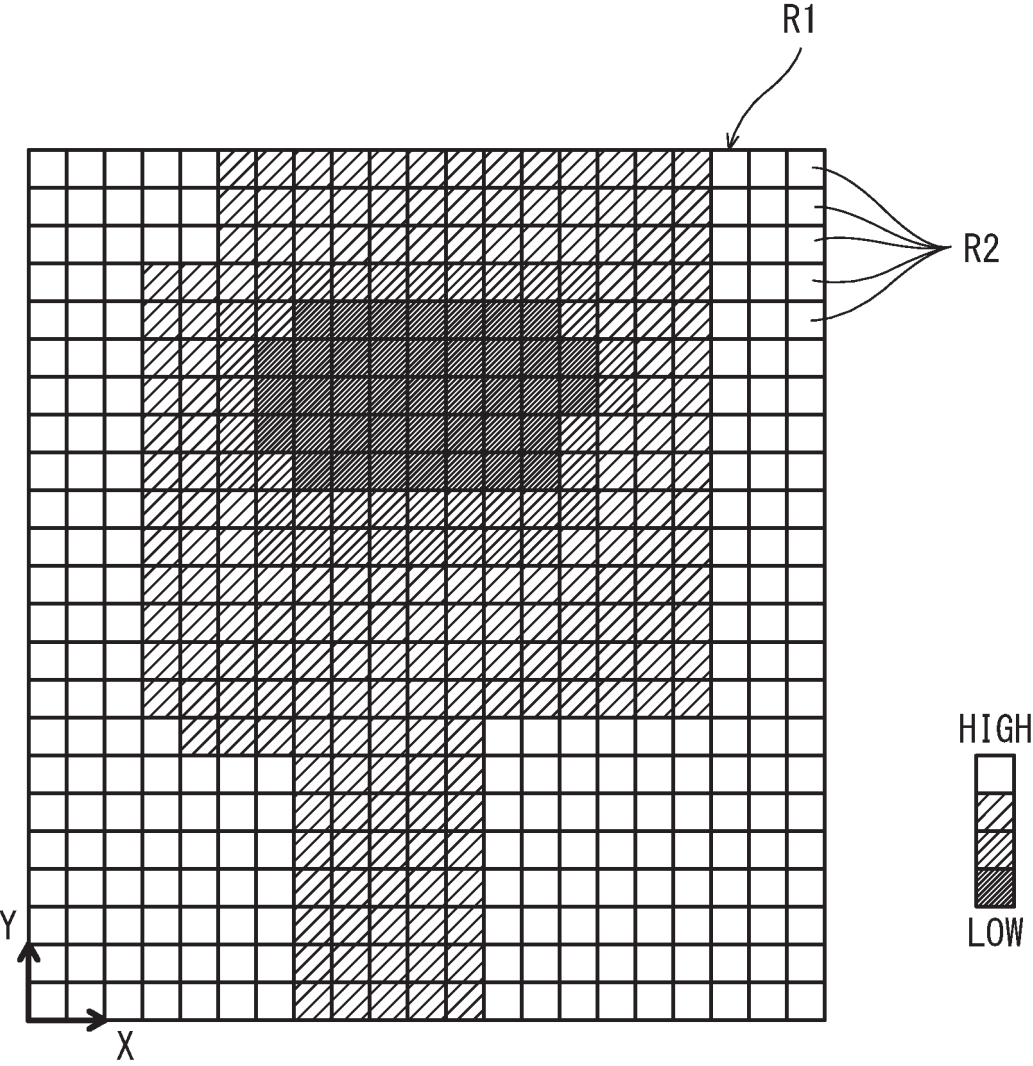


FIG. 5

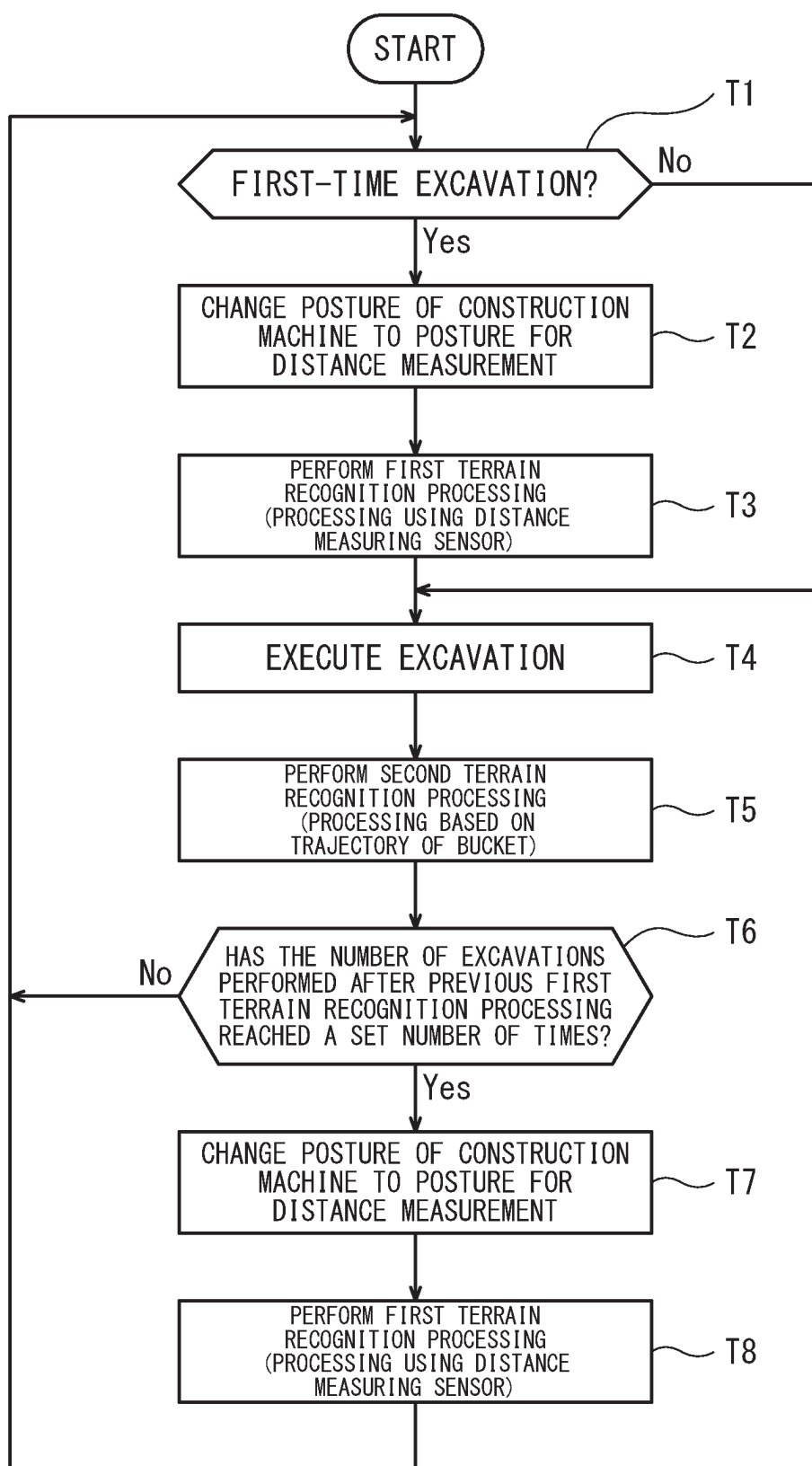


FIG. 6

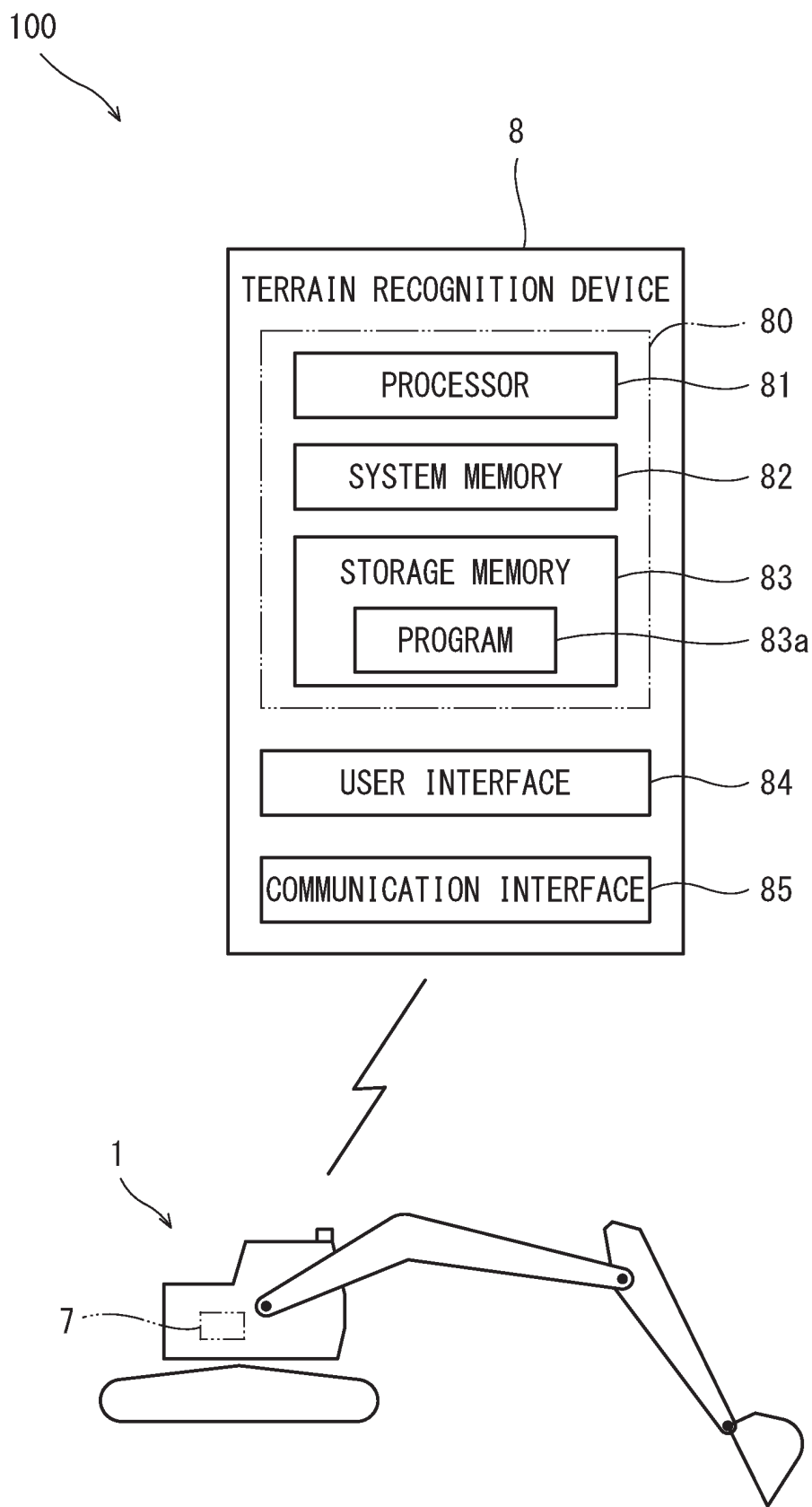


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/037566

A. CLASSIFICATION OF SUBJECT MATTER*E02F 9/20*(2006.01)i

FI: E02F9/20 Q; E02F9/20 M

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02F9/20

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

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2024
 Registered utility model specifications of Japan 1996-2024
 Published registered utility model applications of Japan 1994-2024

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2023-145255 A (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 11 October 2023 (2023-10-11) entire text, all drawings	1-7
A	JP 2022-26596 A (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 10 February 2022 (2022-02-10) entire text, all drawings	1-7
A	JP 2019-190193 A (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 31 October 2019 (2019-10-31) entire text, all drawings	1-7
A	WO 2019/175917 A1 (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 19 September 2019 (2019-09-19) entire text, all drawings	1-7

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

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

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Date of the actual completion of the international search

04 December 2024

Date of mailing of the international search report

17 December 2024

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
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 Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2024/037566

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2019/049248 A1 (HITACHI CONSTRUCTION MACHINERY CO., LTD.) 14 March 2019 (2019-03-14) entire text, all drawings	1-7
A	WO 2019/026802 A1 (SUMITOMO HEAVY INDUSTRIES, LTD.) 07 February 2019 (2019-02-07) entire text, all drawings	1-7
A	JP 2017-71915 A (KOMATSU LTD.) 13 April 2017 (2017-04-13) entire text, all drawings	1-7
A	JP 2022-174248 A (BEIJING BAIDU NETCOM SCIENCE & TECNOLOGY CO., LTD.) 22 November 2022 (2022-11-22) entire text, all drawings	1-7

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2024/037566

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	2023-145255	A	11 October 2023	(Family: none)	
JP	2022-26596	A	10 February 2022	(Family: none)	
JP	2019-190193	A	31 October 2019	(Family: none)	
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JP	2022-174248	A	22 November 2022	US	2023/0003893 A1

REFERENCES CITED IN THE DESCRIPTION

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