



EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
14.10.2020 Bulletin 2020/42

(51) Int Cl.:
G06T 7/00 (2017.01)

(21) Application number: **18900720.6**

(86) International application number:
PCT/JP2018/044473

(22) Date of filing: **04.12.2018**

(87) International publication number:
WO 2019/142523 (25.07.2019 Gazette 2019/30)

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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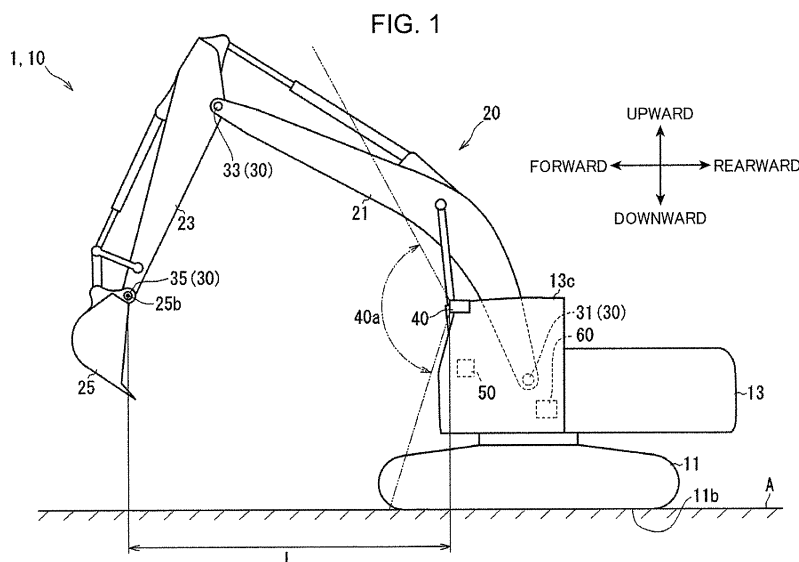
(30) Priority: **19.01.2018 JP 2018007324**

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(54) **TIP ATTACHMENT DISCRIMINATION DEVICE**

(57) A work device 20 includes, at a tip, one of different types of tip attachments 25 that are replaceable with each other. A camera 40 can capture an image within a movable range of the tip attachment 25. The work device posture sensor 30 detects the posture of the work device 20. A controller 60 sets a detection frame (F) that

is a frame of a range including the tip attachment 25 in the image captured by the camera 40 based on the posture of the work device 20 detected by the work device posture sensor 30. The controller 60 discriminates the type of the tip attachment 25 based on the image of the tip attachment 25 within the detection frame (F).



Description

Technical Field

[0001] The present invention relates to a tip attachment discrimination device that discriminates a type of a tip attachment of a work machine.

Background Art

[0002] For example, Patent Literature 1 describes a technique in which a distance sensor measures a distance distribution including a tip attachment (an attachment in Patent Literature 1) and recognizes the tip attachment based on the distance distribution (see claim 1 of Patent Literature 1).

[0003] In the technique described in Patent Literature 1, the type of the tip attachment and the like are recognized based on the distance distribution, and a distance sensor is used to measure the distance distribution. The distance sensor, however, may have higher cost than monocular cameras. When discriminating the type of the tip attachment, it is important to secure the accuracy of the discrimination.

Citation List

Patent Literature

[0004] Patent Literature 1: JP 2017-157016A

Summary of Invention

[0005] Therefore, an object of the present invention is to provide a tip attachment discrimination device that can accurately discriminate the type of the tip attachment without using the distance distribution.

[0006] A tip attachment discrimination device according to one aspect of the present disclosure is a tip attachment discrimination device of a work machine including: a lower travelling body; an upper slewing body provided above the lower travelling body; and a work device including a tip to which one of different types of tip attachments is attached in a replaceable manner, the work device being attached to the upper slewing body. The tip attachment discrimination device includes: a camera attached to the upper slewing body and configured to capture an image within a movable range of the tip attachment; a work device posture sensor configured to detect a posture of the work device; and a controller, in which the controller: sets a detection frame in an area including the tip attachment with respect to the image captured by the camera based on the posture of the work device detected by the work device posture sensor; and discriminates the type of the tip attachment based on the image of the tip attachment within the detection frame.

[0007] With the above-described configuration, it is possible to accurately discriminate the type of the tip at-

tachment without using the distance distribution.

Brief Description of Drawings

[0008]

FIG. 1 is a side view of a work machine 10.

FIG. 2 is a block diagram of a tip attachment discrimination device 1 provided in the work machine 10 shown in FIG. 1.

FIG. 3 is a flowchart of the tip attachment discrimination device 1 shown in FIG. 2.

FIG. 4 is an image captured by a camera 40 shown in FIG. 1.

FIG. 5 is an image captured by the camera 40 shown in FIG. 1.

FIG. 6 is a diagram corresponding to FIG. 1 showing a tip attachment 25 shown in FIG. 1 in a dead angle for the camera 40.

Description of Embodiment

[0009] With reference to FIGS. 1 to 6, a tip attachment discrimination device 1 shown in FIG. 1 will be described.

[0010] The tip attachment discrimination device 1 is a device that automatically discriminates a type of a tip attachment 25, and is provided in a work machine 10. The work machine 10 includes a construction machine that performs work such as construction work. As the construction machine, for example, the work machine 10 such as a hydraulic excavator, a hybrid shovel, a crane, or the like can be employed. The work machine 10 includes a lower travelling body 11, an upper slewing body 13, a work device 20, a work device posture sensor 30, and a camera 40. Furthermore, the work machine 10 includes a monitor 50 and a controller 60 shown in FIG. 2. Note that in the present specification, a front direction of the upper slewing body 13 is described as forward, a rear direction of the upper slewing body 13 is described as rearward, and forward and rearward are collectively described as a front-and-rear direction. When viewed forward from the rear, a left side is described as leftward, a right side is described as rightward, and the left side and the right side are collectively described as a right-and-left direction. A direction perpendicular to each of the front-and-rear direction and the right-and-left direction is described as an up-and-down direction. An upper side of the up-and-down direction is described as upward, and a lower side of the up-and-down direction is described as downward.

[0011] As shown in FIG. 1, the lower travelling body 11 includes, for example, a crawler, and causes the work machine 10 to travel. A bottom surface 11b of the lower travelling body 11 (bottom surface of the work machine 10) is in contact with the ground plane A. The upper slewing body 13 is provided above the lower travelling body 11 and is configured to be pivotable about the up-and-down direction with respect to the lower travelling body

11. The upper slewing body 13 includes a cab 13c (driver's cab).

[0012] The work device 20 is a device that is attached to the upper slewing body 13 and performs work. The work device 20 includes a boom 21, an arm 23, and the tip attachment 25. The boom 21 is rotatably attached to the upper slewing body 13. The arm 23 is rotatably attached to the boom 21.

[0013] The tip attachment 25 is provided at a tip of the work device 20. The tip attachment 25 is replaceable with different types of tip attachments. The types of the tip attachments 25 include a bucket (example shown in FIG. 1), a clamshell, a scissor-shaped device, a hammer, a magnet, and the like. The tip attachment 25 is rotatably attached to the arm 23. A position serving as a reference for the tip attachment 25 is referred to as a reference position 25b. The reference position 25b is a position determined regardless of the type of the tip attachment 25. The reference position 25b is, for example, a proximal portion of the tip attachment 25, and is, for example, a rotational axis (bucket pin or the like) of the tip attachment 25 with respect to the arm 23. Note that in FIGS. 2 and 3, the tip attachment 25 is described as "tip ATT." The boom 21, the arm 23, and the tip attachment 25 are driven by a boom cylinder (not shown), an arm cylinder (not shown), and an attachment cylinder (not shown), respectively.

[0014] The work device posture sensor 30 is a sensor that detects a posture of the work device 20 shown in FIG. 1. The work device posture sensor 30 includes a boom angle sensor 31, an arm angle sensor 33, and a tip attachment angle sensor 35. The boom angle sensor 31 detects an angle of the boom 21 with respect to the upper slewing body 13 (boom 21 angle). The boom angle sensor 31 includes, for example, an angle sensor such as an encoder provided in a proximal portion of the boom 21.

[0015] Here, the boom angle sensor 31 may include, for example, a sensor that detects an expansion and contraction amount of the boom cylinder that drives the boom 21. In this case, the boom angle sensor 31 is required at least to convert the expansion and contraction amount of the boom cylinder into the boom 21 angle and output the boom 21 angle to the controller 60. Alternatively, the boom angle sensor 31 may output the detected expansion and contraction amount to the controller 60, and the controller 60 may convert the expansion and contraction amount into the boom 21 angle. The configuration of detecting the angle by detecting the expansion and contraction amount of the cylinder is also applicable to the arm angle sensor 33 and the tip attachment angle sensor 35. The arm angle sensor 33 detects the angle of the arm 23 with respect to the boom 21 (arm 23 angle). The tip attachment angle sensor 35 detects the angle of the tip attachment 25 with respect to the arm 23 (tip attachment 25 angle).

[0016] The camera 40 (image capturing device) is configured to capture an image within a movable range of

the tip attachment 25. The camera 40 captures an image of the work device 20 and surroundings thereof. The camera 40 is preferably configured to capture the entire range assumed as the movable range of the tip attachment 25.

5 The camera 40 may be attached to the upper slewing body 13, for example, may be attached to the cab 13c (for example, upper left front), and may be attached to, for example, a portion of the upper slewing body 13 other than the cab 13c. The camera 40 is fixed to the upper slewing body 13. The camera 40 may be configured to be movable (for example, pivotable) with respect to the upper slewing body 13. The camera 40 may include, for example, a monocular camera. In order to reduce the cost of the camera 40, the camera 40 is preferably a monocular camera. The camera 40 preferably has, for example, a zoom function such as an optical zoom function. Specifically, a zoom position (focal length) of the camera 40 is preferably continuously variable between a telephoto side and a wide-angle side. Note that FIG. 1 shows one example of an angle of view 40a of the camera 40.

[0017] The monitor 50 displays various information items. The monitor 50 may display an image captured by the camera 40, for example, as shown in FIG. 4. The monitor 50 may display a detection frame F (see FIG. 4). Details of the detection frame F will be described later. The monitor 50 may display a discrimination result of the type of the tip attachment 25.

[0018] As shown in FIG. 2, the controller 60 (control unit) performs input-output of a signal (information), computation (determination, calculation), and the like. The controller 60 includes a first controller 61 (main control unit) and a second controller 62 (auxiliary control unit). The first controller 61 includes, for example, a computer including a processor such as a CPU and a memory such as a semiconductor memory, and controls an operation of the work machine 10 (see FIG. 1). The first controller 61 performs acquisition, processing, storage, and the like of information regarding the work machine 10. The first controller 61 is connected to the work device posture sensor 30, the camera 40, and the monitor 50. The second controller 62 includes, for example, a computer including a processor such as a CPU and a memory such as a semiconductor memory, and discriminates (identifies) the type of the tip attachment 25 from image information including the tip attachment 25 (see FIG. 4). The second controller 62 is a recognition unit that executes image recognition by artificial intelligence (AI). Note that the first controller 61 and the second controller 62 may be integrated into one. At least either one of the first controller 61 and the second controller 62 may be subdivided. For example, the first controller 61 and the second controller 62 may be divided according to different types of function.

(Operation)

[0019] With reference to the flowchart shown in FIG.

3, the operation of the tip attachment discrimination device 1 (mainly operation of the controller 60) will be described. Note that in the following, each component of the tip attachment discrimination device 1 (camera 40, controller 60, and the like) will be mainly described with reference to FIG. 1, and each step of the flowchart will be described with reference to FIG. 3.

[0020] In step S11, the camera 40 captures an image including the tip attachment 25. Here, the camera 40 is required at least to capture an image including the tip attachment 25 successively in terms of time. The controller 60 acquires the image captured by the camera 40 as shown in FIG. 4 (hereinafter referred to as "camera image Im"). Examples of the camera image Im captured by the camera 40 are shown in FIGS. 4 and 5. FIG. 5 shows a remote state in which the tip attachment 25 has become more distant from the camera 40 than in a close state shown in FIG. 4. Note that in FIGS. 4 and 5, illustration of portions other than the work machine 10 is omitted.

[0021] In step S13, the work device posture sensor 30 detects the posture of the work device 20.

In more detail, the boom angle sensor 31 detects the boom 21 angle, the arm angle sensor 33 detects the arm 23 angle, and the tip attachment angle sensor 35 detects the tip attachment 25 angle.

Then, the first controller 61 of the controller 60 acquires posture information on the work device 20 detected by the work device posture sensor 30. The first controller 61 calculates a relative position of the reference position 25b with respect to the upper slewing body 13 based on the boom 21 angle and the arm 23 angle. The first controller 61 can calculate the rough position of the tip attachment 25 based on the position of the reference position 25b and the tip attachment 25 angle. Details of this calculation will be described later.

[0022] In step S20, the first controller 61 sets the detection frame F in the camera image Im as shown in FIG. 4. The detection frame F is a frame within the camera image Im captured by the camera 40 (see FIG. 1), and is a frame set in an area including the tip attachment 25. The image inside the detection frame F is used for discriminating the type of the tip attachment 25. The image outside the detection frame F is not used for discriminating the type of the tip attachment 25.

(Setting of detection frame F)

[0023] The position, size, shape, and the like of the detection frame F in the camera image Im are set as follows. The detection frame F is set such that the entire external shape of the tip attachment 25 is included inside the detection frame F.

[0024] A background portion outside the external shape of the tip attachment 25 in the camera image Im is unnecessary information, that is, noise when discriminating the tip attachment 25. Therefore, the detection frame F is preferably set so as to minimize the back-

ground portion within the detection frame F. That is, the detection frame F is preferably set at a size as small as possible and such that the entire external shape of the tip attachment 25 fits inside the detection frame F. For example, the tip attachment 25 preferably appears in the central portion within the detection frame F.

(Setting of detection frame F based on posture of work device 20)

[0025] The position and size of the tip attachment 25 appearing in the camera image Im change depending on the posture of the work device 20. For example, as shown in FIG. 5, as the tip attachment 25 is more distant from the camera 40, the tip attachment 25 appears smaller in the camera image Im. For example, as the tip attachment 25 is at a higher position, the tip attachment 25 appears at an upper position in the camera image Im. For example, an aspect ratio of the tip attachment 25 in the camera image Im changes depending on the angle of the tip attachment 25 with respect to the arm 23.

[0026] Therefore, the detection frame F is set based on the posture of the work device 20. For example, the detection frame F is set based on the position of the reference position 25b in the camera image Im. For example, the position of the reference position 25b in the camera image Im is calculated based on the boom 21 angle and the arm 23 angle. For example, the position of the reference position 25b in the camera image Im is acquired based on the position of the reference position 25b with respect to the upper slewing body 13 or the camera 40 shown in FIG. 1, which is determined based on the boom 21 angle and the arm 23 angle. Also, the detection frame F is set based on the tip attachment 25 angle.

[0027] Specifically, the reference position 25b is calculated as follows, for example. The first controller 61 reads, from a memory (not shown), a reference position determination table in which correspondence between the boom 21 angle, the arm 23 angle, and the reference position 25b in the camera image Im is determined in advance. Then, the first controller 61 is required at least to acquire the reference position 25b by identifying the reference position 25b corresponding to the boom 31 angle detected by the boom angle sensor 31 and the arm 23 angle detected by the arm angle sensor 33 from the reference position determination table.

[0028] Here, the reference position determination table is created in advance, for example, by a simulation using the specified work machine 10. By this simulation, the camera 40 captures the work device 20 while changing each of the boom 21 angle and the arm 23 angle. Then, the position of the reference position 25b is identified in each of the obtained camera images Im, and a plurality of data sets in which the reference position 25b is associated with the boom 21 angle and the arm 23 angle is generated and stored in the position determination table. As described above, the position determination table is

created. Note that this work may be performed by a person or by image processing.

[0029] Also, the detection frame F is set in the camera image Im as described below. The first controller 61 reads, from a memory (not shown), a detection frame determination table in which correspondence between the boom 21 angle, the arm 23 angle, the tip attachment 25 angle, and detection frame information indicating the size of the detection frame F is determined in advance. Here, the detection frame information includes, for example, the length of the vertical side and the length of the horizontal side of the detection frame F, positioning information indicating a position where the reference position 25b is to be positioned within the detection frame F, and other information. Then, the first controller 61 identifies, from the detection frame determination table, the detection frame information corresponding to the boom 21 angle detected by the boom angle sensor 31, the arm 23 angle detected by the arm angle sensor 33, and the tip attachment 25 angle detected by the tip attachment angle sensor 35. Then, the first controller 61 is required at least to set the detection frame F indicated by the identified detection frame information in the camera image Im. At this time, the first controller 61 is required at least to set the detection frame F such that the reference position 25b is positioned at a position within the detection frame F indicated by the positioning information included in the detection frame information.

[0030] Here, the detection frame determination table is created in advance, for example, by a simulation using the specified work machine 10 to which the specified tip attachment 25 such as a bucket is attached. By this simulation, the camera 40 captures the work device 20 while changing each of the boom 21 angle, the arm 23 angle, and the tip attachment 25 angle. Then, a certain area including the tip attachment 25 is extracted from each of the obtained camera images Im, and the extracted area is set as the detection frame F. Here, as the detection frame F, for example, a quadrilateral area circumscribing the tip attachment 25 in the camera image Im may be employed, or a quadrilateral area slightly larger in size than the circumscribing quadrilateral may be employed. This work may be performed by a person or by image processing.

[0031] In this way, the first controller 61 sets the detection frame F based on the posture of the work device 20. Therefore, the first controller 61 does not need to use an object detection algorithm, which is a process for detecting the tip attachment 25, in the entire area of the camera image Im. Therefore, a calculation load of the first controller 61 can be reduced accordingly. Moreover, since it is not necessary to use the object detection algorithm in the entire area of the camera image Im, the detection position of the tip attachment 25 that is subject to type discrimination is not erroneously recognized. For example, it is assumed that a tip attachment 25 different from the tip attachment 25 attached to the arm 23 is positioned within the angle of view of the camera 40 and

appears in the camera image Im. In this case, the other tip attachment 25, which is not attached to the work machine 10, is not subject to type discrimination. Also, in this case, the other tip attachment 25, which is positioned away from the reference position 25b, appears outside the detection frame F in the camera image Im. Therefore, the present embodiment can prevent the other tip attachment 25 from becoming subject to type discrimination.

(Setting of detection frame F based on structure information on work machine 10)

[0032] The position and size of the tip attachment 25 appearing in the camera image Im change depending on the structure of the work machine 10. For example, the position, size, and the like of the tip attachment 25 in the camera image Im change depending on the length of the boom 21 and the length of the arm 23. Moreover, for example, the type of the tip attachment 25 that is assumed to be provided in the work device 20 changes depending on the size of the work machine 10 (for example, "XX ton class"). Then, the position, size, and the like of the tip attachment 25 in the camera image Im change.

[0033] Therefore, the detection frame F is preferably set based not only on a detection value of the work device posture sensor 30 but also on structure information indicating the structure of the work machine 10. The structure information is included in, for example, main specifications of the work machine 10. The structure information may be, for example, set (stored) in advance by the first controller 61, or may be acquired by some kind of method. The structure information includes, for example, information on the upper slewing body 13, information on the boom 21, and information on the arm 23. The structure information includes, for example, the size (dimension) and relative position of each of the upper slewing body 13, the boom 21, and the arm 23. The structure information includes the position of the camera 40 with respect to the upper slewing body 13. The controller 60 can calculate the posture of the work device 20 more accurately by using not only the detection value of the work device posture sensor 30 but also the structure information on the work machine 10. For example, the controller 60 can calculate the reference position 25b more accurately. As a result, the background portion within the detection frame F can be reduced, and the accuracy of type discrimination of the tip attachment 25 can be improved.

[0034] When setting the detection frame F by using the structure information on the work machine 10, the first controller 61 can perform processing as in the following [Example A1] or [Example A2].

[0035] [Example A1] First, the rough detection frame F is set based on the posture of the work device 20 without using the structure information on the work machine 10. Thereafter, the detection frame F may be corrected based on the structure information on the work machine 10.

[0036] Specifically, the first controller 61 first determines the size of the detection frame F with reference to the detection frame determination table described above. Next, the first controller 61 is required at least to correct the size of the detection frame F by calculating a ratio of weight information on the specified work machine 10 used when creating the detection frame determination table to weight information included in the structure information on the work machine 10, and multiplying the size of the detection frame F identified from the detection frame determination table by the ratio. Note that the weight information is information indicating the size of the work machine 10, such as "XX ton class" described above.

[0037] [Example A2] The detection frame F may be set from the beginning based on the structure information on the work machine 10 and the posture of the work device 20 without performing the correction as in [Example A1] described above. Note that the shape of the detection frame F is rectangular in the example shown in FIG. 4, but may be a polygon, a circle, an ellipse, or a similar shape other than quadrilateral.

[0038] Specifically, the first controller 61 calculates the reference position 25b in the three-dimensional coordinate system of the work machine 10 by using the length of the boom 21 and the length of the arm 23 included in the structure information, and the boom 21 angle detected by the boom angle sensor 31 and the arm 23 angle detected by the arm angle sensor 33. Then, the first controller 61 calculates the reference position 25b in the camera image Im by projecting the reference position 25b in the three-dimensional coordinate system onto a captured surface of the camera 40. Then, the first controller 61 is required at least to set the detection frame F in the camera image Im by using the detection frame determination table described above. At this time, the controller 60 may correct the size of the detection frame F as shown in Example A1.

[0039] Note that even without the structure information on the work machine 10, the structure of the work machine 10 is roughly determined and is limited to a certain range. Therefore, even when the controller 60 does not acquire the structure information on the work machine 10, the controller 60 can set the detection frame F to include the tip attachment 25.

(Change in detection frame F)

[0040] The first controller 61 sequentially changes the setting of the detection frame F according to the change in the posture of the work device 20. Specifically, for example, the detection frame F is changed as follows. When the position of the reference position 25b in the camera image Im changes, the first controller 61 changes the position of the detection frame F according to the changed position of the reference position 25b. When the reference position 25b moves away from the camera 40 and the tip attachment 25 appearing in the camera

image Im becomes smaller, the first controller 61 makes the detection frame F smaller. Similarly, when the reference position 25b comes closer to the camera 40 and the tip attachment 25 appearing in the camera image Im becomes larger, the controller 60 makes the detection frame F larger. When the angle of the tip attachment 25 with respect to the arm 23 changes and it is assumed that the aspect ratio of the tip attachment 25 appearing in the camera image Im changes, the first controller 61 changes the aspect ratio of the detection frame F. Note that in the detection frame determination table described above, a quadrilateral area circumscribing the tip attachment 25 appearing in the camera image Im or a quadrilateral area slightly larger in size than the circumscribing quadrilateral is set as the detection frame F. Therefore, if the detection frame F is set using the detection frame determination table, the size of the detection frame F is set smaller as the reference position 25b moves away from the camera 40, and the size of the detection frame F is set larger as the reference position 25b comes closer to the camera 40.

[0041] In step S31, the first controller 61 determines whether the position of the tip attachment 25 is a position that can be in a dead angle for the camera 40 as shown in FIG. 6. For example, during excavation work of the work machine 10 or the like, the tip attachment 25 may be in a dead angle for the camera 40. In order to make this determination, the first controller 61 stores information in which a predetermined posture condition is set in advance in a memory. The predetermined posture condition is a condition of the posture of the work device 20 and a condition in which the position of the tip attachment 25 can be in a dead angle for the camera 40. Specifically, this is a condition in which at least part of the tip attachment 25 can be disposed on the Z2 side opposite to the Z1 side where the camera 40 is disposed with respect to the ground plane A of the work machine 10. The ground plane A is a virtual plane parallel to the bottom surface 11b and including the bottom surface 11b. When the ground plane A is a horizontal plane, the "Z2 side" is a lower side of the ground plane A.

[0042] At the time of step S31, the type of the tip attachment 25 is unknown, and the structure (dimension, shape, and the like) of the tip attachment 25 is unknown. Therefore, even if the posture of the work device 20 is known, it is unknown whether the tip attachment 25 is actually disposed on the Z2 side of the ground plane A. Therefore, for example, the predetermined posture condition may be the posture of the work device 20 in which the largest tip attachment 25 among the tip attachments 25 assumed to be provided in the work device 20 is disposed on the Z2 side of the ground plane A. For example, the predetermined posture condition may be set based on the distance from the ground plane A to the reference position 25b.

[0043] Specifically, on the assumption that the assumed largest tip attachment 25 has been attached, the first controller 61 determines the position of the tip of the

tip attachment 25 from the boom 21 angle, the arm 23 angle, and the tip attachment 25 angle respectively detected by the boom angle sensor 31, the arm angle sensor 33, and the tip attachment angle sensor 35. Then, when the distance in the up-and-down direction between the position of the tip of the tip attachment 25 and the reference position 25b is longer than the distance in the up-and-down direction from the reference position 25b to the ground plane A, the first controller 61 may determine that the predetermined posture condition is satisfied.

[0044] As shown in FIG. 1, when the posture of the work device 20 detected by the work device posture sensor 30 does not satisfy the predetermined posture condition (NO in step S31), the process proceeds to step S33 in order to perform type discrimination of the tip attachment 25. As shown in FIG. 6, when the posture of the work device 20 satisfies the predetermined posture condition (YES in S31), the first controller 61 does not perform type discrimination of the tip attachment 25. In this case, the current flow is finished, and the process returns to, for example, "start." In this manner, when the tip attachment 25 is disposed at a position that can be in a dead angle for the camera 40, type discrimination of the tip attachment 25 is not performed. Therefore, erroneous discrimination can be eliminated, and unnecessary processing can be eliminated.

[0045] Note that in the flowchart shown in FIG. 3, after the image information of the camera 40 shown in FIG. 1 is acquired (S11), the posture information on the work device 20 is acquired (S13), and the determination in step S31 is performed. However, this is one example, and in the present invention, in a state where the image information of the camera 40 has not been acquired, that is, in a state where the processing of S11 has not been performed, the posture information on the work device 20 may be acquired (S13), and the determination of step S31 may be performed. The same is true of the determinations in steps S33 and S35. This is because the processing of steps S31, S33, and S35 does not need the camera image Im. When the posture of the work device 20 satisfies the predetermined posture condition (YES in step S31), the current flow may be finished. The same is true of NO in step S33. In this case, in a case where the type discrimination of the tip attachment 25 is not performed, the first controller 61 can omit the processing of step S11 for acquiring the image information of the camera 40. Note that in this case, it is only required that the processing of step S11 is provided between steps S35 and S37.

[0046] In step S33, the first controller 61 determines a corresponding distance L corresponding to the distance from the camera 40 to the tip attachment 25. When the corresponding distance L is too long, in the camera image Im shown in FIG. 5, the tip attachment 25 may appear small, an image of a portion of the tip attachment 25 may be unclear even if enlarged, and the accuracy of type discrimination of the tip attachment 25 may not be se-

cured. Therefore, it is determined whether the corresponding distance L shown in FIG. 1 is short enough to secure the accuracy of discrimination. In more detail, the first controller 61 acquires the corresponding distance L corresponding to the distance from the tip attachment 25 to the camera 40 based on the posture of the work device 20 detected by the work device posture sensor 30.

[0047] At the time of step S33, the type of the tip attachment 25 is unknown, and the structure of the tip attachment 25 is unknown. Therefore, the actual distance from the camera 40 to the tip attachment 25 is unknown. Therefore, in the determination of step S33, the corresponding distance L corresponding to the actual distance from the camera 40 to the tip attachment 25 is used. For example, the corresponding distance L is a distance in the front-and-rear direction from the camera 40 to the reference position 25b. The same is true of step S35. Alternatively, the corresponding distance L may be, for example, a distance in the front-and-rear direction between the camera 40 and the largest tip attachment 25 among the tip attachments 25 assumed to be provided in the work device 20. The same is true of step S35.

[0048] When the corresponding distance L is equal to or shorter than a first predetermined distance determined in advance (YES in step S33), the process proceeds to step S35 in order to perform type discrimination of the tip attachment 25. A value of the first predetermined distance is set in the first controller 61 in advance. The first predetermined distance is set according to whether the accuracy of discriminating the tip attachment 25 can be secured. For example, the first predetermined distance is set according to the performance of the camera 40, discriminating capability of the second controller 62, and the like. The same is true of a second predetermined distance used in step S35. Note that, for example, when a zoom function of the camera 40 is used, it is only required that the accuracy of discrimination of the tip attachment 25 can be secured with the zoom position being on the most telephoto side. The first predetermined distance is 5 m in the example shown in FIG. 3, but can be set in various manners.

[0049] When the corresponding distance L is longer than the first predetermined distance (NO in step S33), the first controller 61 does not perform type discrimination of the tip attachment 25. In this case, the current flow is finished, and the process returns to, for example, "start." In this way, when the corresponding distance L corresponding to the distance from the camera 40 to the tip attachment 25 is long and there is a possibility that the accuracy of type discrimination of the tip attachment 25 may not be secured, type discrimination of the tip attachment 25 is not performed. Therefore, erroneous discrimination can be eliminated, and unnecessary processing can be eliminated.

[0050] In step S35, the first controller 61 determines whether to set the zoom position of the camera 40 at a position on the telephoto side from the most wide-angle side based on the corresponding distance L. When the

corresponding distance L is equal to or longer than the second predetermined distance (YES step S35), the process proceeds to step S37. A value of the second predetermined distance is set by the controller 60 in advance. The second predetermined distance is shorter than the first predetermined distance. The second predetermined distance is 3 m in the example shown in FIG. 3, but can be set in various manners. When the corresponding distance L is shorter than the second predetermined distance (NO in step S35), the zoom position of the camera 40 is set on the most wide-angle side, and the process proceeds to step S40. Note that it is possible to set the corresponding distance L at various distances. For example, the corresponding distance L used in the determination of step S33 and the corresponding distance L used in the determination of step S35 may be the same or different from each other.

[0051] In step S37, the first controller 61 sets the zoom position of the camera 40 at a position on the telephoto side from the most wide-angle side. As the corresponding distance L increases, the zoom position of the camera 40 is set on the telephoto side more, and the image including the detection frame F is enlarged. This control is performed when the corresponding distance L is equal to or shorter than a first predetermined value (YES in S33) (for example, 5 m or shorter) and equal to or longer than a second predetermined value (YES in S35) (for example, 3 m or longer). By setting the zoom position of the camera 40 on the telephoto side, the image of the tip attachment 25 becomes clearer than when the image of the tip attachment 25 is enlarged as it is and magnified, and the accuracy of type discrimination of the tip attachment 25 can be improved.

[0052] Note that when the zoom position of the camera 40 is set on the telephoto side in step S37, the first controller 61 is required at least to change the size of the detection frame F according to a telephoto ratio. In this case, the first controller 61 is required at least to read, from a memory, a table in which correspondence between the telephoto ratio and an enlargement ratio of the detection frame F according to the telephoto ratio is defined in advance, refer to the table to identify the enlargement ratio of the detection frame F according to the telephoto ratio, and enlarge the detection frame F that is set in step S20 by the identified enlargement ratio. In this table, for example, the enlargement ratio of the detection frame F is stored in the camera image Im captured by telephotography such that the size of the detection frame F is enlarged to a size that includes the entire area of the image of the tip attachment.

[0053] In step S40, the second controller 62 of the controller 60 discriminates the type of the tip attachment 25. This discrimination is performed based on the image of the tip attachment 25 within the detection frame F. The discrimination is performed by comparing a feature amount of the tip attachment 25 acquired from the image of the tip attachment 25 within the detection frame F with a feature amount that is set in advance by the second

controller 62. The feature amount used for the discrimination is, for example, a contour shape (external shape) of the tip attachment 25.

[0054] In more detail, the first controller 61 shown in FIG. 2 cuts out the image within the detection frame F (see FIG. 4) from the camera image Im under arbitrary conditions and timing. That is, the first controller 61 eliminates an area other than the detection frame F from the camera image Im. The number of images to be cut out within the detection frame F may be one, or may be two or more. Specifically, the first controller 61 may cut out a plurality of detection frames F by cutting out the detection frame F from each of the plurality of camera images Im successive on a time-series basis.

[0055] The first controller 61 outputs the cut out images to the second controller 62. In a memory of the second controller 62, a feature amount of a reference image serving as a reference for type discrimination of the tip attachment 25 is stored in advance in association with a type name of the tip attachment 25. The reference image includes images of various postures of various types of tip attachments 25. The second controller 62 acquires the image within the detection frame F input from the first controller 61 as an input image, and calculates the feature amount from the input image. Here, as the feature amount, for example, a contour shape of the image within the detection frame F can be employed. The second controller 62 is required at least to extract the contour shape of the image within the detection frame F by applying, for example, a predetermined edge detection filter to the acquired input image, and calculate the contour shape as the feature amount.

[0056] Then, the second controller 62 discriminates the type of the tip attachment 25 by comparing the feature amount of the input image with the feature amount of the reference image. As tendencies of the feature amount of the input image and the feature amount of the reference image match more, the accuracy of type discrimination of the tip attachment 25 increases. Moreover, as the number of reference images increases and an amount of learning increases, the accuracy of type discrimination of the tip attachment 25 increases. Then, the second controller 62 outputs a discrimination result to the first controller 61.

[0057] Specifically, the second controller 62 is required at least to identify the feature amount of the reference image having the highest similarity to the feature amount of the input image among the feature amounts of the reference image stored in the memory, and output the type name of the tip attachment 25 associated with the identified feature amount of the reference image to the first controller 61 as the discrimination result.

[0058] The feature amount of the reference image is generated in advance by performing machine learning on a plurality of images of the tip attachment 25 having different postures for each of different types. As the machine learning, for example, a neural network, clustering, Bayesian network, support vector machine, and the like

can be employed. As the feature amount, in addition to the outline shape, for example, the Haar-LIKE feature amount, pixel difference feature amount, edge of histogram (EOH) feature amount, histogram of oriented gradients (HOG) feature amount, and the like can be employed.

[0059] Alternatively, the second controller 62 stores, in a memory, a neural network obtained by performing machine learning on a plurality of images of the tip attachment 25 using the type name of the tip attachment 25 as a teacher signal. Then, the second controller 62 may input the input image acquired from the first controller 61 into the neural network, and output the type name of the tip attachment 25 output from the neural network as the discrimination result to the first controller 61.

[0060] Note that when a mode is employed in which a plurality of images of the detection frame F is input from the first controller 61, the second controller 62 is required at least to compare each of the feature amounts of the plurality of images of the detection frame F with each of the feature amounts of the plurality of reference images stored in a memory to determine the type of the tip attachment 25 by majority decision. That is, the second controller 62 is required at least to determine the type of the tip attachment 25 most often discriminated in the discrimination result for each of the plurality of images of the detection frame F as the final type of the tip attachment 25.

[0061] Here, a capturing angle of the camera 40 with respect to the tip attachment 25 is limited more when the camera 40 shown in FIG. 1 is fixed to the upper slewing body 13 than when the camera 40 is not fixed to the upper slewing body 13. Therefore, when the camera 40 is fixed to the upper slewing body 13, the reference image required for type discrimination of the tip attachment 25 can be reduced. This facilitates collection of the reference image.

[0062] In step S50, the first controller 61 outputs the discrimination result input from the second controller 62 to the monitor 50. In this case, the first controller 61 may output the discrimination result to the monitor 50 by outputting a display command for displaying the discrimination result to the monitor 50. Here, the monitor 50 may display, for example, a character string indicating the type name of the tip attachment 25, an icon that graphically indicates the type of the tip attachment 25, or both the character string and the icon.

[0063] Note that the discrimination result may be used for interference prevention control of the work machine 10. Specifically, the first controller 61 determines the tip position of the tip attachment 25 by using the discrimination result of the tip attachment 25, the boom 21 angle, the arm 23 angle, and the tip attachment 25 angle. Then, when the first controller 61 determines that the tip position is positioned in an interference prevention area that is set around the work machine 10, the first controller 61 is required at least to execute interference prevention control such as reducing the operation speed of the work

device 20 or stopping the operation of the work device 20.

(Comparison with technology using distance sensor)

[0064] An examination is performed into a case where type discrimination of the tip attachment 25 shown in FIG. 1 is performed based on the distance distribution (distance image, depth distribution) detected by the distance sensor. In this case, there is a problem that the distance sensor has a higher cost than the monocular camera. Also, there is a problem that the distance sensor is more affected by dust than the monocular camera. Meanwhile, in the present embodiment, the monocular camera can be used as the camera 40. When the camera 40 is the monocular camera, these problems can be eliminated.

[0065] Furthermore, the distance sensor such as a time of flight (TOF) sensor has a narrow angle of view, and thus has a more limited detection range than the monocular camera. Therefore, it is considered to measure the distance distribution around the tip attachment 25 by using the distance sensor, for example, with the work device 20 in a specified limited posture, such as a posture in which the tip attachment 25 is in contact with the ground. However, in this case, when discriminating the type of the tip attachment 25, it is necessary to set the work device 20 in the specified posture, taking much time. Meanwhile, in the present embodiment, when discriminating the type of the tip attachment 25, the posture of the work device 20 can be set in almost any posture. Therefore, in the present embodiment, the degree of freedom of posture of the work device 20 when discriminating the type of the tip attachment 25 is high. In more detail, in the present embodiment, except for a state where type discrimination of the tip attachment 25 is not performed as in a case of YES in S31 and NO in S33 of FIG. 3, type discrimination of the tip attachment 25 can be performed with the work device 20 in any posture. Note that the condition under which type discrimination of the tip attachment 25 is not performed can be set in various manners.

(Advantageous effects)

[0066] Advantageous effects of the tip attachment discrimination device 1 shown in FIG. 1 are as follows.

(First advantageous effect of the invention)

[0067] The tip attachment discrimination device 1 includes the work device 20, the camera 40, the work device posture sensor 30, and the controller 60. The work device 20 is attached to the upper slewing body 13 of the work machine 10. The work device 20 includes a tip (tip of the work device 20) including a plurality of types of tip attachment 25 in a replaceable manner. The camera 40 is attached to the upper slewing body 13 and can capture an image within a movable range of the tip attachment 25. The work device posture sensor 30 detects the pos-

ture of the work device 20.

[0068] [Configuration 1-1] The controller 60 sets the detection frame F (see FIG. 4) in an area including the tip attachment 25 with respect to the image captured by the camera 40 based on the posture of the work device 20 detected by the work device posture sensor 30. Hereinafter, FIG. 4 is referred to for the detection frame F.

[0069] [Configuration 1-2] The controller 60 discriminates the type of the tip attachment 25 based on the image of the tip attachment 25 within the detection frame F.

[0070] In the above-described [Configuration 1-2], the controller 60 performs type discrimination of the tip attachment 25 based on the image. Therefore, the controller 60 can discriminate the type of the tip attachment 25 without using the distance distribution. As a result, the cost of the camera 40 can be reduced more than when the camera 40 needs to acquire the distance distribution.

[0071] Meanwhile, it can be said that there is less information for discrimination by distance information when type discrimination of the tip attachment 25 is performed based on the image than when type discrimination is performed using the distance distribution. Therefore, even if there is little information for discrimination, it is important to secure the accuracy of type discrimination of the tip attachment 25. Here, the appearance of the tip attachment 25 in the camera image Im (for example, position, size, shape, and the like) changes depending on the posture of the work device 20.

[0072] Therefore, in the above-described [Configuration 1-1], the controller 60 sets the detection frame F including the tip attachment 25 based on the posture of the work device 20. Therefore, the controller 60 can set the detection frame F suitable for type discrimination of the tip attachment 25. For example, the controller 60 can set the detection frame F such that the entire tip attachment 25 is included and the background portion around the tip attachment 25 is minimized. Therefore, it is possible to make the accuracy of type discrimination of the tip attachment 25 better than when the detection frame F is not set based on the posture of the work device 20. Therefore, the tip attachment discrimination device 1 can accurately perform type discrimination of the tip attachment 25 even without using the distance distribution.

(Second advantageous effect of the invention)

[0073] [Configuration 2] The camera 40 is fixed to the upper slewing body 13.

[0074] With the above-described [Configuration 2], the capturing angle of the camera 40 with respect to the tip attachment 25 is limited more than when the camera 40 is not fixed to the upper slewing body 13. Therefore, an amount of information required for type discrimination of the tip attachment 25 can be reduced.

(Third advantageous effect of the invention)

[0075] [Configuration 3] The controller 60 sequentially changes the setting of the detection frame F according to a change in the posture of the work device 20 detected by the work device posture sensor 30.

[0076] With the above-described [Configuration 3], after the detection frame F is set, even if the posture of the work device 20 changes, the controller 60 can perform type discrimination of the tip attachment 25.

(Fourth advantageous effect of the invention)

[0077] [Configuration 4] The controller 60 sets the detection frame F based on the structure information on the work machine 10.

[0078] With the above-described [Configuration 1-1] and [Configuration 4], the controller 60 sets the detection frame F based on the posture of the work device 20 detected by the work device posture sensor 30 and the structure information on the work machine 10. Therefore, the controller 60 can set the detection frame F more suitable for type discrimination of the tip attachment 25 than when the detection frame F is set based only on the posture of the work device 20.

(Fifth advantageous effect of the invention)

[0079] [Configuration 5] The camera 40 has a zoom function. The controller 60 calculates the distance from the tip attachment 25 to the camera 40 based on the posture of the work device 20 detected by the work device posture sensor 30, and sets the zoom position of the camera 40 on the telephoto side as the distance increases.

[0080] With the above-described [Configuration 5], even if the distance from the tip attachment 25 to the camera 40 becomes longer, by setting the zoom position of the camera 40 on the telephoto side, the resolution of the image of the tip attachment 25 within the detection frame F can be increased. Therefore, the accuracy of type discrimination of the tip attachment 25 can be improved.

(Sixth advantageous effect of the invention)

[0081] As shown in FIG. 6, the predetermined posture condition is set in advance in the controller 60. The predetermined posture condition is a condition of the posture of the work device 20, and is a condition in which the tip attachment 25 can be disposed on the Z2 side opposite to the Z1 side on which the work machine 10 is disposed with respect to the ground plane A of the work machine 10.

[0082] [Configuration 6-1] When the posture of the work device 20 detected by the work device posture sensor 30 does not satisfy the predetermined posture condition (NO in step S31 of FIG. 3), the controller 60 per-

forms type discrimination of the tip attachment 25 shown in FIG. 6.

[0083] [Configuration 6-2] When the posture of the work device 20 detected by the work device posture sensor 30 satisfies the predetermined posture condition (YES in step S31 of FIG. 3), the controller 60 does not perform type discrimination of the tip attachment 25 shown in FIG. 6.

[0084] When the tip attachment 25 can be disposed on the Z2 side with respect to the ground plane A, at least part of the tip attachment 25 may be in a dead angle for the camera 40. Then, type discrimination of the tip attachment 25 cannot be performed or the accuracy of discrimination cannot be secured in some cases. Therefore, the tip attachment discrimination device 1 has the above-described [Configuration 6-2]. Therefore, it is possible to inhibit the controller 60 from erroneously discriminating the type of the tip attachment 25, and to eliminate unnecessary processing of the controller 60. Also, the above-described [Configuration 6-2] makes it possible to perform type discrimination of the tip attachment 25 in a state where it is easy to secure the accuracy of type discrimination of the tip attachment 25. As a result, the accuracy of type discrimination of the tip attachment 25 can be improved.

(Seventh advantageous effect of the invention)

[0085] The controller 60 acquires the corresponding distance L corresponding to the distance from the tip attachment 25 to the camera 40 based on the posture of the work device 20 detected by the work device posture sensor 30.

[0086] [Configuration 7-1] When the corresponding distance L is equal to or shorter than the first predetermined distance determined in advance (predetermined distance) (when YES in step S33 of FIG. 3), the controller 60 performs type discrimination of the tip attachment 25 shown in FIG. 1.

[0087] [Configuration 7-2] When the corresponding distance L is longer than the first predetermined distance (when NO in step S33 of FIG. 3), the controller 60 does not perform type discrimination of the tip attachment 25 shown in FIG. 1.

[0088] There is a possibility that, as the corresponding distance L increases and the distance from the camera 40 to the tip attachment 25 increases, in the camera image Im (see FIG. 4), the tip attachment 25 appears smaller, and it becomes more difficult to secure the accuracy of type discrimination of the tip attachment 25. Therefore, the tip attachment discrimination device 1 has the above-described [Configuration 7-2]. Therefore, it is possible to inhibit the controller 60 from erroneously discriminating the type of the tip attachment 25, and to eliminate unnecessary processing of the controller 60. Also, the above-described [Configuration 7-1] enables type discrimination of the tip attachment 25 in a state where it is easy to perform discrimination while the accuracy of type dis-

crimination of the tip attachment 25 is secured. As a result, the accuracy of type discrimination of the tip attachment 25 can be improved.

5 (Modification)

[0089] The above-described embodiment may be modified in various manners. For example, connections between blocks in the block diagram shown in FIG. 2 may be changed. For example, order of steps in the flow-chart shown in FIG. 3 may be changed. For example, the number of components of the tip attachment discrimination device 1 shown in FIGS. 1 and 2 may be changed, and some of the components may not be provided.

10 **[0090]** Some components of the tip attachment discrimination device 1 may be provided outside the work machine 10. For example, the second controller 62 shown in FIG. 2 may be provided outside the work machine 10. For example, the monitor 50 may not be provided.

Claims

25 1. A tip attachment discrimination device of a work machine including: a lower travelling body; an upper slewing body provided above the lower travelling body; and a work device including a tip to which one of different types of tip attachments is attached in a replaceable manner, the work device being attached to the upper slewing body, the tip attachment discrimination device comprising:

30 a camera attached to the upper slewing body and configured to capture an image within a movable range of the tip attachment;
35 a work device posture sensor configured to detect a posture of the work device; and
40 a controller,
wherein the controller:

45 sets a detection frame in an area including the tip attachment with respect to the image captured by the camera based on the posture of the work device detected by the work device posture sensor; and
50 discriminates the type of the tip attachment based on the image of the tip attachment within the detection frame.

2. The tip attachment discrimination device according to claim 1, wherein the camera is fixed to the upper slewing body.

55 3. The tip attachment discrimination device according to claim 1 or 2, wherein the controller sequentially changes a setting of the detection frame according to a change in the posture of the work device detect-

ed by the work device posture sensor.

4. The tip attachment discrimination device according to any one of claims 1 to 3, wherein the controller sets the detection frame based on structure information on the work machine. 5

5. The tip attachment discrimination device according to any one of claims 1 to 4, wherein the camera has a zoom function, and the controller calculates a distance from the tip attachment to the camera based on the posture of the work device detected by the work device posture sensor, and sets a zoom position of the camera on a telephoto side as the distance increases. 10 15

6. The tip attachment discrimination device according to any one of claims 1 to 5, wherein in the controller, a posture in which the tip attachment is disposed on a side opposite to a side on which the camera is disposed with respect to a ground plane of the work machine is set in advance as a predetermined posture condition, and the controller: 20 25
 - performs processing for discriminating the type of the tip attachment when the posture of the work device detected by the work device posture sensor does not satisfy the predetermined posture condition; and 30
 - does not perform the processing for discriminating the type of the tip attachment when the posture of the work device detected by the work device posture sensor satisfies the predetermined posture condition. 35

7. The tip attachment discrimination device according to any one of claims 1 to 6, wherein the controller:
 - acquires a corresponding distance corresponding to the distance from the tip attachment to the camera based on the posture of the work device detected by the work device posture sensor; 40
 - performs the processing for discriminating the type of the tip attachment when the corresponding distance is equal to or shorter than a predetermined distance determined in advance; and 45
 - does not perform the processing for discriminating the type of the tip attachment when the corresponding distance is longer than the predetermined distance. 50

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FIG. 1

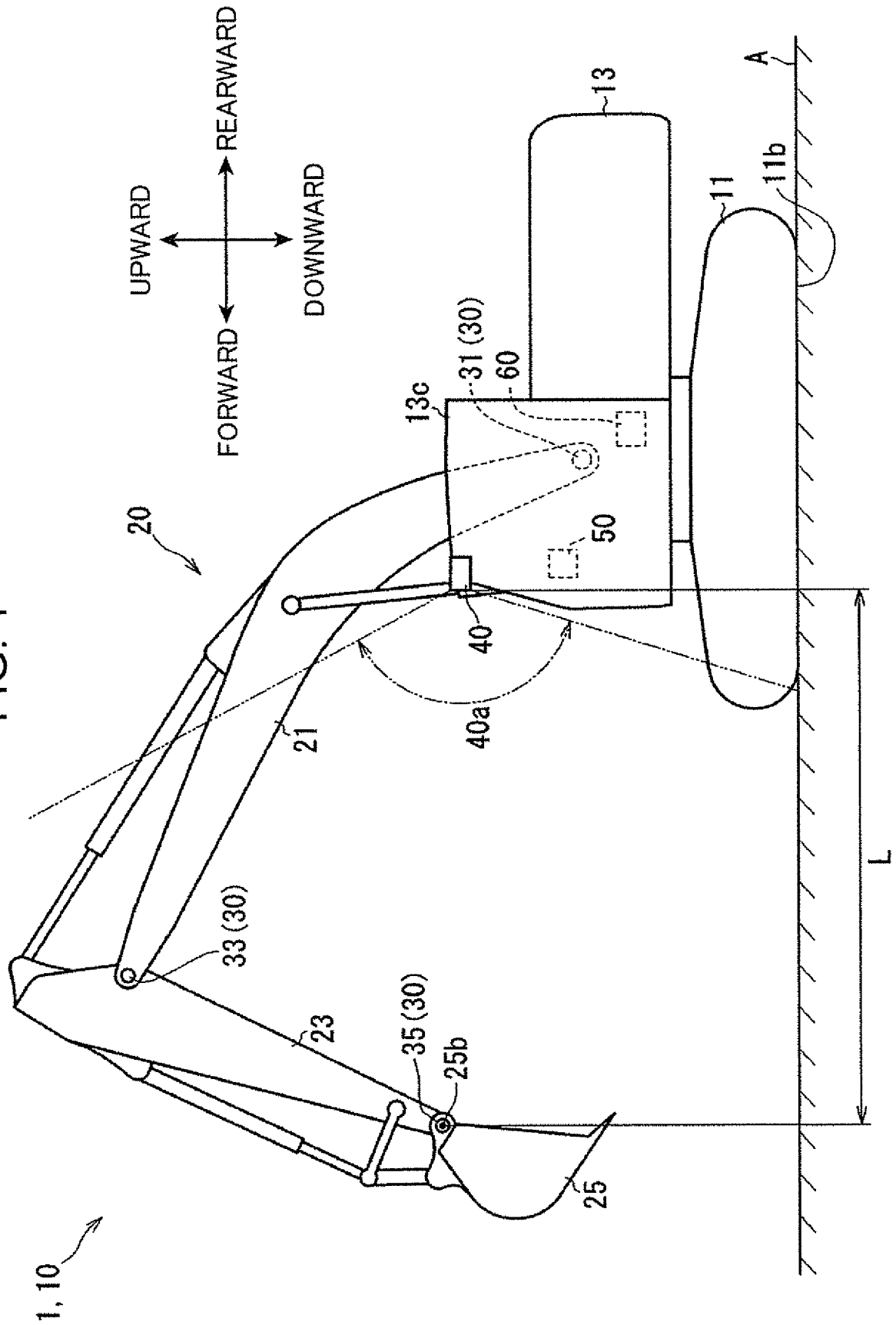


FIG. 2

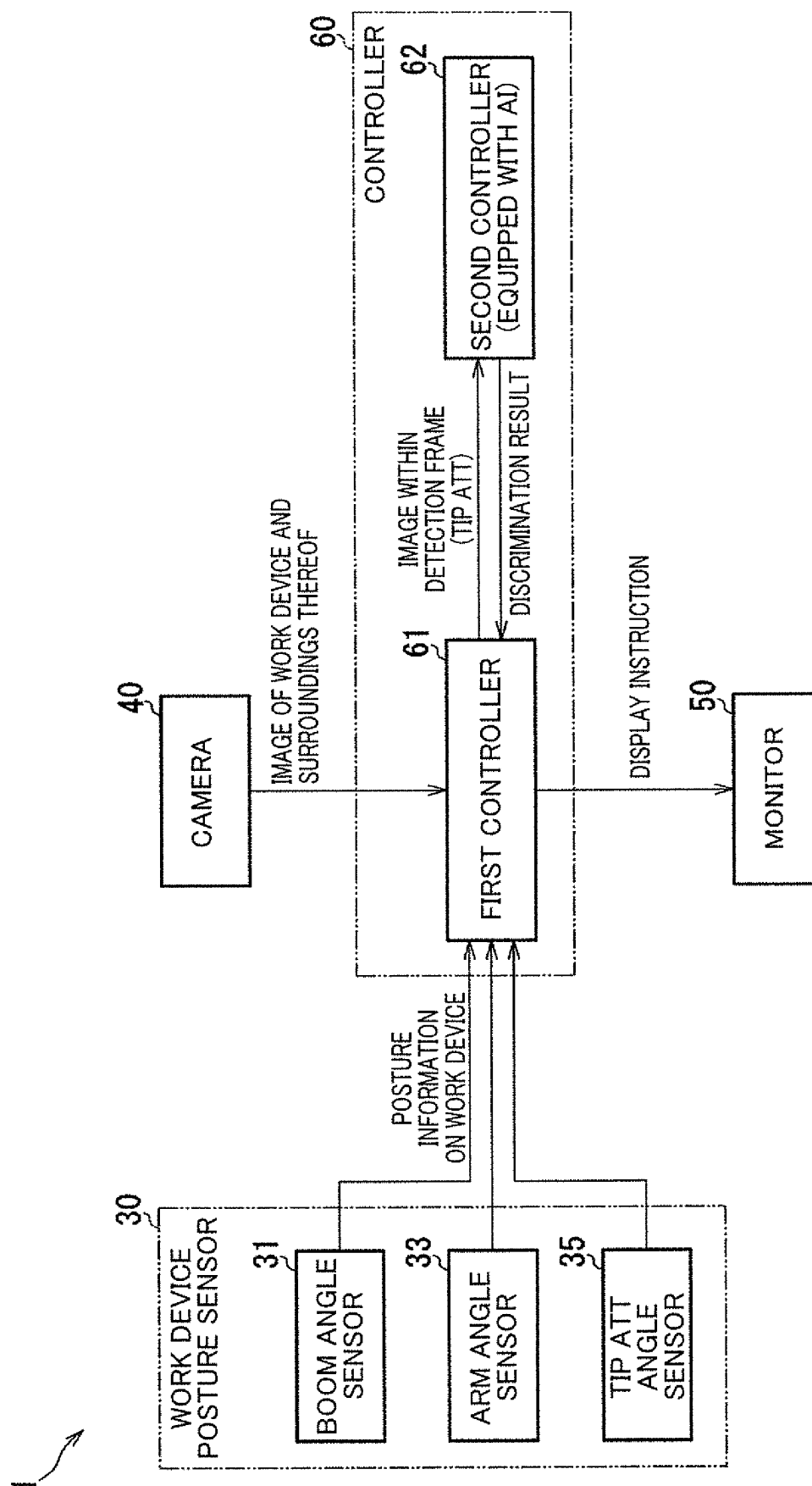


FIG. 3

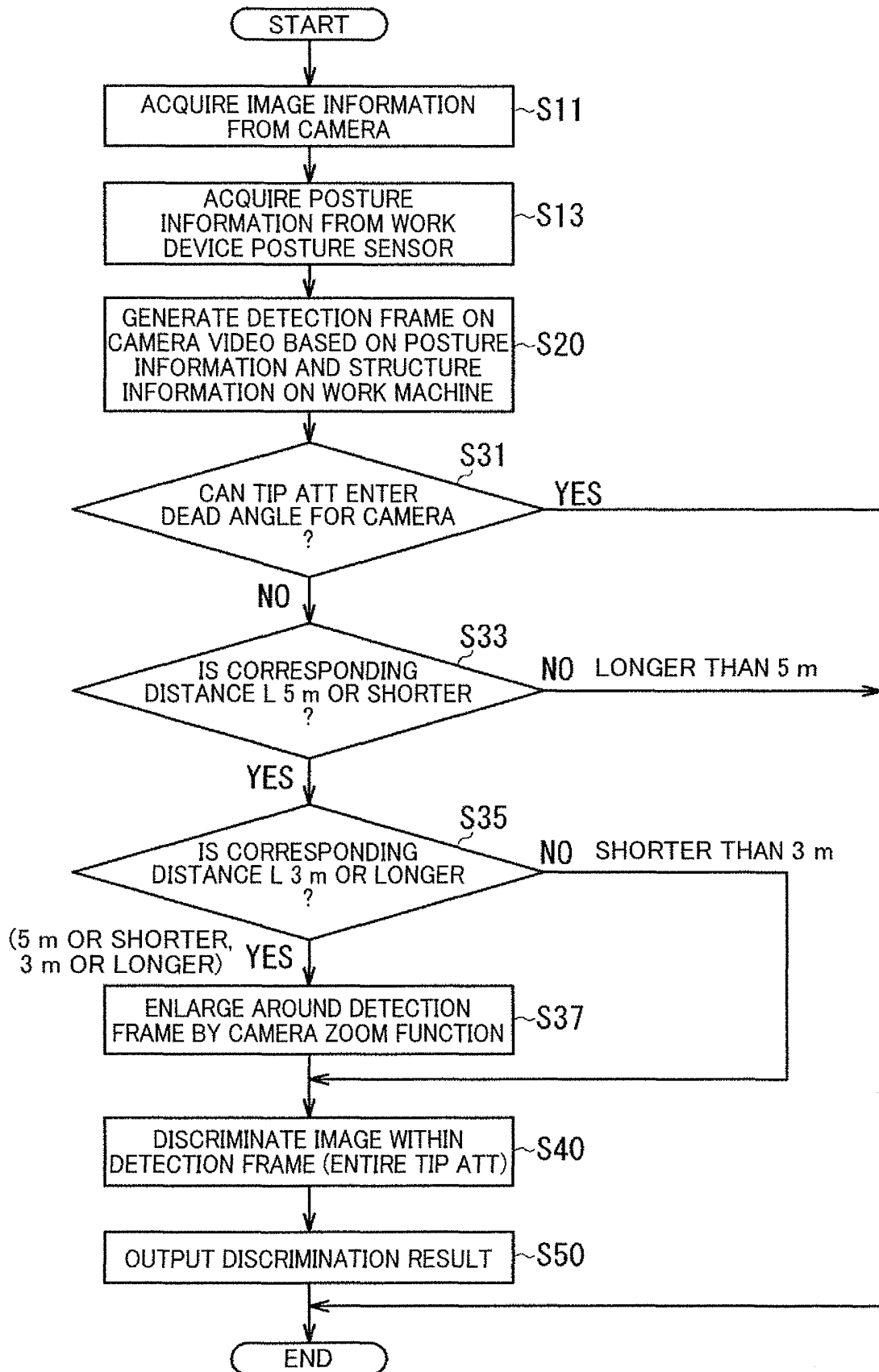


FIG. 4

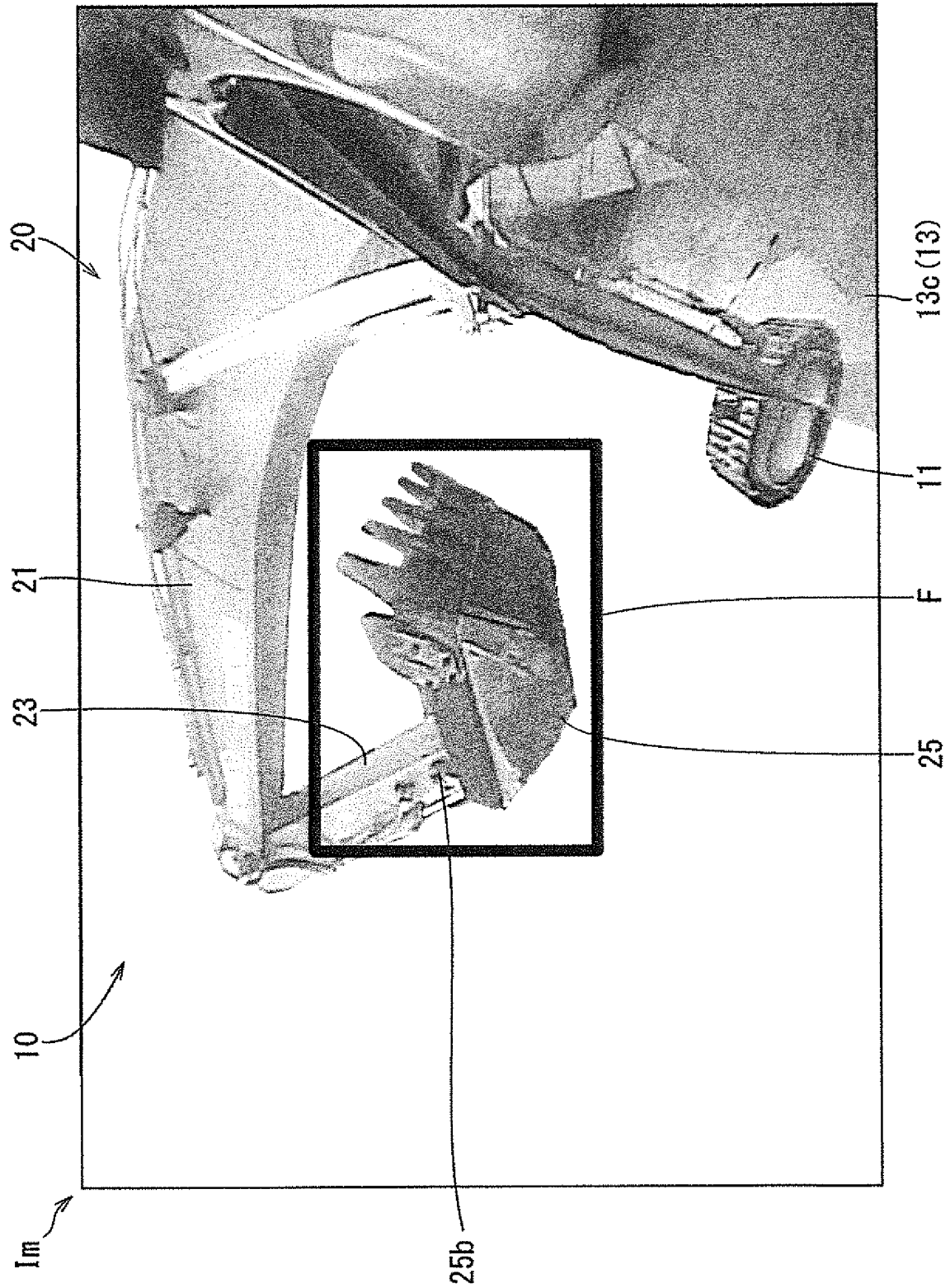
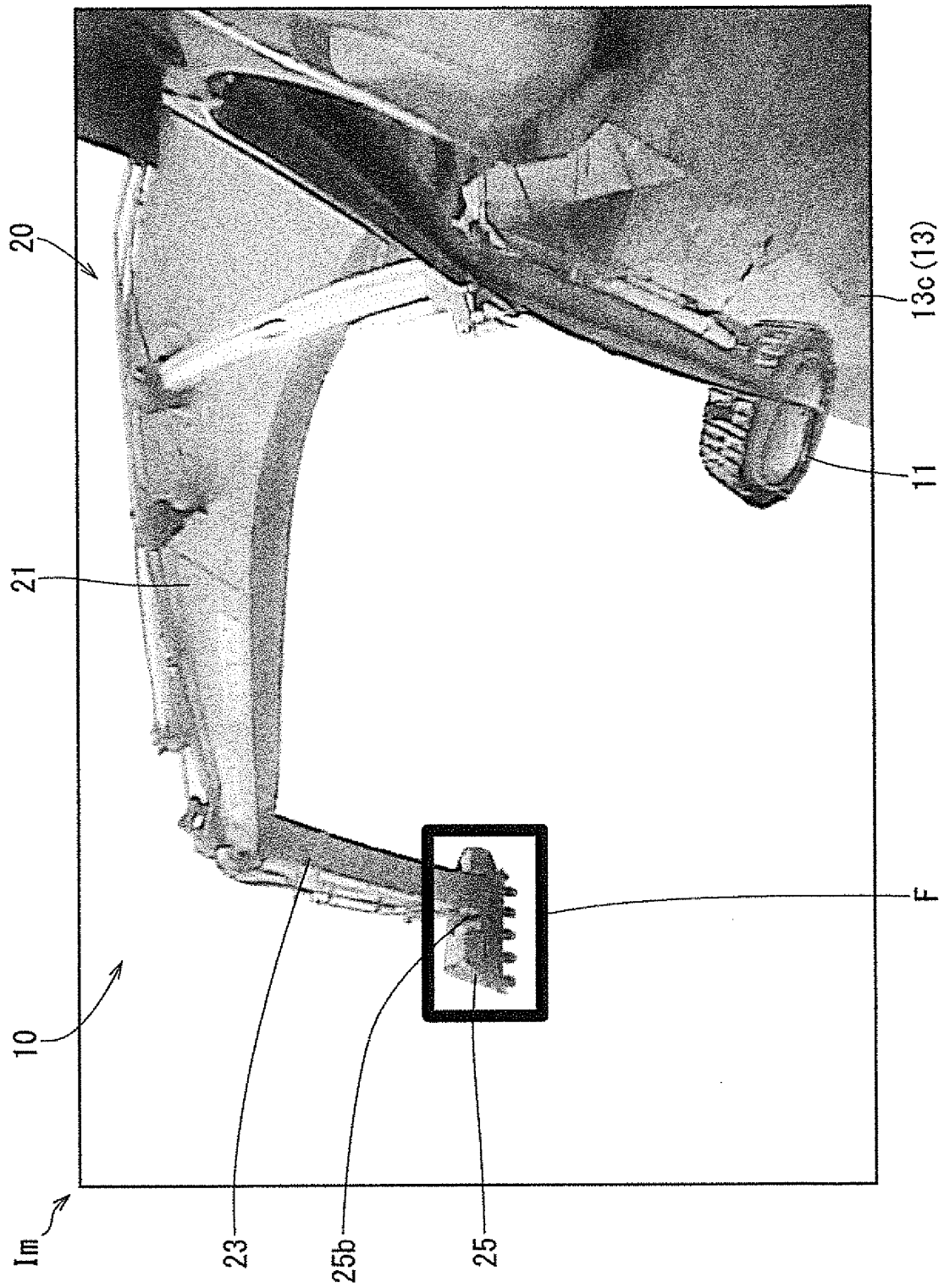
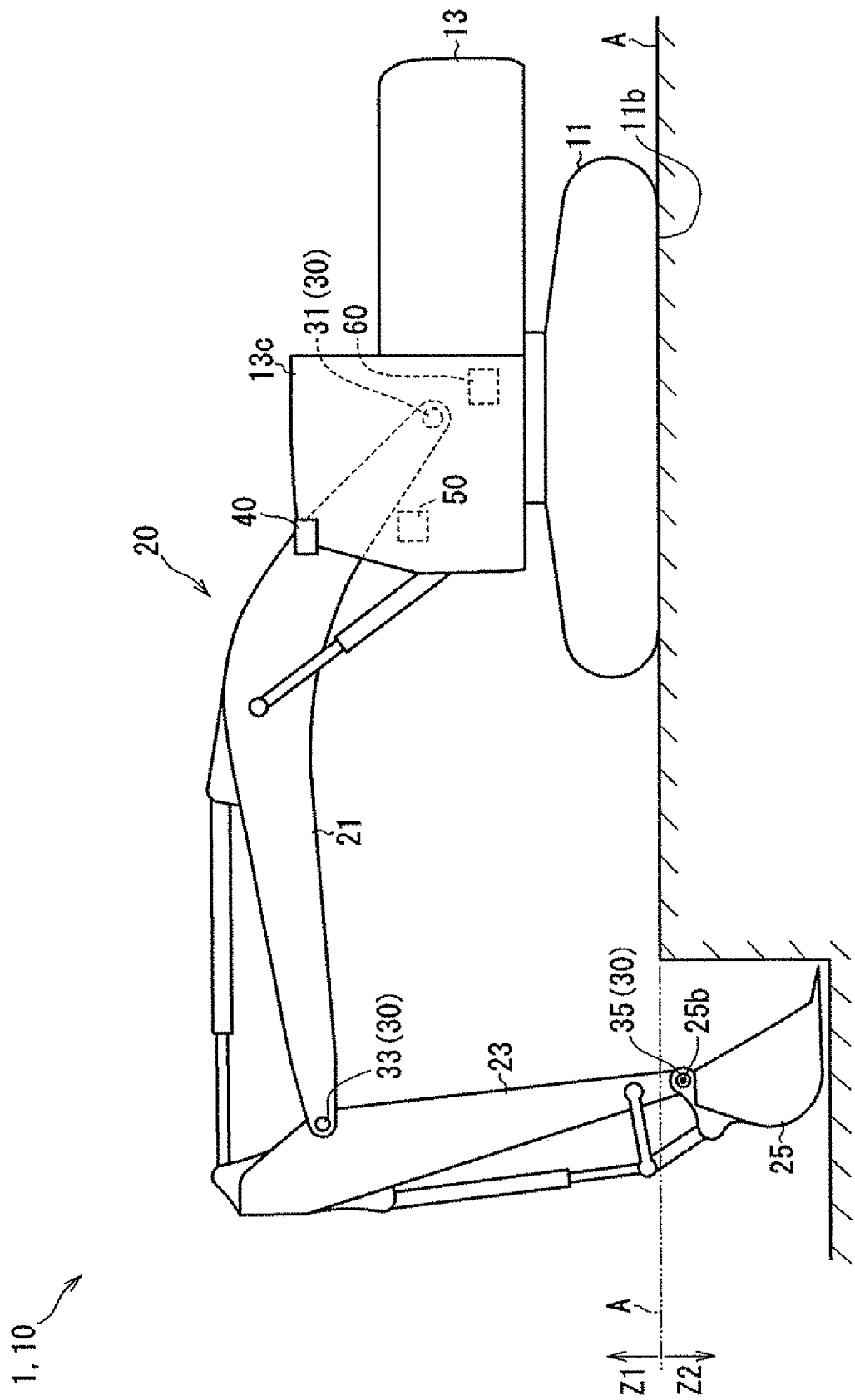


FIG. 5



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/044473

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. G06T7/00 (2017.01) i

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)

Int.Cl. G06T7/00

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 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

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. |
|-----------|---|-----------------------|
| Y A | JP 2017-157016 A (KOBELCO STEEL, LTD., KOBELCO CONSTRUCTION MACHINERY CO., LTD.) 07 September 2017, paragraphs [0027]-[0031], [0043]-[0044], [0046], [0048]-[0054], [0062], [0070]-[0071] & EP 3409848 A1, paragraphs [0014]-[0018], [0030]-[0031], [0033], [0035]-[0041], [0049], [0057]-[0058] & CN 108713083 A | 1-5, 7 6 |

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

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Date of the actual completion of the international search
25 February 2019 (25.02.2019)Date of mailing of the international search report
05 March 2019 (05.03.2019)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/044473

| C (Continuation). | DOCUMENTS CONSIDERED TO BE RELEVANT | |
|-------------------|---|-----------------------|
| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| Y | JP 2008-60988 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 13 March 2008, paragraphs [0067]-[0068] (Family: none) | 5, 7 |

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REFERENCES CITED IN THE DESCRIPTION

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