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(54) **CONTROL DEVICE, ROBOT SYSTEM, OBJECT PRESENCE/ABSENCE DETERMINATION METHOD, AND PROGRAM**

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CPC ***B25J 9/1697*** (2013.01); ***B25J 9/161*** (2013.01); ***B25J 13/08*** (2013.01); ***B25J 19/023*** (2013.01)

(57) **ABSTRACT**

A control device comprising an image acquisition unit which acquires a distance image captured by a visual sensor; and a determination unit which, on the basis of the distance image, determines whether or not an object has been placed within a range specified by predetermined input information.

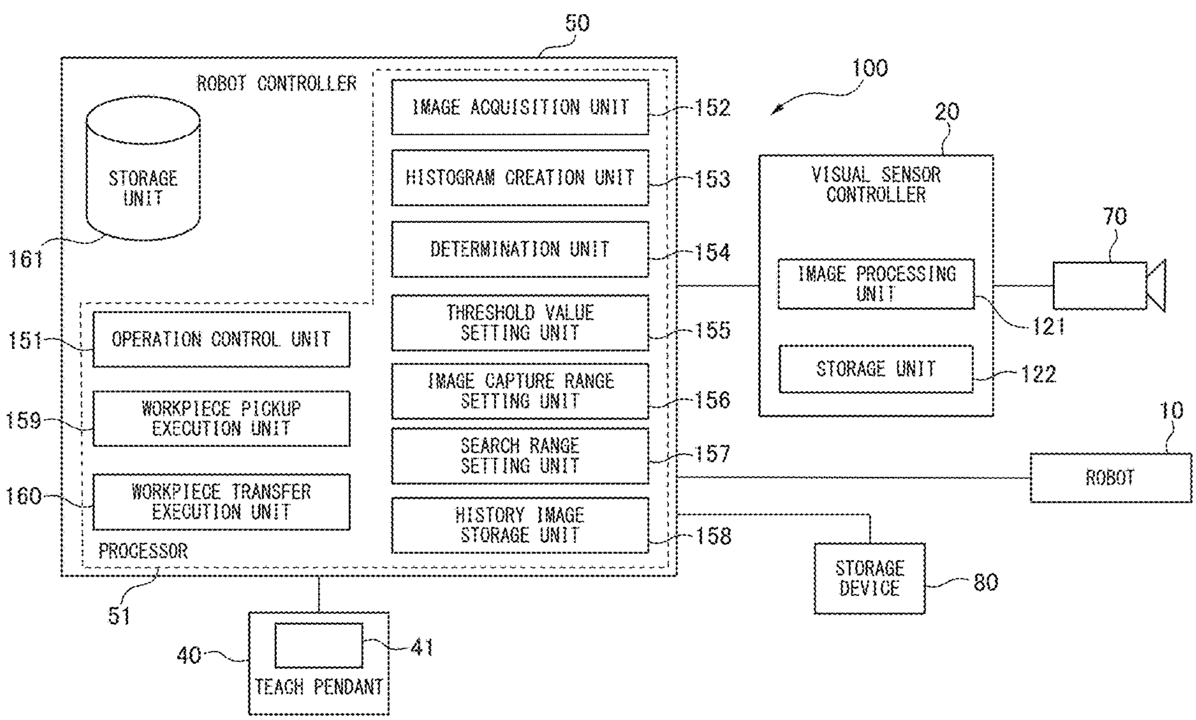


Fig. 1

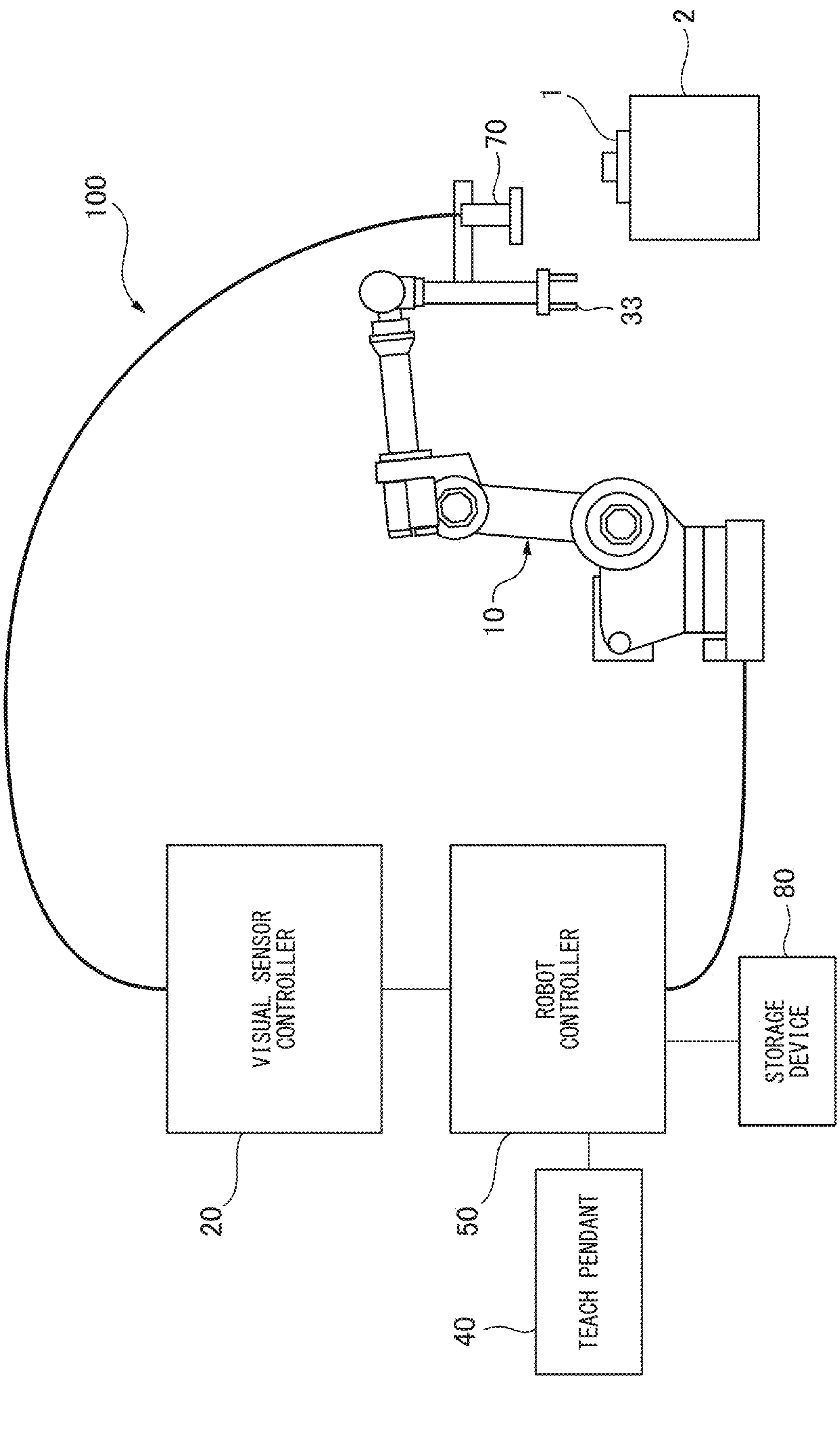
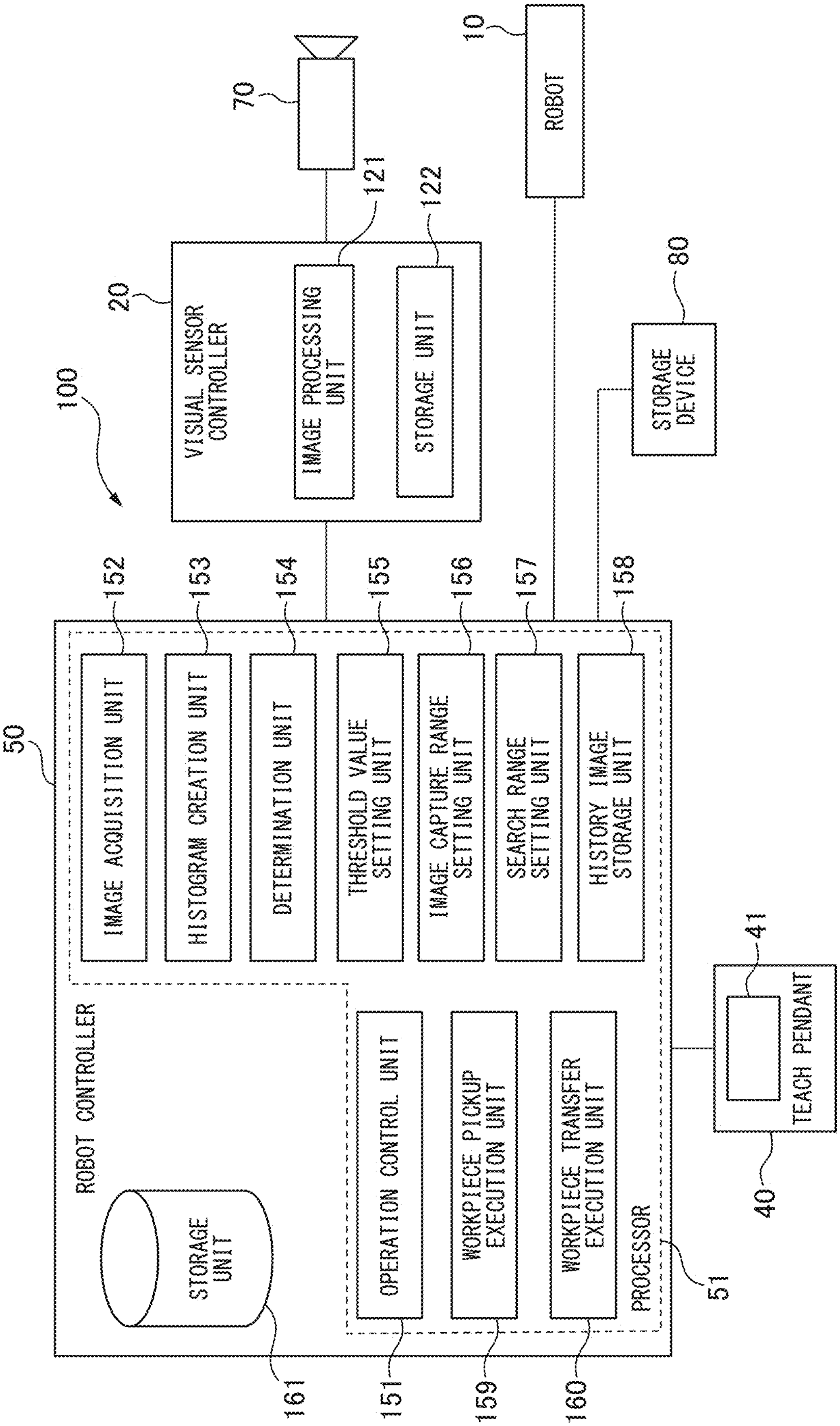

100
70
2
1
33
10
VISUAL SENSOR CONTROLLER
ROBOT CONTROLLER
STORAGE DEVICE
TEACH PENDANT
20
50
40
80

Fig. 2



100
50
ROBOT CONTROLLER
STORAGE UNIT
161
IMAGE ACQUISITION UNIT
152
HISTOGRAM CREATION UNIT
153
DETERMINATION UNIT
154
THRESHOLD VALUE SETTING UNIT
155
IMAGE CAPTURE RANGE SETTING UNIT
156
SEARCH RANGE SETTING UNIT
157
HISTORY IMAGE STORAGE UNIT
158
OPERATION CONTROL UNIT
151
WORKPIECE PICKUP EXECUTION UNIT
159
WORKPIECE TRANSFER EXECUTION UNIT
160
PROCESSOR
51
VISUAL SENSOR CONTROLLER
20
IMAGE PROCESSING UNIT
121
STORAGE UNIT
122
70
ROBOT
10
STORAGE DEVICE
80
TEACH PENDANT
40
41

Fig. 3

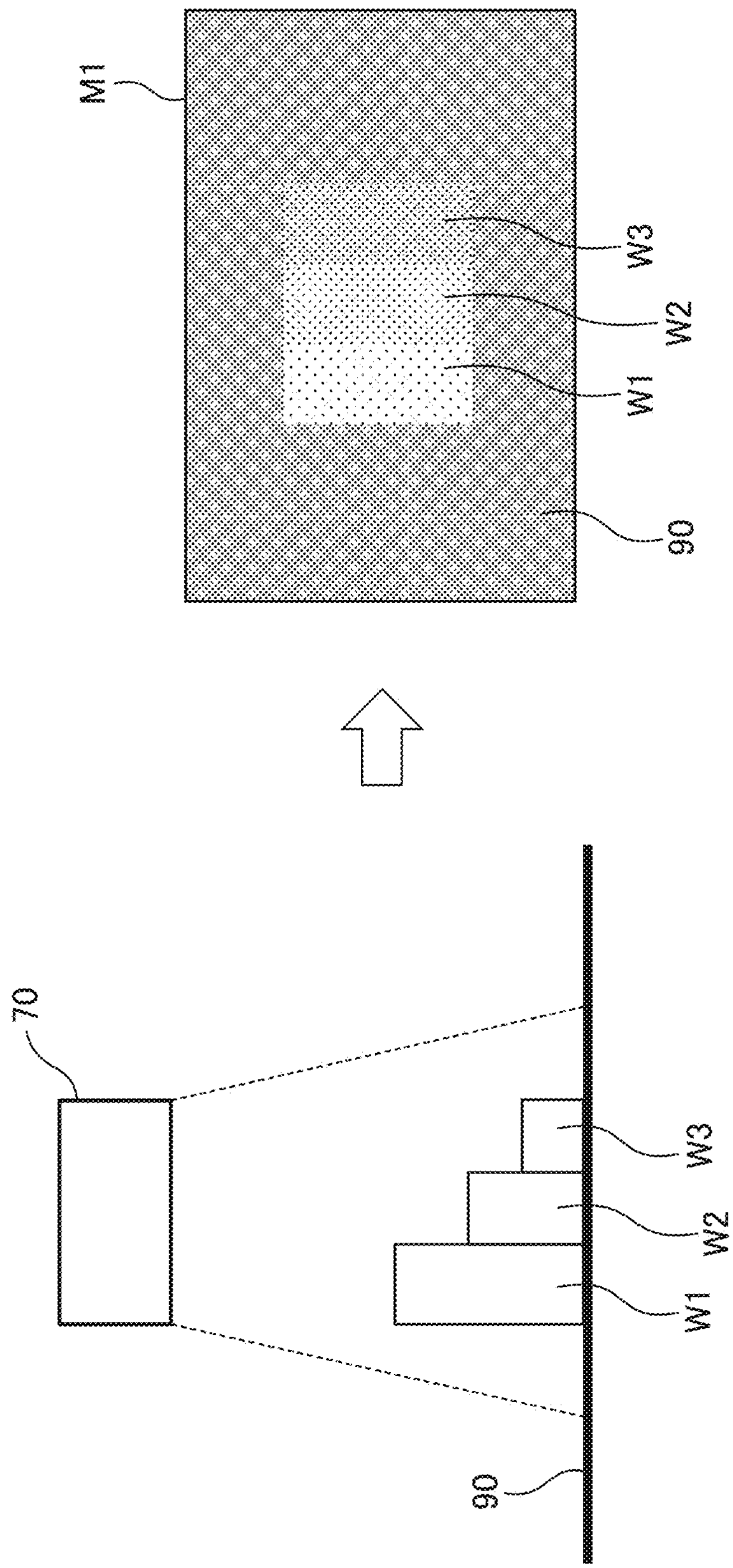


Fig. 4

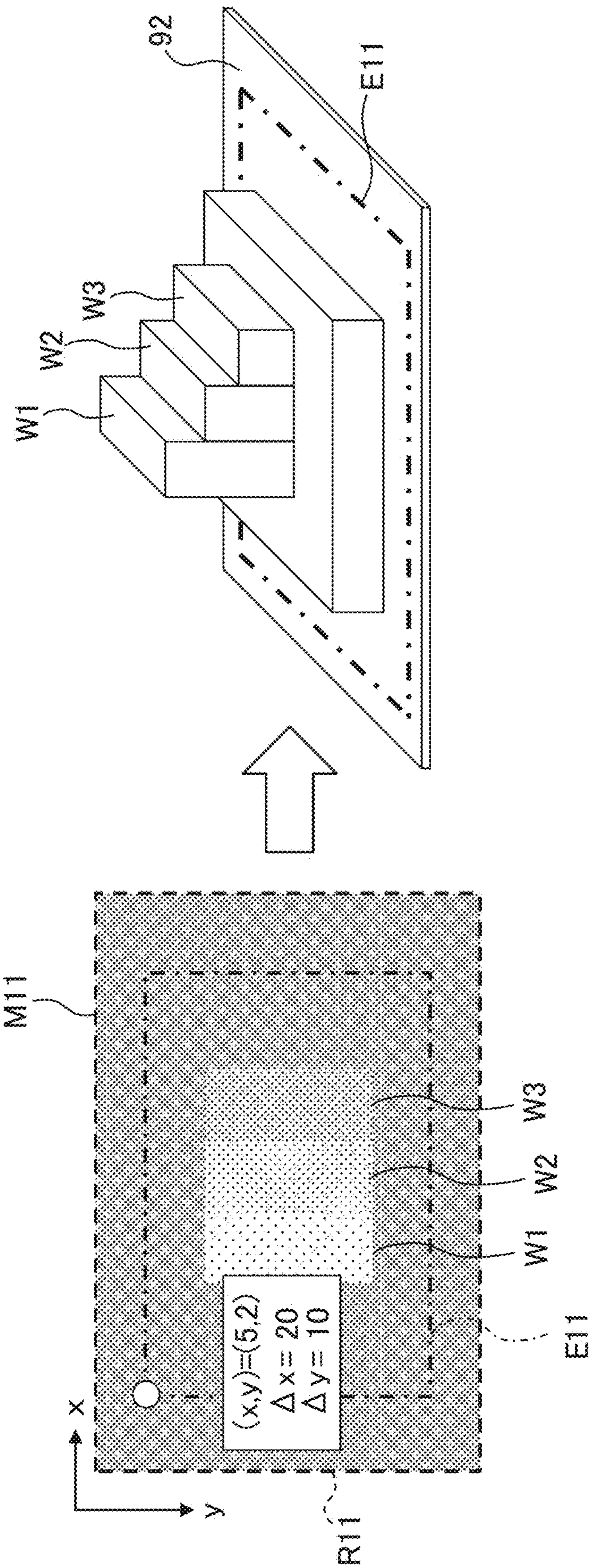


Fig. 5

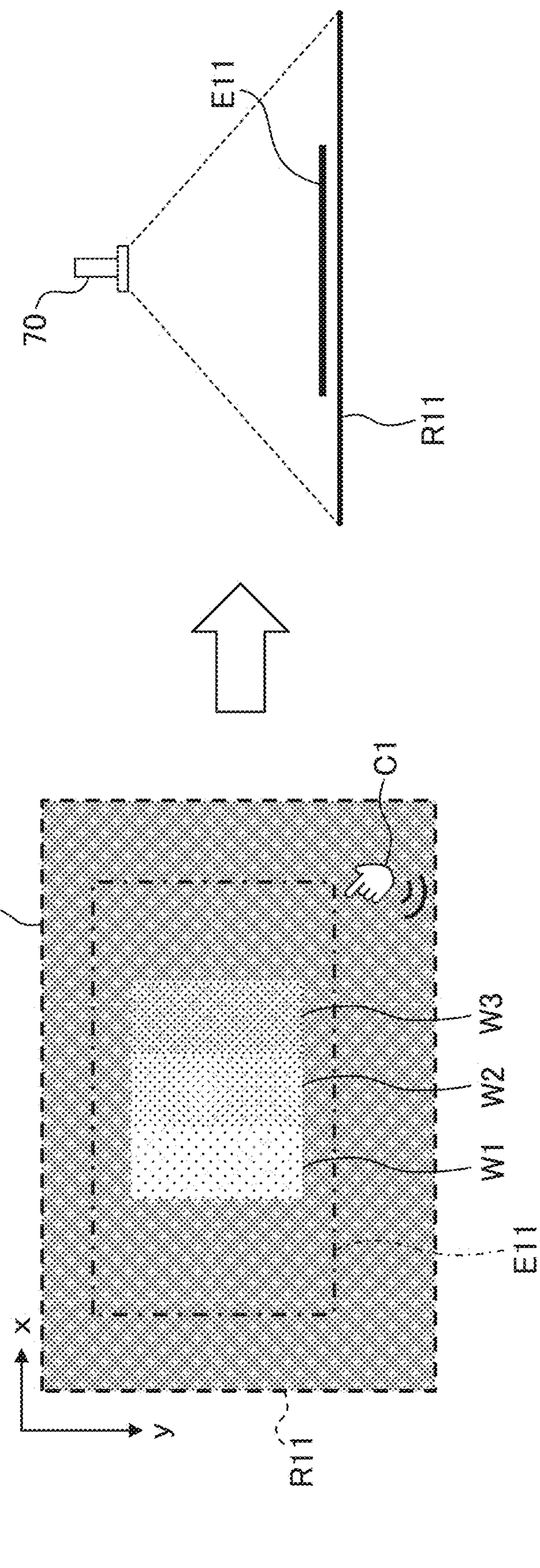


Fig. 6

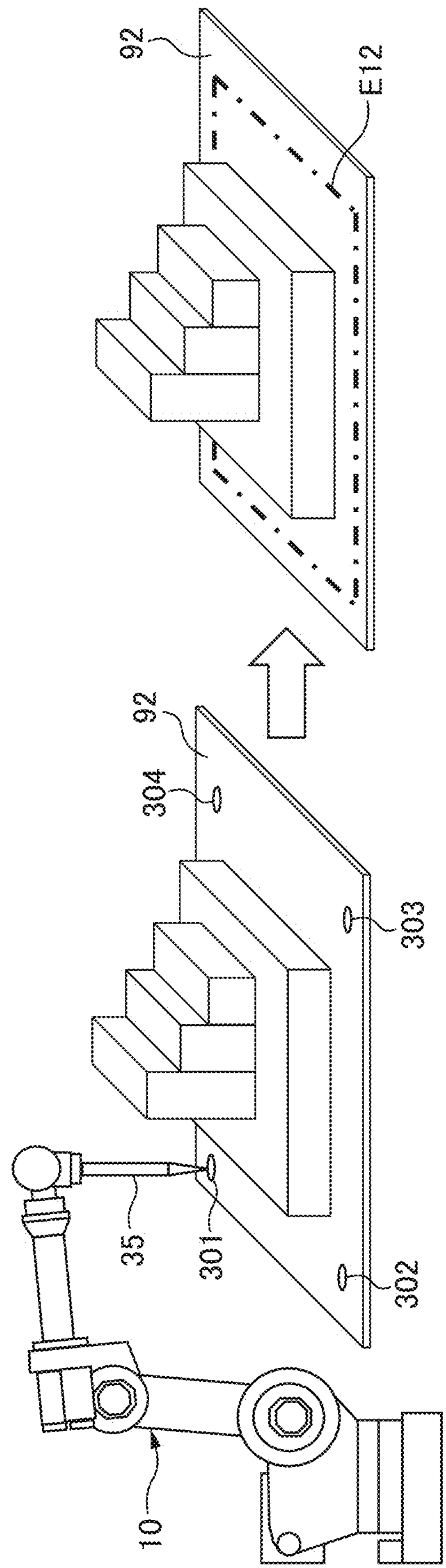


Fig. 7

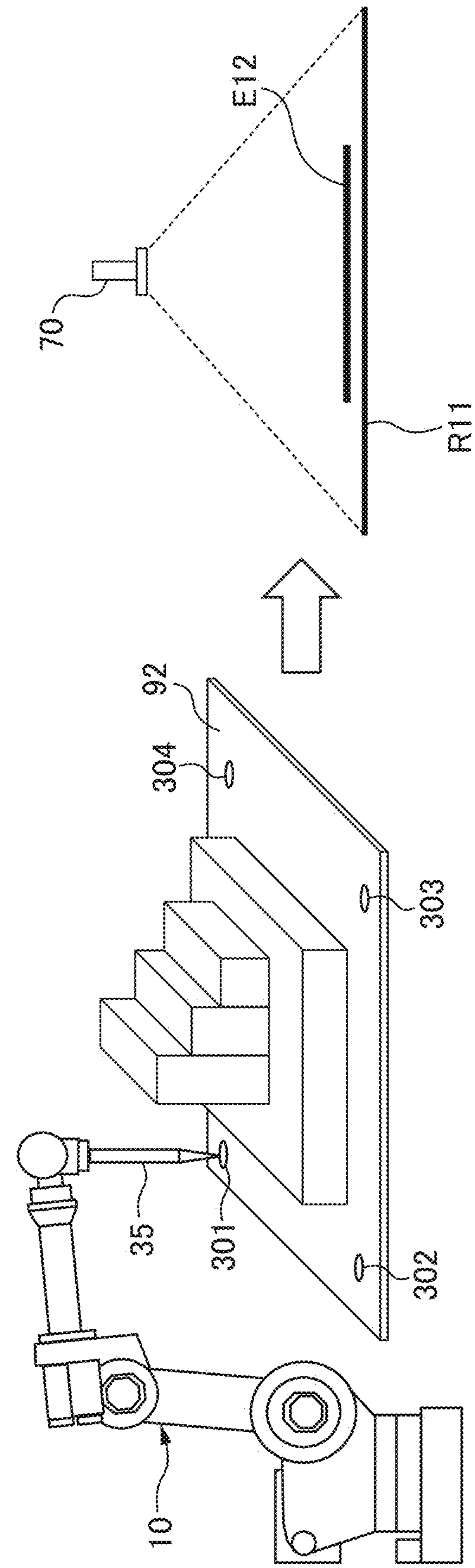


Fig. 8

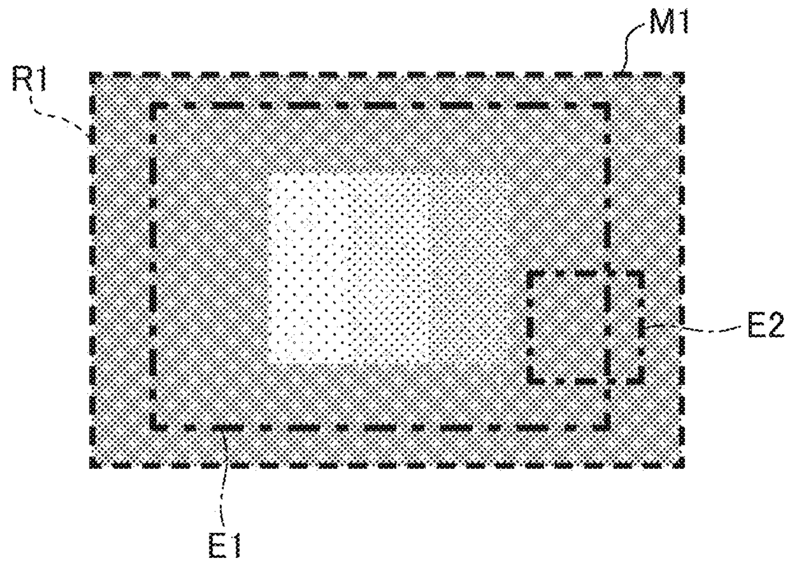


Fig. 9

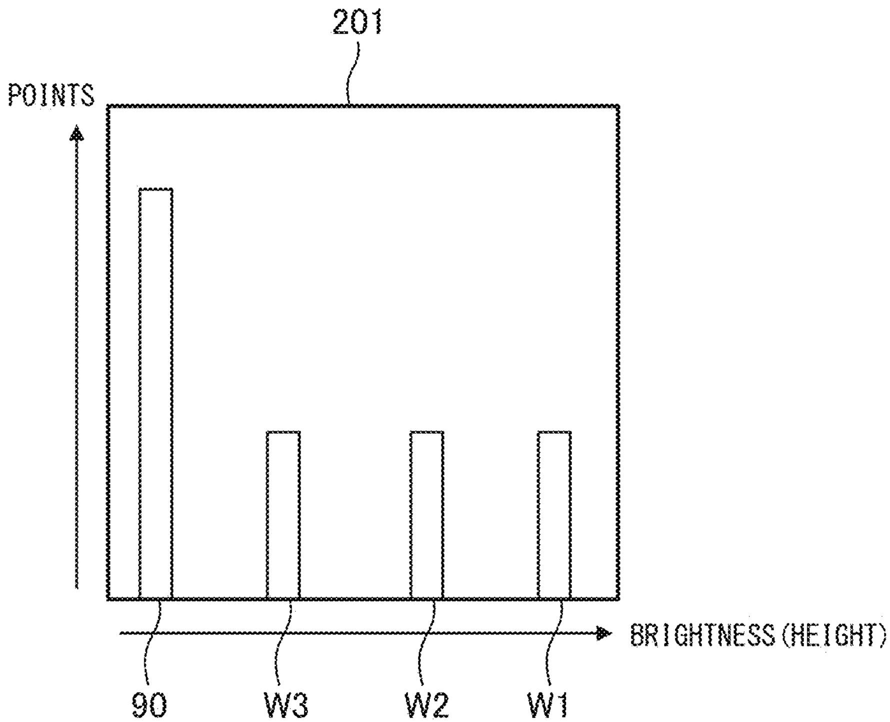


Fig. 10

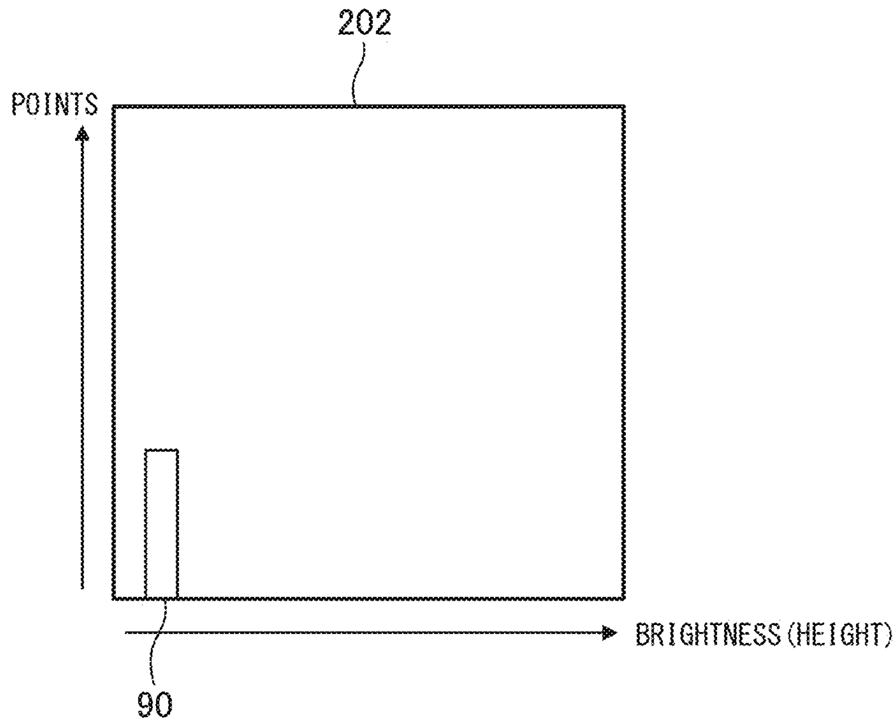

202
POINTS
BRIGHTNESS (HEIGHT)
90

Fig. 11

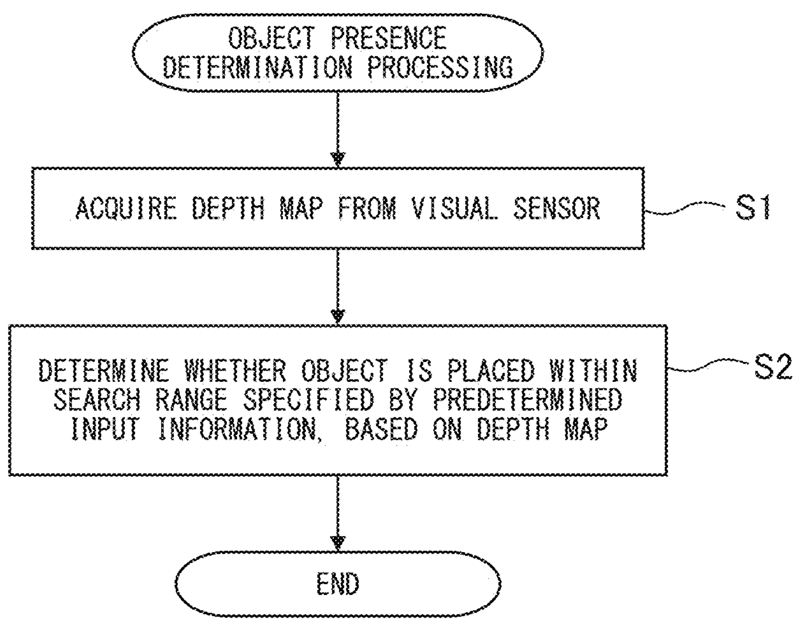

OBJECT PRESENCE DETERMINATION PROCESSING
ACQUIRE DEPTH MAP FROM VISUAL SENSOR
S1
DETERMINE WHETHER OBJECT IS PLACED WITHIN SEARCH RANGE SPECIFIED BY PREDETERMINED INPUT INFORMATION, BASED ON DEPTH MAP
S2
END

Fig. 12

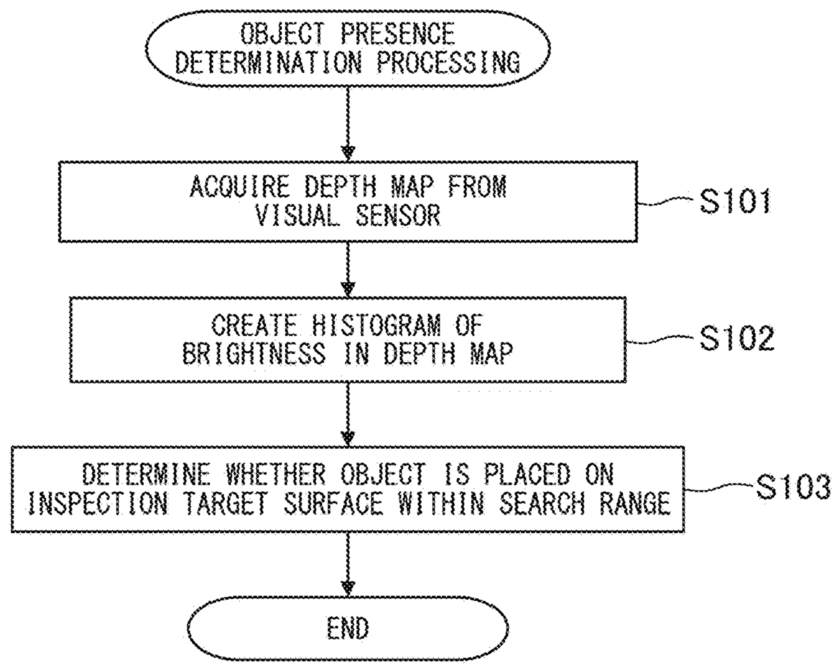

OBJECT PRESENCE DETERMINATION PROCESSING
ACQUIRE DEPTH MAP FROM VISUAL SENSOR
S101
CREATE HISTOGRAM OF BRIGHTNESS IN DEPTH MAP
S102
DETERMINE WHETHER OBJECT IS PLACED ON INSPECTION TARGET SURFACE WITHIN SEARCH RANGE
S103
END

Fig. 13

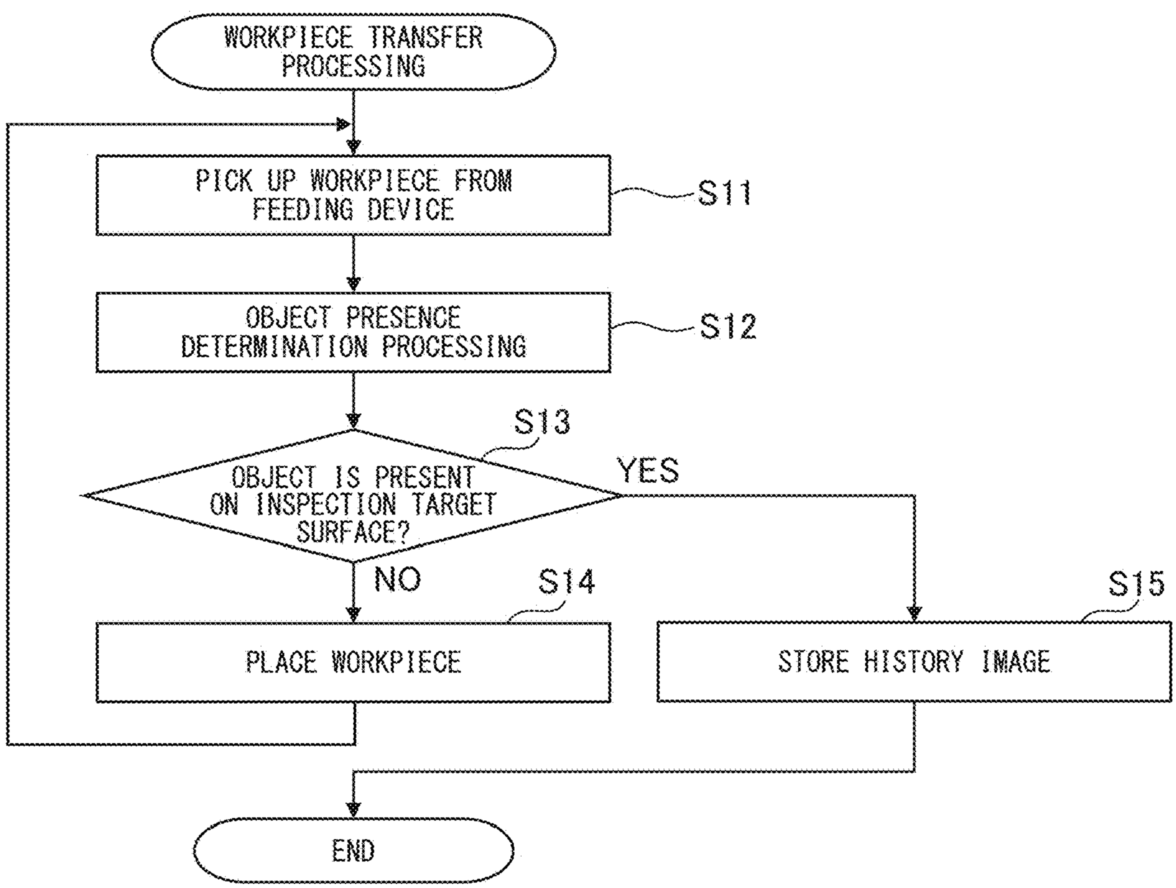

WORKPIECE TRANSFER PROCESSING
PICK UP WORKPIECE FROM FEEDING DEVICE
S11
OBJECT PRESENCE DETERMINATION PROCESSING
S12
S13
OBJECT IS PRESENT ON INSPECTION TARGET SURFACE?
YES
NO
S14
PLACE WORKPIECE
S15
STORE HISTORY IMAGE
END

Fig. 14

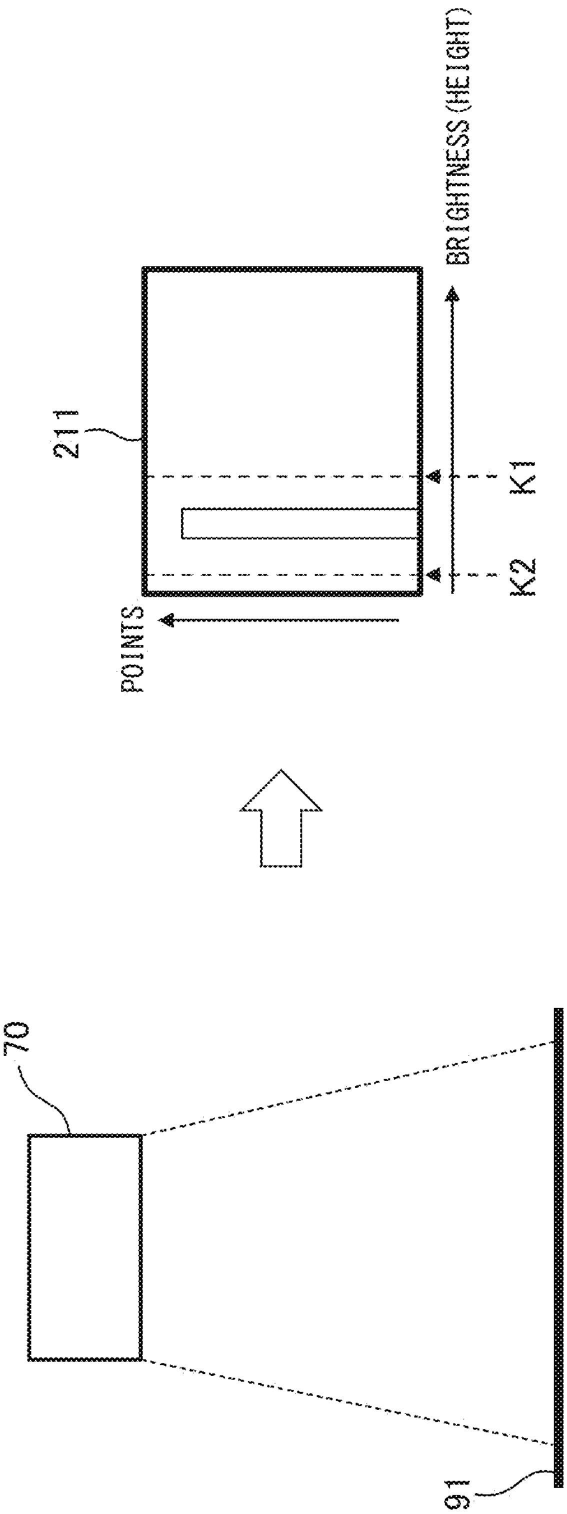


Fig. 15

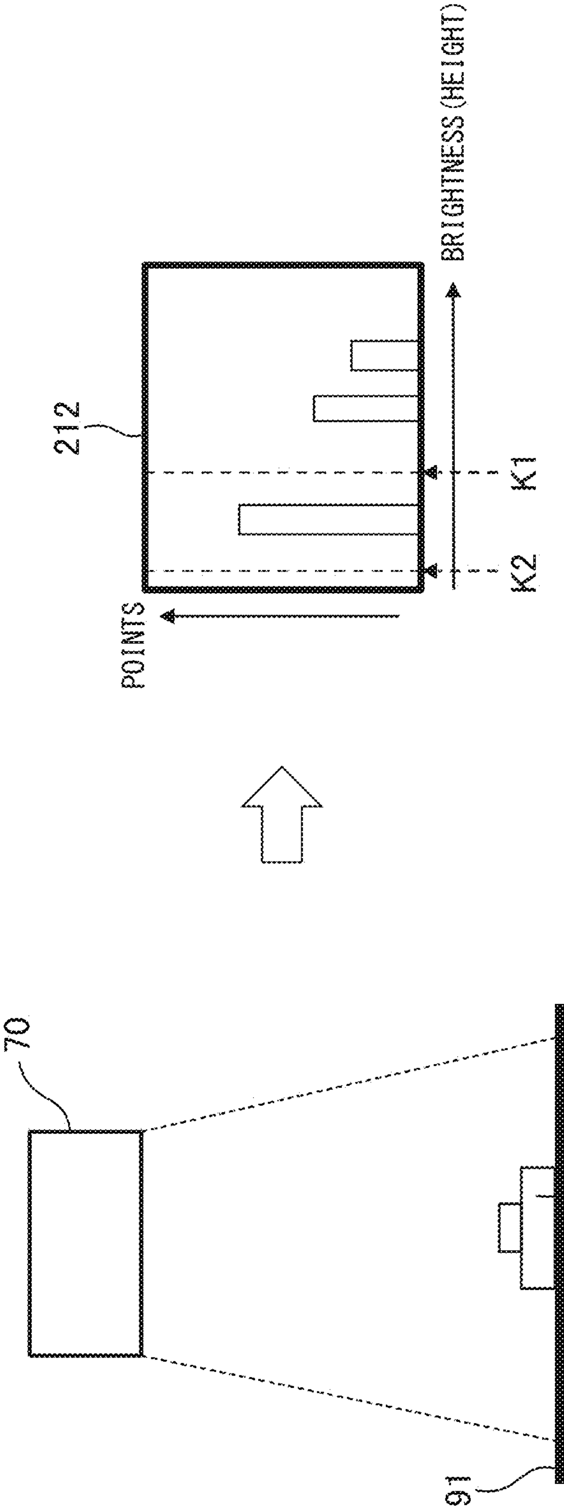


Fig. 16

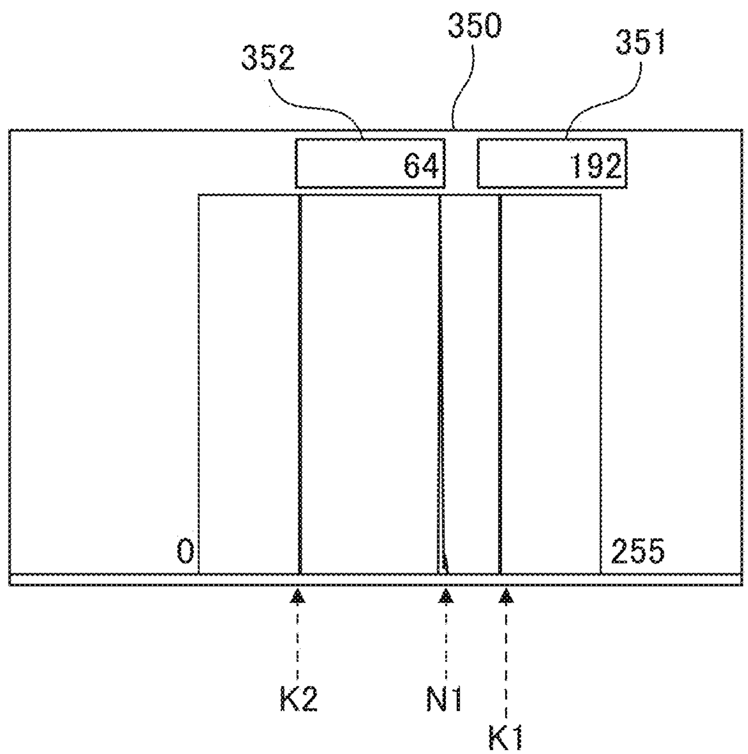


Fig. 17

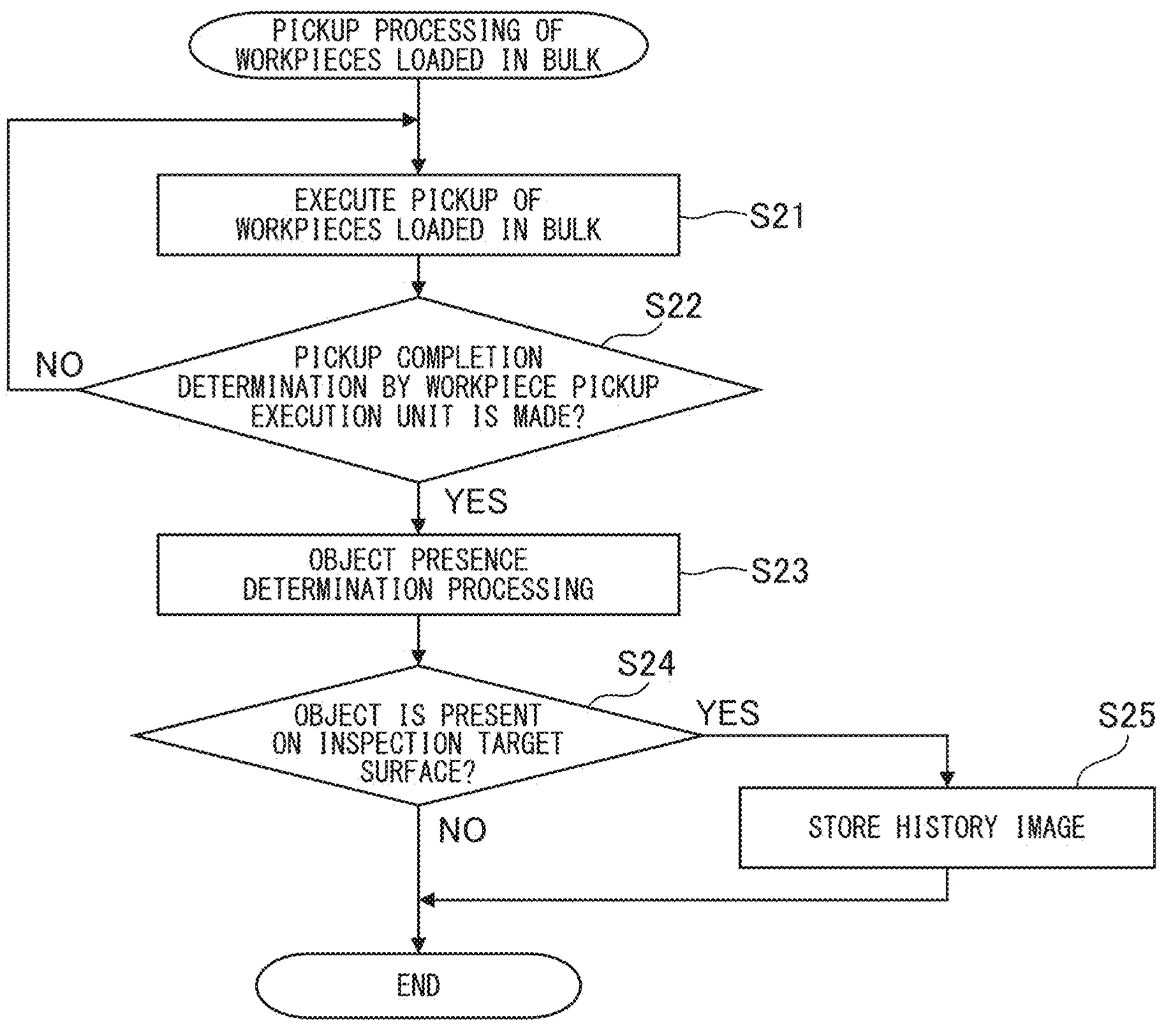

PICKUP PROCESSING OF WORKPIECES LOADED IN BULK
EXECUTE PICKUP OF WORKPIECES LOADED IN BULK
S21
S22
PICKUP COMPLETION DETERMINATION BY WORKPIECE PICKUP EXECUTION UNIT IS MADE?
NO
YES
OBJECT PRESENCE DETERMINATION PROCESSING
S23
S24
OBJECT IS PRESENT ON INSPECTION TARGET SURFACE?
YES
S25
STORE HISTORY IMAGE
NO
END

Fig. 18

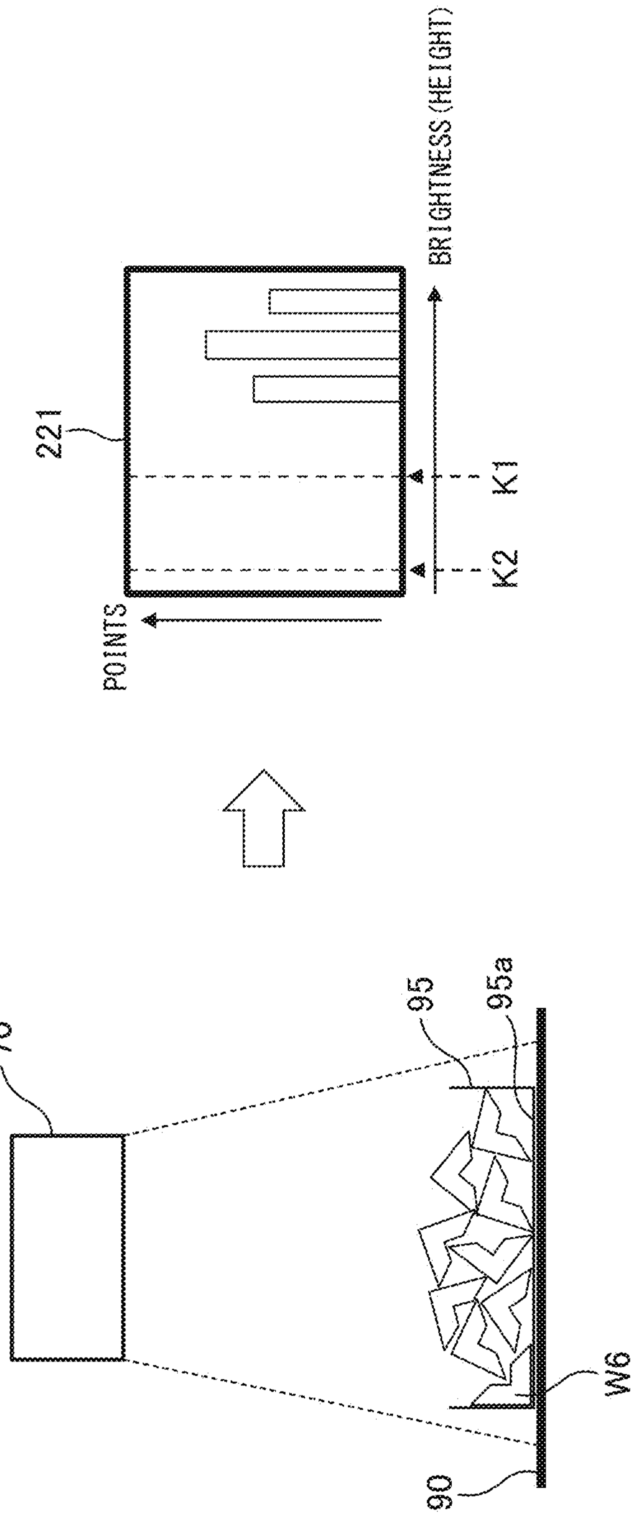


Fig. 19

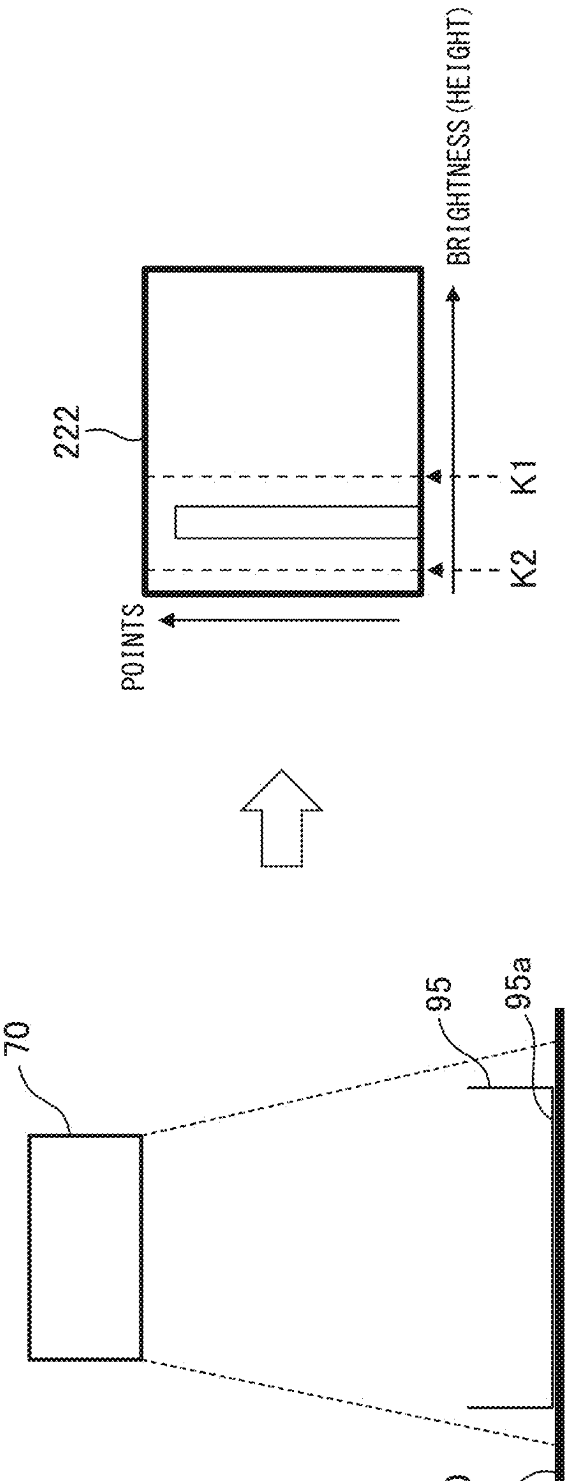
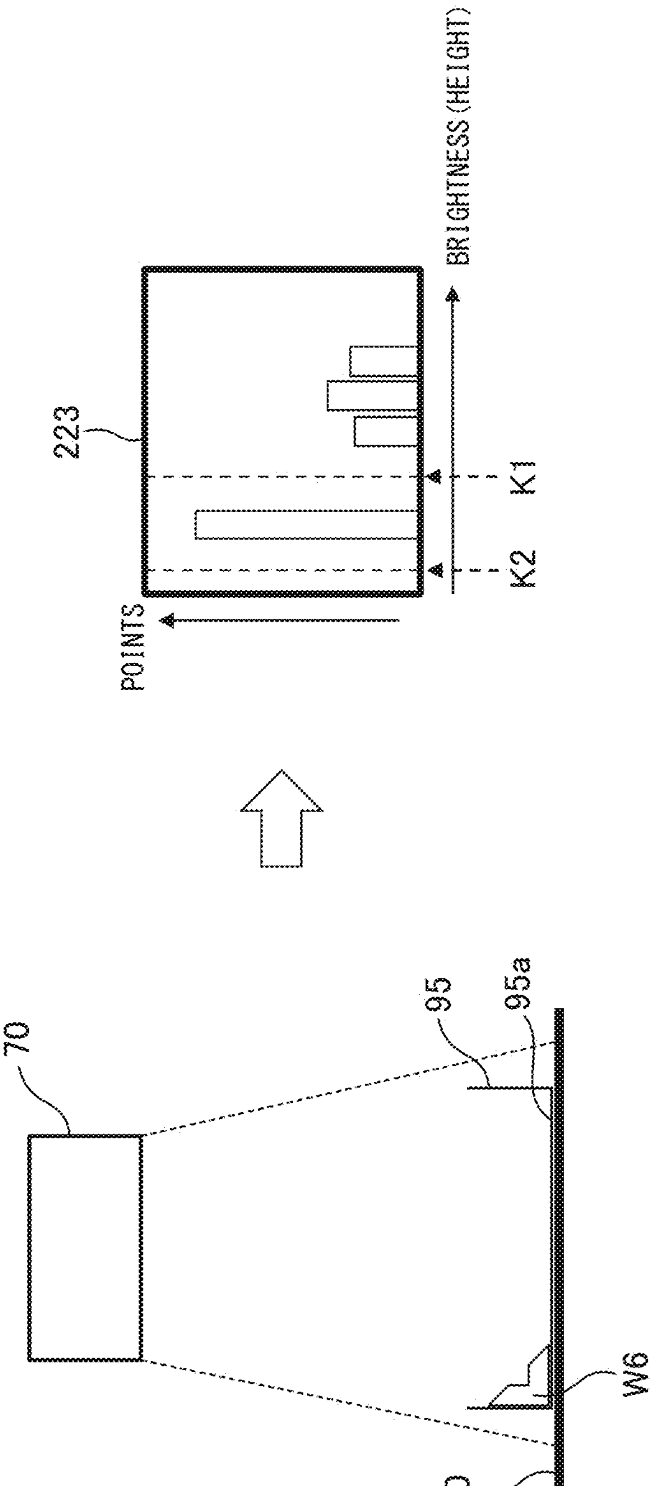


Fig. 20



CONTROL DEVICE, ROBOT SYSTEM, OBJECT PRESENCE/ABSENCE DETERMINATION METHOD, AND PROGRAM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a bypass continuation application of International Application No. PCT/JP2022/047928 filed Dec. 26, 2022.

BACKGROUND

Field

[0002] The present disclosure relates to a controller of an industrial robot, a robot system, an object presence determination method, and a program.

Discussion of the Related Art

[0003] A robot system executing workpiece pickup work of picking up, by a robot, workpieces (e.g., workpieces loaded in bulk) placed at undefined positions by detecting the workpieces by a visual sensor, and arranging the workpieces on a worktable, a conveying device, or the like is known.

[0004] For example, PTL 1 describes a handling system for workpiece transfer used when applying grinder finishing to a plate-like metal workpiece acquired by fusion cutting or the like.

[0005] PTL 2 describes a surveillance device included in a robot system performing predetermined work on a workpiece. The surveillance device includes a three-dimensional camera and determines whether an object is present in a restricted region, based on the distances from the camera to a plurality of measurement points set on the surface of the workpiece.

[0006] For example, in a robot system performing handling of workpieces such as pickup and transfer of workpieces, a situation in which, due to some cause, a workpiece placed by a robot in a preceding operation remains present at a location where another workpiece is to be placed by the robot may occur. When such a situation occurs, a malfunction (such as suspension of a production cycle) may occur in the robot system due to mutual interference between workpieces when the robot attempts to place a workpiece.

[0007] A technology enabling detection of whether an object is present at an inspection target location and thereby reliably enabling detection of a malfunction in handling work of workpieces by the robot and prevention of occurrence of such a malfunction is desired.

SUMMARY

[0008] An embodiment of the present disclosure is a controller including an image acquisition unit acquiring a depth map captured by a visual sensor and a determination unit determining whether an object is placed within a range specified by predetermined input information, based on the depth map.

[0009] The objects, the features, and the advantages of the present invention, and other objects, features, and advantages will become more apparent from the detailed description of typical embodiments of the present invention illustrated in accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1** is a diagram illustrating a configuration of a robot system including a robot controller according to an embodiment.

[0011] FIG. **2** is a functional block diagram of the robot controller and a visual sensor control unit.

[0012] FIG. **3** is a diagram for illustrating a depth map acquired by a three-dimensional camera.

[0013] FIG. **4** is a diagram for illustrating a first example of a search range setting function provided by a search range setting unit.

[0014] FIG. **5** is a diagram for illustrating a second example of the search range setting function provided by the search range setting unit.

[0015] FIG. **6** is a diagram for illustrating a third example of the search range setting function provided by the search range setting unit.

[0016] FIG. **7** is a diagram for illustrating a fourth example of the search range setting function provided by the search range setting unit.

[0017] FIG. **8** is a diagram for illustrating an image capture range and a search range.

[0018] FIG. **9** is a diagram illustrating a histogram for a first search range illustrated in FIG. **8**.

[0019] FIG. **10** is a diagram illustrating a histogram for a second search range illustrated in FIG. **8**.

[0020] FIG. **11** is a flowchart in a case of generally expressing an object presence determination function executed by the robot controller.

[0021] FIG. **12** is a flowchart illustrating a specific operation of object presence determination processing executed by the robot controller.

[0022] FIG. **13** is a flowchart in a case of applying the object presence determination processing to workpiece transfer processing.

[0023] FIG. **14** is a diagram illustrating a state in which a visual sensor captures a depth map in a situation in which nothing is placed on a placement surface, and a histogram of the depth map acquired at that time.

[0024] FIG. **15** is a diagram illustrating a state of the visual sensor capturing a depth map in a state in which a workpiece is placed on the placement surface, and a histogram of the depth map acquired at that time.

[0025] FIG. **16** is a diagram illustrating an example of a graphical user interface for setting a threshold value.

[0026] FIG. **17** is a flowchart in a case of applying the object presence determination processing to pickup processing of workpieces loaded in bulk.

[0027] FIG. **18** is a diagram illustrating a situation in which the visual sensor captures a depth map in a state in which many workpieces are present in a container, and a histogram of the depth map acquired at that time.

[0028] FIG. **19** is a diagram illustrating a situation in which the visual sensor captures a depth map in a state in which no object is present in the container, and a histogram of the depth map acquired at that time.

[0029] FIG. **20** is a diagram illustrating a situation in which the visual sensor captures a depth map in a state in which one workpiece remains in the container, and a histogram of the depth map acquired at that time.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0030] Next, embodiments of the present disclosure will be described with reference to the drawings. In the referenced drawings, similar components or functional parts are given similar reference signs. For ease of understanding, the drawings use different scales as appropriate. Further, configurations illustrated in the drawings are examples for implementing the present invention, and the present invention is not limited to the illustrated configurations.

[0031] FIG. **1** is a diagram illustrating a configuration of robot system **100** including robot controller **50** according to an embodiment. As illustrated in FIG. **1**, robot system **100** includes robot **10** equipped with hand **33** on the arm tip, robot controller **50** controlling robot **10**, teach pendant **40** connected to robot controller **50**, visual sensor **70** attached to the arm tip of robot **10**, and visual sensor controller **20** controlling visual sensor **70**. For example, robot system **100** can perform detection of target object **1** on worktable **2** by visual sensor **70** and handling of target object **1** with hand **33** mounted on robot **10**. Robot system **100** is further configured to be able to determine whether an object is placed within a range specified by predetermined input information, based on a depth map captured by visual sensor **70**.

[0032] Robot system **100** may further include storage device **80** for storing execution history data and other information. For example, storage device **80** is an external memory connected to robot controller **50**. Alternatively, storage device **80** may be a storage, an external computer, or the like connected to robot controller **50** through a network. It should be noted that, while FIG. **1** illustrates a configuration in which robot system **100** includes an independent device as storage device **80**, the function as storage device **80** may be provided in robot controller **50** or teach pendant **40**. A configuration of the storage device **80** being connected to the teach pendant **40** is a possible example.

[0033] While robot **10** is a vertical articulated robot in the present embodiment, another type of robot such as a parallel link robot or a dual-arm robot may be used depending on the purpose of the work. Robot **10** can execute desired work with an end effector attached to the wrist. FIG. **1** illustrates an example of using hand **33** as an end effector.

[0034] It is assumed that visual sensor **70** has a function as a two-dimensional camera capturing a gray image or a color image, and a function as a three-dimensional camera acquiring a depth map. A plurality of visual sensors may be arranged in robot system **100**. For example, a time-of-flight (TOF) camera capturing a depth map by a time-of-flight method or a stereo camera including two cameras may be used as the three-dimensional camera. It should be noted that, while FIG. **1** illustrates a configuration example of mounting visual sensor **70** on robot **10**, visual sensor **70** may be a fixed camera fixed to a workspace.

[0035] Visual sensor controller **20** holds a model pattern of a target object and can execute image processing of detecting the target object by pattern matching between an image of the target object in a captured image and the model pattern. It is assumed that visual sensor **70** is calibrated and visual sensor controller **20** holds calibration data defining a relative positional relation between visual sensor **70** and robot **10**. Thus, a position in a two-dimensional image captured by visual sensor **70** can be transformed into a position in a coordinate system fixed to the workspace (e.g., a robot coordinate system).

[0036] While visual sensor controller **20** is configured to be a device separately provided from robot controller **50** in FIG. **1**, the function as visual sensor controller **20** may be embedded in robot controller **50**.

[0037] Robot controller **50** controls the operation of robot **10** in accordance with an operation program or a command from teach pendant **40**. Robot controller **50** may have a hardware configuration as a common computer including processor **51** (FIG. **2**), memories (e.g., a ROM, a RAM, and a nonvolatile memory), a storage, an operation unit, an input-output interface, a network interface, and the like.

[0038] Teach pendant **40** is used as an operation terminal for teaching (program creation) of robot **10**, and various settings. A teaching device configured with a tablet computer or the like may be used as teach pendant **40**. Teach pendant **40** may have a hardware configuration as a common computer including a processor, memories (e.g., a ROM, a RAM, and a nonvolatile memory), a storage, an operation unit, display unit **41** (FIG. **2**), an input-output interface, a network interface, and the like. For example, display unit **41** (FIG. **2**) includes a liquid crystal display.

[0039] Visual sensor controller **20** may have a hardware configuration as a common computer including a processor, memories (e.g., a ROM, a RAM, and a nonvolatile memory), a storage, an operation unit, a display unit, an input-output interface, a network interface, and the like.

[0040] FIG. **2** illustrates a functional block diagram of robot controller **50** and visual sensor controller **20**. As illustrated in FIG. **2**, robot controller **50** includes operation control unit **151**, image acquisition unit **152**, histogram creation unit **153**, determination unit **154**, threshold value setting unit **155**, image capture range setting unit **156**, search range setting unit **157**, history image storage unit **158**, workpiece pickup execution unit **159**, and workpiece transfer execution unit **160**. The functional blocks may be provided by execution of software by processor **51** in robot controller **50**. Robot controller **50** further includes storage unit **161**.

[0041] For example, storage unit **161** is a storage configured with a nonvolatile memory, a hard disk device, or the like. A robot program for controlling robot **10**, a program (a vision program) for performing image processing such as detection of a workpiece based on an image captured by visual sensor **70**, various types of setting information, and the like are stored in storage unit **161**.

[0042] Operation control unit **151** controls the operation of the robot in accordance with the robot program or a command from teach pendant **40**. Robot controller **50** includes a servo control unit (unillustrated) executing servo control on a servomotor on each axis in accordance with a command to the axis generated by operation control unit **151**.

[0043] Image acquisition unit **152** has a function of acquiring a depth map and a two-dimensional image that are captured by visual sensor **70** from visual sensor controller **20**.

[0044] Histogram creation unit **153** provides a function of creating a histogram being a frequency distribution related to distance information of each point in an acquired depth map. Histogram creation unit **153** may further have a function of displaying the created histogram on a display screen (e.g., display unit **41** of the teach pendant **40**).

[0045] Determination unit **154** provides a function of determining whether an object is placed within a range specified by predetermined input information, based on a depth map acquired by image acquisition unit **152**. The range specified by the predetermined input information may be a search range searched by determination unit **154** for making a determination or an image capture range of visual sensor **70**. As an example, determination unit **154** may be configured to determine whether an object is placed on an inspection target surface within a specified search range, based on a histogram created by histogram creation unit **153**.

[0046] Threshold value setting unit **155** provides a function for setting a threshold value for distinguishing between distance information of the inspection target surface and distance information of another object on the inspection target surface in a histogram. Threshold value setting unit **155** may have a function of automatically setting the threshold value, based on a depth map captured by visual sensor **70**. Threshold value setting unit **155** may be configured to accept setting of the threshold value through a user interface (UI) screen. Alternatively, threshold value setting unit **155** may be configured to accept input of the threshold value from an external device. Threshold value setting unit **155** may set the threshold value in accordance with information related to threshold value setting (e.g., a variable defining the threshold value) described in the robot program (e.g., a workpiece pickup program, a workpiece transfer program, or the vision program).

[0047] Image capture range setting unit **156** provides a function for setting an image capture range when the visual sensor **70** captures a depth map. Image capture range setting unit **156** may be configured to accept specification of the image capture range through a UI screen. Image capture range setting unit **156** may be configured to accept input of the image capture range from an external device. Image capture range setting unit **156** may set an image capture range (e.g., a size and a position) in accordance with information being related to specification of the image capture range (e.g., a variable defining the image capture range) and being described in the robot program (e.g., the workpiece pickup program, the workpiece transfer program, or the vision program). Image capture range setting unit **156** transmits a signal instructing visual sensor **70** (visual sensor controller **20**) to perform image capture within the set image capture range. When changing the position and posture of robot **10** for movement of the image capture range, image capture range setting unit **156** transmits a command for changing the position and posture of robot **10** to operation control unit **151**.

[0048] Search range setting unit **157** provides a function of setting a search range searched by determination unit **154** when determination unit **154** determines whether an object is placed in the workspace, based on predetermined input information. For example, the predetermined input information may be information being related to specification of the search range and being described in the robot program (e.g., a variable defining the search range), setting information input through a user interface (UI), information input from an external device, or the like. Details of setting of the search range by search range setting unit **157** will be described later.

[0049] History image storage unit **158** provides a function of storing, in, for example, the storage device **80**, history information including a history image obtained when workpiece detection processing is executed by visual sensor **70**, or the like.

[0050] The workpiece pickup program for causing robot **10** to execute pickup work of workpieces loaded in bulk and the workpiece transfer program for causing robot **10** to pick up a workpiece and transfer the workpiece to a separate location are stored in storage unit **161**. Workpiece pickup execution unit **159** is a functional block provided by execution of the workpiece pickup program by processor **51**. Workpiece pickup execution unit **159** executes the pickup operation of workpieces loaded in bulk in cooperation with operation control unit **151** and visual sensor controller **20**. Workpiece transfer execution unit **160** is a functional block provided by execution of the workpiece transfer program by processor **51**. Workpiece transfer execution unit **160** executes the transfer operation of a workpiece in cooperation with operation control unit **151** and visual sensor controller **20**. Visual sensor controller **20** includes image processing unit **121** and storage unit **122**. For example, storage unit **122** is a storage configured with a nonvolatile memory. Storage unit **122** stores various settings used for generation of a depth map, calibration data, and various types of data required for image processing, such as model data of a workpiece. Image processing unit **121** executes various types of image processing such as workpiece detection processing.

[0051] A depth map acquired by the function of visual sensor **70** as a three-dimensional camera will be described with reference to FIG. **3**. FIG. **3** illustrates a state of capturing an image of three workpieces W**1**, W**2**, and W**3** with different heights by visual sensor **70**, the workpieces being arranged on floor surface **90**, and a captured depth map M**1**. A depth map is an image in which the brightness varies with the height of an object within an image capture range. In other words, a depth map represents a point cloud in which the brightness of a point varies with the distance from a camera. In the depth map M**1**, each point is displayed in a color closer to white as the height increases and a color closer to black as the height decreases. Therefore, a part (a point cloud) related to workpiece W**1** is displayed in the brightest color, a part (a point cloud) related to workpiece W**2** is displayed in a next brightest color, a part (a point cloud) related to workpiece W**3** is displayed in a next brightest color, and a part (a point cloud) related to floor surface **90** is displayed in the darkest color in the depth map M**1**.

[0052] Details of the search range setting function provided by search range setting unit **157** will be described with reference to FIG. **4** to FIG. **7**. The search range setting function provided by search range setting unit **157** includes (F1) to (F4) described below.

[0053] (F1) A function of setting a search range specified on a captured image as a range defined in a real workspace.

[0054] (F2) A function of setting a search range specified on a captured image in association with the image capture range of the visual sensor.

[0055] (F3) A function of setting a search range in a real space.

[0056] (F4) A function of setting a search range specified in a real space in association with the image capture range of the visual sensor.

[0057] In the aforementioned functions (F1) and (F2), search range setting unit **157** accepts input of specifying a search range as a range on an image. As an example, search range setting unit **157** is configured to be able to accept, as a technique of specifying a search range as a range on an image,

[0058] (a1) a technique of specifying a search range as numerical value information conforming to coordinates on an image and

[0059] (a2) a technique of specifying a search range on a graphical user interface (GUI).

[0060] In the aforementioned specification technique (a1), for example, search range setting unit **157** accepts input of specifying a search range E**11** as numerical value information conforming to coordinates on depth map M**11**, as illustrated on the left-hand side of FIG. **4**. In the example on the left-hand side of FIG. **4**, a coordinate value [(x, y)=(5, 2)] of the upper-left corner and a width ($\Delta x=20$, $\Delta y=10$) in the x-axis and y-axis directions are specified as the position of the search range E**11** in a coordinate system with the upper-left corner of the depth map M**11** as the origin. It should be noted that, while an example of defining a search range as a rectangular region and specifying the position and the size of the search range as numerical value information is described, a search range is not limited to a rectangle and may be specified as another shape such as a circle, or a polygon. When a search range is specified as another shape, for example, information specifying a geometric center, an outer diameter, or vertex positions may be used as numerical value information. Search range setting unit **157** may accept such specification of a search range by numerical value information conforming to coordinates on an image as, for example, input from the robot program or may accept a user operation of inputting numerical value information on a UI. It should be noted that such a UI screen may be provided on display unit **41** of the teach pendant **40**.

[0061] In the aforementioned specification technique (a2), for example, search range setting unit **157** provides a GUI allowing specification of the position and the size of the frame line of a rectangle indicating a search range on the depth map M**11**, as illustrated in an example on the left-hand side of FIG. **5**. For example, such a GUI may be displayed on display unit **41** of the teach pendant **40**. An operator can specify the position and the size of a frame indicating search range E**11** by moving a cursor C**1** by a mouse operation or a touch operation. It should be noted that, while an example of setting a search range as a rectangular region on a GUI is described, a search range may be set as another shape such as a circle or a polygon on the GUI. In the specification method (a2), an operator can specify a search range by an intuitive operation.

[0062] Search range setting unit **157** may be configured to accept specification of a search range in the form of simultaneously applying the aforementioned specification techniques (a1) and (a2). In this case, for example, search range setting unit **157** accepts specification by a procedure of setting a search range on the GUI by an operator and then exactly setting the search range by numerical value information.

[0063] The aforementioned function (F1) will be described with reference to FIG. **4**. As an example, it is assumed that the aforementioned specification technique (a1) is used as the technique for specifying a search range. The depth map M**11** illustrated on the left-hand side of FIG. **4** is a depth map of a region on installation surface **92** in the workspace in which workpieces W**1** to W**3** are arranged (image capture range R**11**). When the search range E**11** is specified on the image by the specification technique (a1), search range setting unit **157** sets the search range E**11** specified on the image as a search range defined in the real space (indicated by giving the same sign E**11** on the right-hand side of FIG. **4**), as illustrated on the right-hand side of FIG. **4**. In this case, search range setting unit **157** can make a transformation into the position of the search range in the real space related to the search range on the image by using calibration data and the like.

[0064] In this function (F1), search range setting unit **157** defines a search range specified by the specification technique (a1) or (a2) as described above as a range fixed in the real space. Accordingly, even when the position or the posture of visual sensor **70** changes, the search range can remain fixed in the real space.

[0065] Based on a depth map, determination unit **154** determines whether an object is placed, with a range corresponding to the search range E**11** in the real space as a determination target. Since the search range is set as a range fixed in the real space, even when the position or the posture of visual sensor **70** changes and the image capture range moves, a fixed range in the real space can be set as a determination target. This function (F1) is an effective function when the workplace of the robot is set at a predetermined position.

[0066] The aforementioned function (F2) will be described with reference to FIG. **5**. As an example, it is assumed that the aforementioned specification technique (a2) is used as the technique for specifying a search range. When the search range E**11** is specified on the image, the search range setting unit **157** sets the search range E**11** as a range associated with the image capture range R**11** of the captured image M**11**, as illustrated on the right-hand side of FIG. **5**. In other words, search range setting unit **157** sets the search range E**11** as a range the position of which is fixed relative to the image capture range R**11** (see the right-hand side of FIG. **5**). Accordingly, when the position or the posture of visual sensor **70** changes and the image capture range R**11** moves, the search range E**11** follows the movement of the image capture range R**11**.

[0067] In this function, determination unit **154** determines whether an object is placed, with the search range E**11** set to the captured depth map M**11** as a determination target. Since the search range is set in such a way as to be tied to the image capture range, the range of the determination target on the captured image can be always fixed.

[0068] In the aforementioned functions (F3) and (F4), search range setting unit **157** accepts input of specifying a search range as a range in the real workspace. As an example, search range setting unit **157** is configured to be able to accept, as a technique for specifying a search range as a range in the real space,

[0069] (b1) a technique of specifying a search range in the real space by operating the robot to perform touch-up and

[0070] (b2) a technique of specifying a search range as positional information in the real space from an input source such as the robot program or a user setting.

[0071] The aforementioned function (F3) will be described with reference to FIG. **6**. An example of using the specification technique (b1) will be described. In this function (F3), an operator specifies a search range by performing an operation of touching up a plurality of points in the workspace with touch-up pin **35** attached to the arm tip of robot **10** by operating robot **10**, as illustrated on the left-hand side of FIG. **6**. In the example illustrated on the left-hand side of FIG. **6**, four points **301**, **302**, **302**, and **304** related to the positions of the four corners of a search range are specified on installation surface **92** in the workspace by the touch-up operation. The three-dimensional positions of the points **301** to **304** are acquired by the touch-up operation.

[0072] In this case, search range setting unit **157** sets a range of a rectangle having the four points **301** to **304** as four corners as a search range E**12** in the real space, as illustrated on the right-hand side of FIG. **6**. In this function (F3), the search range E**12** is set as a range fixed in the real space. The operator can set a search range at a desired position in the workspace.

[0073] Determination unit **154** determines whether an object is placed, using a range, in the depth map, corresponding to the search range E**12** in the real space as a determination target. It should be noted that, when performing image processing such as determination on an image, determination unit **154** acquires a search range on the image related to the search range E**12** specified as a position in the real space, based on the calibration data or the like. In this example, the search range is determined in the real space, and therefore, even when the position or the posture of visual sensor **70** changes and the image capture range moves, a fixed range in the real space can be set as a determination target. This function (F3) is an effective function when the workplace of the robot is set at a predetermined position.

[0074] The aforementioned function (F4) will be described with reference to FIG. **7**. An example of using the aforementioned specification technique (b1) will be described. An operator specifies a plurality of points in the real space by operating the robot to perform touch-up, similarly to the aforementioned function (F3) (see the left-hand side of FIG. **7**). Thus, three-dimensional coordinate values representing the positions of the four corners of a search range are acquired.

[0075] Search range setting unit **157** sets a search range E**12** in the real space specified by the touch-up operation as a search range associated with the image capture range R**11** of the visual sensor **70** (indicated by giving the same sign E**12** on the right-hand side of FIG. **7**). Accordingly, in this function, the search range E**12** is set as a position based on the image capture range R**11**, and even when the position or the posture of the visual sensor changes and the image capture range R**11** moves, the search range follows the movement. In other words, the position of the search range in the captured image can be always fixed.

[0076] In this function, determination unit **154** determines whether an object is placed, with the search range E**12** set to the depth map of the image capture range R**11** as a determination target. Since the search range is set in such a way as to be tied to the image capture range, the range of the determination target on a captured image can be always fixed.

[0077] As described above, according to the present embodiment, a search range may be specified as a range on an image or may be specified as a range in the real space. Accordingly, an operator can specify a suitable search range according to various conditions including the content of the work, an environmental condition of the workspace, and the like. As described above, a specification technique based on the robot program, a specification technique based on a user input through a UI, a specification technique based on operation of the robot to perform touch-up, and the like may be employed as the input technique for specifying a search range. Thus, the present embodiment can provide a high degree of freedom related to the specification technique of a search range.

[0078] Determination unit **154** determines whether an object is placed, based on a depth map, with a search range set as described above as a determination target. As a specific example of processing of determining, by determination unit **154**, whether an object is placed within a search range, a case of performing an operation of determining whether an object is placed on the inspection target surface, based on a frequency distribution (histogram) created from the depth map by histogram creation unit **153** will be described below. A technique other than the technique using a frequency distribution (histogram) illustrated herein may be used as the technique for determining whether an object is placed.

[0079] Histogram creation unit **153** creates a histogram with distance (brightness) as a variable for an image in which the brightness varies with distance, such as the depth map M**1**. In creation of a histogram, histogram creation unit **153** may be configured to create a histogram by searching a point cloud within a search range set on a depth map by the function of search range setting unit **157**. The depth map M**1** acquired as illustrated in FIG. **3** will be described as an example. It is assumed that a search range E**1** is specified on the depth map M**1** as illustrated in FIG. **8**. FIG. **9** illustrates a histogram **201** created by histogram creation unit **153** in this case. In the histogram **201** in FIG. **9**, the horizontal axis (a variable) represents the brightness of a point, and the vertical axis represents the sum of the number of points (a frequency). In the search range E**1**, the ratio of floor surface **90** is highest, and therefore, the frequency of floor surface **90** represented by the darkest point cloud is indicated highest. The top surfaces of workpieces W**1**, W**2**, and W**3** with heights different from each other have the same area. Therefore, the respective frequencies of the point clouds of the brightness representing workpieces W**1**, W**2**, and W**3** are the same.

[0080] Referring to FIG. **9**, it can be understood that specification of the brightness of floor surface **90** as an inspection target surface allows determination of whether an object with a height different from that of floor surface **90** is placed on floor surface **90**. In the example in FIG. **9**, since point clouds with brightness different from that of floor surface **90** are distributed at three locations, three workpieces W**1**, W**2**, and W**3** with different heights can be determined to be placed on floor surface **90**. As for specification of the brightness of the inspection target surface (floor surface **90**), the brightness of the inspection target surface (a threshold value for determining whether given brightness is the brightness of the inspection target surface) may be set by a user input. The brightness of the inspection target surface (the threshold value for determining whether given brightness is the brightness of the inspection target surface) may be automatically set by determination unit **154**. Details of the method for setting the brightness of the inspection target surface (the threshold value for determining whether given brightness is the brightness of the inspection target surface) will be described later.

[0081] A case of a search range E**2** being specified on the depth map M**1** as illustrated in FIG. **8** will be considered.

FIG. **10** illustrates a histogram **202** created by histogram creation unit **153** in this case. Since the search range E**2** is a region including only floor surface **90**, there is only one type of brightness having a frequency in the histogram **202**, and the frequency is lower compared with the case of the search range E**1**.

[0082] By specifying a wide search range, such as the search range E**1**, within an image capture range R**1**, a histogram can be acquired for a wide range and the presence of an object within the wide range can be confirmed. On the other hand, specifying a relatively narrow search range, such as the search range E**2**, is useful when high-speed determination of the presence of an object for a limited region is desired. Further, limiting a search range to a relatively narrow range can reduce the possibility of inclusion of an outlier in a histogram.

[0083] FIG. **8** also illustrates the image capture range R**1** of visual sensor **70**. Image capture range setting unit **156** accepts specification of the size and the position of an image capture range within an allowable image capture range of visual sensor **70**. Image capture range setting unit **156** may be configured to provide a graphical user interface for setting at least one of the size and the position of a rectangular image representing an image capture range on a screen as illustrated in FIG. **8**. Such a user interface may be provided on display unit **41** of the teach pendant **40**.

[0084] Histogram creation unit **153** may have a function of displaying a histogram (e.g., the histogram **201** or **202**) created for a range (an image capture range or a search range) specified as described above on, for example, display unit **41** of the teach pendant **40** in response to a predetermined operation on the operation unit of the teach pendant **40**. It should be noted that histogram creation unit **153** may have a function of storing distance information within a specified range (an image capture range or a search range) into, for example, storage unit **161** as numerical value information (a numerical value table representing a histogram) and displaying the distance information on, for example, display unit **41** of the teach pendant **40** in response to a predetermined operation on the operation unit of the teach pendant **40**.

[0085] As described above, robot controller **50** has a function of determining whether an object is placed within a search range specified by predetermined input information. FIG. **11** is a flowchart generally describing such a function (object presence determination processing) provided by determination unit **154**. This processing is executed under the control of processor **51**. As illustrated in FIG. **11**, image acquisition unit **152** acquires a depth map captured by visual sensor **70** (step S**1**). Next, determination unit **154** determines whether an object is placed within the search range specified by the predetermined input information, based on the depth map (step S**2**).

[0086] According to the present embodiment, robot controller **50** is configured to be able to determine whether an object is placed on an inspection target surface (floor surface **90** in the case of the histogram **201**), based on the aforementioned histogram. FIG. **12** is a flowchart illustrating a specific operation example of the object presence determination processing executed by robot controller **50** (processor **51**). First, image acquisition unit **152** acquires, from visual sensor **70**, a depth map in which an image capture range including an inspection target surface is captured (step S**101**). Next, histogram creation unit **153** creates a histogram of brightness in the depth map (step S**102**). The histogram may be created for the inside of a search range set as described above. Then, determination unit **154** determines whether an object is placed on the inspection target surface within the search range, based on the histogram related to brightness in the depth map (step S**103**).

[0087] The details about the object presence determination processing will be described below by citing two examples of applying the object presence determination processing in FIG. **12** to handling work on a workpiece by robot **10**.

[0088] A first example is an operation example of applying the object presence determination processing to transfer work of a workpiece by workpiece transfer execution unit **160**. FIG. **13** is a flowchart in a case of applying the object presence determination processing to workpiece transfer processing. This processing is executed under the control of processor **51** in robot controller **50**.

[0089] Workpiece transfer execution unit **160** picks up a workpiece from a feeding device such as a belt conveyor by robot **10** (step S**11**). In placement of the workpiece on the destination of the workpiece (e.g., a conveying device or a worktable), workpiece transfer execution unit **160** executes the object presence determination processing in order to confirm that no object is placed on the destination (step S**12**). It is assumed in this example that the operation of placing the workpiece on the destination is taught to robot **10** on the assumption that no object (obstacle) is present on the destination.

[0090] A specific example of the object presence determination processing executed in step S**12** will be described with reference to FIG. **14** and FIG. **15**. FIG. **14** illustrates a state in which visual sensor **70** captures a depth map in a situation in which nothing is placed on placement surface **91** being the destination and illustrates a histogram **211** of the depth map acquired at that time. FIG. **15** illustrates a state in which visual sensor **70** captures a depth map in a situation in which workpiece W**5** is placed on placement surface **91** and illustrates a histogram **212** acquired at that time.

[0091] Robot controller **50** may acquire, in advance, the histogram **211** acquired in the state in which nothing is placed on placement surface **91** and store the histogram in storage unit **161**. Determination unit **154** can determine whether an object is placed on placement surface **91** by comparison between the prestored histogram **211** and the histogram **212** of the depth map acquired in step S**12** at execution of the workpiece transfer processing.

[0092] As illustrated in the histogram **211** in FIG. **14**, threshold value setting unit **155** provides a function of setting threshold values for determining whether a frequency of a height (brightness) other than the height (brightness) of placement surface **91** is present in the depth map. For example, the threshold values may be set as an upper limit K**1** and a lower limit K**2** for determining, with reference to the height (brightness) of placement surface **91**, a range including the reference height (brightness), as illustrated in FIG. **14**. Determination unit **154** can determine that an object is placed on placement surface **91** when the presence of a point cloud with brightness outside the range determined by the upper limit K**1** and the lower limit K**2** is perceived.

[0093] The threshold values (the upper limit K**1** and the lower limit K**2**) may be set by a user or may be automatically set by threshold value setting unit **155**. Threshold value setting unit **155** may perform automatic setting of the threshold values (the upper limit K**1** and the lower limit K**2**) by the following procedure:

[0094] r1) specify brightness having a frequency in the prestored histogram **211** as the brightness of placement surface **91**, and

[0095] r2) set, as the upper limit K**1**, brightness acquired by adding a predetermined margin to the brightness of placement surface **91**, and set, the lower limit K**2**, brightness acquired by subtracting a predetermined margin from the brightness of placement surface **91**.

[0096] A technique of automatically setting the threshold values by threshold value setting unit **155**, based on a depth map previously acquired in a state in which nothing is present on the inspection target surface has been described. As another technique, for example, an algorithm determining a point cloud satisfying a condition being:

[0097] (d1) having the highest frequency in the depth map at inspection or

[0098] (d2) having the highest frequency and the darkest color in the depth map at inspection to be the inspection target surface may be employed depending on the situation of the inspection target surface. The algorithm (d1) is effective in a situation in which basically not so many objects are assumed to be placed on the inspection target surface in many cases. The algorithm (d2) is effective when basically not so many objects are placed on the inspection target surface in many cases and the inspection target surface is at the lowest position within an image capture range (or within a search range), such as a floor surface.

[0099] When threshold value setting unit **155** accepts user setting of the threshold values (the upper limit K**1** and the lower limit K**2**), a graphical user interface screen (GUI screen **350**) as illustrated in FIG. **16** may be provided to display unit **41** of the teach pendant **40**. GUI screen **350** illustrated in FIG. **16** is configured to display a histogram created by histogram creation unit **153**, based on a depth map captured in a state in which no object is present on the inspection target surface, and accept setting of the threshold values on the screen. GUI screen **350** illustrated in FIG. **16** is configured to allow entry of the upper limit K**1** and the lower limit K**2** being the threshold values into numerical value entry fields **351** and **352** with the brightness N**1** of the inspection target surface being sandwiched between the threshold values. A user can set a desired upper limit K**1** and a desired lower limit K**2** being the threshold values to the numerical value entry fields **351** and **352**. Thus, by allowing setting of the threshold values on a screen displaying a histogram of the inspection target surface, the user can intuitively perform setting of the threshold values with reference to the histogram.

[0100] A situation in which workpiece W**5** remains on placement surface **91** at inspection (i.e., in the object presence determination processing in step S**12**) as illustrated in FIG. **15** is assumed. In this case, the histogram **212** as illustrated on the right-hand side of FIG. **15** is generated. Then, determination unit **154** specifies the presence of a point cloud with brightness exceeding the upper limit K**1** being the threshold value (i.e., the presence of workpiece W**5**). In this case, an object is determined to be placed on the inspection target surface in step S**13** (S**13**: YES), the work of placing a workpiece is interrupted, and the processing advances to step S**15**.

[0101] On the other hand, when an object is determined not to be placed on the inspection target surface in step S**13** (S**13**: NO), workpiece transfer execution unit **160** executes the work of placing a workpiece on placement surface **91** (step S**14**). Then, workpiece transfer execution unit **160** may continue the work of picking-up and transferring a next workpiece.

[0102] In step S**15**, history image storage unit **158** stores, as a history image, a two-dimensional image in which the state in which workpiece W**5** remains on placement surface **91** is captured by the two-dimensional camera function of visual sensor **70** into storage device **80** together with other history information. Then, workpiece transfer execution unit **160** ends this processing.

[0103] Thus, according to the workpiece transfer processing according to the present embodiment, the absence of an object at a location where a workpiece is to be placed can be reliably detected, and therefore, safety in the operation of placing a workpiece can be improved. In case some object (obstacle) is present at a location where a workpiece is to be placed, the work of placing the workpiece by the robot can be interrupted. Therefore, the occurrence of a malfunction (e.g. suspension of a production cycle) due to the robot performing the operation of placing a workpiece at a location where another workpiece is placed and causing interference between the workpieces can be prevented. Accordingly, the present embodiment enables safer and smoother workpiece transfer processing.

[0104] The history image stored in step S**15** can be utilized in recognition of the situation in which workpiece W**5** remains on placement surface **91**, analysis of the cause, and the like. Further, necessary measures can be taken by utilization of the history image.

[0105] Histogram creation unit **153** may be configured to display a histogram based on a depth map acquired by visual sensor **70** on a display screen (display unit **41**) in response to a predetermined user operation while the workpiece transfer processing is performed. In the workpiece transfer processing, determination unit **154** may determine whether an object is placed on the inspection target surface in a set range (an image capture range or a search range).

[0106] A second example of applying the object presence determination processing to handling work of a workpiece by robot **10** will be described. The second example is an operation example of applying the object presence determination processing to pickup processing of workpieces loaded in bulk performed by workpiece pickup execution unit **159**. FIG. **17** is a flowchart in a case of applying the object presence determination processing to the pickup processing of workpieces loaded in bulk. This processing is executed under the control of processor **51** of the robot controller **50**. It is assumed that work of picking-up workpieces W**6** loaded in bulk (only part of the workpieces is given a sign) in container **95** on floor surface **90** is executed as illustrated in FIG. **18** and FIG. **19**.

[0107] Workpiece pickup execution unit **159** executes the pickup processing of workpieces loaded in bulk in accordance with the workpiece pickup program stored in storage unit **161** (step S**21**). Then, workpiece pickup execution unit **159** determines whether the pickup of the workpieces loaded in bulk is completed by a predetermined completion determination condition (step S**22**). For example, the predetermined completion determination condition is non-detection of workpiece W**6** as a detection result of executing detection processing of workpiece W**6**, based on a two-dimensional image in which the inside of container **95** is captured by visual sensor **70**. When pickup of the workpiece is determined not to be completed (S**22**: NO), the pickup processing of workpieces is continued.

[0108] When workpiece pickup execution unit **159** determines that the pickup processing of the workpiece is completed (S**22**: YES), the object presence determination processing is executed (step S**23**). In this object presence determination processing, whether workpiece W**6** remains in container **95** is determined.

[0109] The object presence determination processing executed in step S**23** will be described with reference to FIG. **18** to FIG. **20**. FIG. **18** illustrates a situation in which visual sensor **70** captures a depth map in a state in which many workpieces W**6** are present in container **95**, and a histogram **221** of the depth map acquired at that time. FIG. **19** illustrates a situation in which visual sensor **70** captures a depth map in a situation in which no object is present in container **95**, and a histogram **222** of the depth map acquired at that time. FIG. **20** illustrates a situation in which visual sensor **70** captures a depth map in a situation in which one workpiece W**6** remains in container **95**, and a histogram **223** of the depth map acquired at that time.

[0110] It should be noted that it is assumed in this example that the histogram **222** acquired in the situation in which no object is present in container **95** as illustrated in FIG. **19** is prestored in storage unit **161**. It is assumed that threshold value setting unit **155** specifies the height (brightness) of bottom surface **95***a* of container **95**, based on the histogram **222**, and determines the upper limit K**1** and the lower limit K**2** being the threshold values based on the brightness. Specification of the brightness of bottom surface **95***a* and setting of the threshold values (the upper limit K**1** and the lower limit K**2**) can be performed by the aforementioned procedures (r1) and (r2). It should be noted that, in the situation in which many workpieces W**6** are present in container **95** as illustrated in FIG. **18**, many point clouds are distributed in a brightness range beyond the range determined by the upper limit K**1** and the lower limit K**2** being the threshold values based on bottom surface **95***a* in the histogram **221**. On the other hand, in the situation in which no workpiece W**6** remains in the container as illustrated in FIG. **19**, no point cloud having a frequency in the brightness range beyond the range determined by the upper limit K**1** and the lower limit K**2** being the threshold values based on bottom surface **95***a* is present.

[0111] When no point cloud having brightness beyond the range determined by the upper limit K**1** and the lower limit K**2** being the threshold values is present as a result of the object presence determination processing, it is determined that no object is present on bottom surface **95***a* as the inspection target surface (S**24**: NO). In this case, pickup of the workpieces loaded in bulk is suitably ended, and this processing is ended.

[0112] It is assumed that workpiece W**6** remains in container **95** as illustrated in FIG. **20** when the object presence determination processing is executed. In this case, determination unit **154** determines the presence of an object on the inspection target surface, based on the histogram **223** illustrated in FIG. **20**. In the histogram **223**, distribution of a point cloud is perceived in a brightness range beyond the range determined by the upper limit K**1** and the lower limit K**2** being the threshold values. Accordingly, in this case, determination unit **154** determines that an object is present on bottom surface **95***a* being the inspection target surface (S**24**: YES).

[0113] In this case (S**24**: YES), history image storage unit **158** stores, as a history image, a two-dimensional image in which the state in which workpiece W**6** remains on bottom surface **95***a* is captured by the two-dimensional camera function of visual sensor **70**, in storage device **80** together with other history information (step S**25**). Then, workpiece pickup execution unit **159** ends this processing.

[0114] As described above, the workpiece pickup processing according to the present embodiment enables reliable detection of a malfunction that the robot controller makes a workpiece pickup completion determination in a state in which a workpiece remains in the container.

[0115] The history image stored in step S**25** can be utilized for analyzing the cause of workpiece pickup execution unit **159** making the pickup completion determination in the state in which workpiece W**6** remains. For example, in a situation in which one side of workpiece W**6** remains in close contact with the inner surface of container **95** as illustrated in FIG. **20**, it may be assumed that detection processing of applying pattern matching to a two-dimensional image cannot satisfactorily detect workpiece W**6**. On the other hand, as described above, determination by the object presence determination processing can suitably determine the presence of workpiece W**6**. Accordingly, by storing the situation in which workpiece W**6** remains as illustrated in FIG. **20** as a history image, the aforementioned cause can be analyzed, and necessary measures can be taken.

[0116] It should be noted that, in the aforementioned second example, the image capture range or the search range may be previously adjusted in such a way that the side of container **95** is not measured. By thus setting the image capture range or the search range, frequencies of only the heights of bottom surface **95***a* of container **95** and workpiece W**6** (when workpiece W**6** is present) appear in the histogram, which enables more satisfactory object presence determination.

[0117] As described above, according to the present embodiment, whether an object is placed at an inspection target location can be reliably determined, and prevention of the occurrence of a malfunction in handling work of a workpiece by the robot and detection of the occurrence of a malfunction can be reliably performed.

[0118] In the aforementioned embodiment, the placement of functions in the functional block diagram illustrated in FIG. **2** is an example, and various modified examples may be configured for the placement of functions. For example, a configuration of placing part of the functional blocks placed in robot controller **50** (e.g., threshold value setting unit **155**, image capture range setting unit **156**, and search range setting unit **157**) on teach pendant **40** side is a possible example.

[0119] The functions as teach pendant **40** (e.g., the functions of the display unit and the operation unit as user interfaces) may be included in the functions of robot controller **50** and the functions of the robot controller may be defined as such.

[0120] While an operation example of determining whether an object is placed within a search range by using a histogram of a depth map by determination unit **154** has been described in the aforementioned embodiment, the operation example of determining whether an object is placed within a search range by the determination unit is not limited to the above. For example, determination unit **154** may determine whether an object is placed within a specified search range by using distance data of each point in a depth map. In this case, for example, when the presence of an object with a specific height based on the height of a reference plane in a search range is perceived, the object may be determined to be placed within the search range (on the reference plane). It should be noted that when the determination unit is configured as described above, the functions related to determination based on a histogram (histogram creation unit **153** and threshold value setting unit **155**) may be omitted.

[0121] The functional blocks in the robot controller and the visual sensor controller that are illustrated in FIG. **2** may be provided by executing various types of software stored in the storage by the processors of the controllers or may be provided by a configuration mainly based on hardware such as an application specific integrated circuit (ASIC).

[0122] The aforementioned object presence determination processing (FIG. **11** and FIG. **12**) can be executed on various information processing devices.

[0123] Programs executing various types of processing such as the object presence determination processing (FIG. **11** and FIG. **12**), the workpiece transfer processing (FIG. **13**), and the workpiece pickup processing (FIG. **17**) in the aforementioned embodiment can be recorded on various computer-readable recording media (e.g., semiconductor memories such as a ROM, an EEPROM, and a flash memory; a magnetic recording medium; and optical disks such as a CD-ROM and a DVD-ROM).

[0124] While the present disclosure has been described in detail, the present disclosure is not limited to each of the aforementioned embodiments. Various additions, substitutions, changes, partial deletions, and the like may be made to the embodiments without departing from the spirit of the present disclosure or without departing from the scope of the present disclosure derived from the contents described in the claims and the equivalents thereof. Further, the embodiments may be implemented in combination. For example, the operation order or processing order is described as an example in the aforementioned embodiments and is not limited thereto. Further, the above also holds when a numerical value or a mathematical expression is used in the description of the aforementioned embodiments.

[0125] The following Supplementary Notes are further disclosed with regard to the aforementioned embodiments and the modified examples thereof.

Supplementary Note 1

[0126] A controller (**50**) including an image acquisition unit (**152**) configured to acquire a depth map captured by a visual sensor (**70**) and a determination unit (**154**) configured to determine whether an object is placed within a range specified by predetermined input information, based on the depth map.

Supplementary Note 2

[0127] The controller (**50**) according to Supplementary Note 1, further including a search range setting unit (**157**) configured to set the range specified by the predetermined input information as a search range.

Supplementary Note 3

[0128] The controller (**50**) according to Supplementary Note 2, wherein the predetermined input information is information specifying the search range as a range on an image.

Supplementary Note 4

[0129] The controller (**50**) according to Supplementary Note 2, wherein the predetermined input information is information specifying the search range as a range in a real space.

Supplementary Note 5

[0130] The controller (**50**) according to any one of Supplementary Notes 1 to 4, wherein the predetermined input information is described in a robot program.

Supplementary Note 6

[0131] The controller (**50**) according to any one of Supplementary Notes 1 to 4, wherein the predetermined input information is information input through a user interface.

Supplementary Note 7

[0132] The controller (**50**) according to any one of Supplementary Notes 2 to 4, wherein the search range setting unit (**157**) sets the search range as a range defined in a real space.

Supplementary Note 8

[0133] The controller (**50**) according to any one of Supplementary Notes 2 to 4, wherein the search range setting unit (**157**) sets the search range as a range associated with an image capture range of the visual sensor (**70**).

Supplementary Note 9

[0134] The controller (**50**) according to Supplementary Note 3, wherein the range on the image is represented as numerical value information based on a coordinate on the image.

Supplementary Note 10

[0135] The controller (**50**) according to Supplementary Note 3, wherein the search range setting unit (**157**) provides a graphical user interface for specifying the range on the image by a graphical operation.

Supplementary Note 11

[0136] The controller (**50**) according to Supplementary Note 4, wherein the search range setting unit (**157**) acquires, as the information specifying the search range as a range in a real space, three-dimensional coordinates of a plurality of points in a real space acquired by causing a robot (**10**) to execute an operation of touching up the plurality of points.

Supplementary Note 12

[0137] The controller (**50**) according to Supplementary Note 1, further including an image capture range setting unit (**156**) configured to set the range specified by the predetermined input information as the image capture range within which the visual sensor (**70**) captures an image, wherein the image capture range setting unit (**156**) transmits, to the visual sensor (**70**), a signal instructing the visual sensor to perform image capture in the set image capture range.

Supplementary Note 13

[0138] The controller (**50**) according to any one of Supplementary Notes 1 to 12, wherein the determination unit (**154**) determines whether an object is placed on an inspection target surface within the specified range.

Supplementary Note 14

[0139] The controller (**50**) according to Supplementary Note 13, wherein the determination unit (**154**) determines whether an object is placed on the inspection target surface, based on a frequency distribution related to distance information of each point in the acquired depth map.

Supplementary Note 15

[0140] The controller (**50**) according to Supplementary Note 14, further including a threshold value setting unit (**155**) configured to set a threshold value for distinguishing between distance information of the inspection target surface in the frequency distribution and distance information of another object on the inspection target surface, wherein the determination unit (**154**) determines whether an object is placed on the inspection target surface by using the threshold value.

Supplementary Note 16

[0141] The controller (**50**) according to Supplementary Note 15, wherein the threshold value setting unit (**155**) sets the threshold value, based on a frequency distribution related to distance information of each point in a depth map acquired in a situation in which no object is placed on the inspection target surface.

Supplementary Note 17

[0142] The controller (**50**) according to Supplementary Note 15, wherein the threshold value setting unit (**155**) is configured to provide a user interface accepting setting of the threshold value by a user operation.

Supplementary Note 18

[0143] The controller (**50**) according to Supplementary Note 17, wherein the user interface is configured as a graphical user interface including an image representing a frequency distribution of the depth map.

Supplementary Note 19

[0144] The controller (**50**) according to Supplementary Note 15, wherein the threshold value setting unit (**155**) sets the threshold value in accordance with threshold value information described in a robot program.

Supplementary Note 20

[0145] The controller (**50**) according to any one of Supplementary Notes 14 to 19, further including a histogram creation unit (**153**) configured to generate an image representing the frequency distribution, based on distance information of each point in the acquired depth map, and display the image on a display screen.

Supplementary Note 21

[0146] The controller (**50**) according to Supplementary Note 20, wherein the histogram creation unit (**153**) is configured to generate an image representing the frequency distribution in a specified range in the depth map.

Supplementary Note 22

[0147] The controller (**50**) according to any one of Supplementary Notes 14 to 21, further including a workpiece transfer execution unit (**160**) configured to execute workpiece transfer work of picking up a workpiece from a feeding device and placing the workpiece on a predetermined placement surface by a robot (**10**), wherein the determination unit (**154**) determines whether an object is present on the placement surface, based on a depth map in which the placement surface is captured before the workpiece transfer execution unit (**160**) places the workpiece on the placement surface.

Supplementary Note 23

[0148] The controller (**50**) according to any one of Supplementary Notes 14 to 21, further including a workpiece pickup execution unit (**159**) configured to execute pickup work of a robot (**10**) picking up one or more workpieces loaded in bulk in a container, wherein, when the workpiece pickup execution unit (**159**) makes a completion determination on pickup of one or more workpieces, based on a predetermined completion determination condition, the determination unit (**154**) determines whether an object is present on a bottom surface of the container, based on a depth map in which a bottom surface of the container is captured.

Supplementary Note 24

[0149] The controller (**50**) according to Supplementary Note 22 or 23, further including a history image storage unit (**158**) configured to store a history image when an object is determined to be present by the determination unit (**154**).

Supplementary Note 25

[0150] The controller according to any one of Supplementary Notes 14 to 24, wherein the depth map is an image representing the distance information of each point by brightness, and the frequency distribution represents a distribution of brightness of each point in the depth map.

Supplementary Note 26

[0151] A robot system (**100**) including a robot (**10**), a visual sensor (**70**), and the controller (**50**) according to any one of Supplementary Notes 1 to 25, wherein the controller (**50**) controls the robot (**10**).

Supplementary Note 27

[0152] An object presence determination method executed on an information processing device, the method including:

[0153] acquiring a depth map captured by a visual sensor (**70**); and

[0154] determining whether an object is placed within a range specified by predetermined input information, based on the depth map.

Supplementary Note 28

[0155] A program for causing a processor in a computer to execute:

[0156] a step of acquiring a depth map captured by a visual sensor (**70**); and

[0157] a step of determining whether an object is placed within a range specified by redetermined input information, based on the depth map.

REFERENCE SIGNS LIST

[0158] **10** Robot
[0159] **20** Visual sensor controller
[0160] **33** Hand
[0161] **40** Teach pendant
[0162] **50** Robot controller
[0163] **51** Processor
[0164] **70** Visual sensor
[0165] **80** Storage device
[0166] **90** Floor surface
[0167] **91** Placement surface
[0168] **95** Container
[0169] **95*a*** Bottom surface
[0170] **100** Robot system
[0171] **121** Image processing unit
[0172] **122** Storage unit
[0173] **151** Operation control unit
[0174] **152** Image acquisition unit
[0175] **153** Histogram creation unit
[0176] **154** Determination unit
[0177] **155** Threshold value setting unit
[0178] **156** Image capture range setting unit
[0179] **157** Search range setting unit
[0180] **158** History image storage unit
[0181] **159** Workpiece pickup execution unit
[0182] **160** Workpiece transfer execution unit
[0183] **161** Storage unit
[0184] **350** GUI screen

What is claimed is:

1. A controller comprising:

an image acquisition unit configured to acquire a depth map captured by a visual sensor; and

a determination unit configured to determine whether an object is placed within a range specified by predetermined input information, based on the depth map.

2. The controller according to claim **1**, further comprising a search range setting unit configured to set the range specified by the predetermined input information as a search range.

3. The controller according to claim **2**, wherein the predetermined input information is information specifying the search range as a range on an image.

4. The controller according to claim **2**, wherein the predetermined input information is information specifying the search range as a range in a real space.

5. The controller according to claim **1**, wherein the predetermined input information is described in a robot program.

6. The controller according to claim **1**, wherein the predetermined input information is information input through a user interface.

7. The controller according to claim **2**, wherein the search range setting unit sets the search range as a range defined in a real space.

8. The controller according to claim **2**, wherein the search range setting unit sets the search range as a range associated with an image capture range of the visual sensor.

9. The controller according to claim **3**, wherein the range on the image is represented as numerical value information based on a coordinate on the image.

10. The controller according to claim **3**, wherein the search range setting unit provides a graphical user interface for specifying the range on the image by a graphical operation.

11. The controller according to claim **4**, wherein the search range setting unit acquires, as the information specifying the search range as a range in a real space, three-dimensional coordinates of a plurality of points in a real space acquired by causing a robot to execute an operation of touching up the plurality of points.

12. The controller according to claim **1**, further comprising an image capture range setting unit configured to set the range specified by the predetermined input information as an image capture range within which the visual sensor captures an image, wherein the image capture range setting unit transmits, to the visual sensor, a signal instructing the visual sensor to perform image capture in the set image capture range.

13. The controller according to claim **1**, wherein the determination unit determines whether an object is placed on an inspection target surface within the specified range.

14. The controller according to claim **13**, wherein the determination unit determines whether an object is placed on the inspection target surface, based on a frequency distribution related to distance information of each point in the acquired depth map.

15. The controller according to claim **14**, further comprising a threshold value setting unit configured to set a threshold value for distinguishing between distance information of the inspection target surface in the frequency distribution and distance information of another object on the inspection target surface, wherein the determination unit determines whether an object is placed on the inspection target surface by using the threshold value.

16. The controller according to claim **15**, wherein the threshold value setting unit sets the threshold value, based on a frequency distribution related to distance information of each point in a depth map acquired in a situation in which no object is placed on the inspection target surface.

17. The controller according to claim **15**, wherein the threshold value setting unit is configured to provide a user interface accepting setting of the threshold value by a user operation.

18. The controller according to claim **17**, wherein the user interface is configured as a graphical user interface including an image representing a frequency distribution of the depth map.

19. The controller according to claim **15**, wherein the threshold value setting unit sets the threshold value in accordance with threshold value information described in a robot program.

20. The controller according to claim **14**, further comprising a histogram creation unit configured to generate an image representing the frequency distribution, based on distance information of each point in the acquired depth map, and display the image on a display screen.

21. The controller according to claim **20**, wherein the histogram creation unit is configured to generate an image representing the frequency distribution within a specified range in the depth map.

22. The controller according to claim **14**, further comprising a workpiece transfer execution unit configured to execute workpiece transfer work of picking up a workpiece from a feeding device and placing the workpiece on a predetermined placement surface by a robot, wherein the determination unit determines whether an object is present on the placement surface, based on a depth map in which the placement surface is captured before the workpiece transfer execution unit places the workpiece on the placement surface.

23. The controller according to claim **14**, further comprising a workpiece pickup execution unit configured to execute pickup work of a robot picking up one or more workpieces loaded in bulk in a container, wherein, when the workpiece pickup execution unit makes a completion determination on pickup of one or more workpieces, based on a predetermined completion determination condition, the determination unit determines whether an object is present on a bottom surface of the container, based on a depth map in which a bottom surface of the container is captured.

24. The controller according to claim **22**, further comprising a history image storage unit configured to store a history image when an object is determined to be present by the determination unit.

25. The controller according to claim **14**, wherein the depth map is an image representing the distance information of each point by brightness, and the frequency distribution represents a distribution of brightness of each point in the depth map.

26. A robot system comprising:

a robot;

a visual sensor; and

the controller according to claim **1**, wherein the controller controls the robot.

27. An object presence determination method executed on an information processing device, the method comprising:

acquiring a depth map captured by a visual sensor; and

determining whether an object is placed within a range specified by predetermined input information, based on the depth map.

28. A non-transitory computer readable storage medium storing instructions that, when executed by a processor of a computer, cause the processor to perform:

acquiring a depth map captured by a visual sensor; and

determining whether an object is placed within a range specified by predetermined input information, based on the depth map.

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