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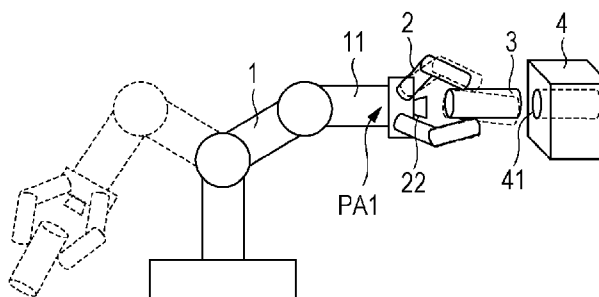
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(54) Title: ROBOT SYSTEM FOR REORIENTING A HELD WORKPIECE

[Fig. 1B]



(57) Abstract: In a robot system including an arm capable of adjusting a position/posture of an arm leading end portion thereof, a hand that is attached to the arm leading end portion, is provided with a holding portion for holding a workpiece, and is capable of adjusting a position/posture of the workpiece held by the holding portion relative to the arm leading end portion, and a position/posture measurement device configured to measure the position/posture of the workpiece relative to the arm leading end portion, the position/posture of the workpiece is measured while the arm leading end portion moves after the holding portion has held the workpiece and the position/posture of the hand relative to the arm leading end portion is corrected on the basis of a result of the measurement so that a predetermined position/posture of the workpiece relative to the arm leading end portion is set.

Description

Title of Invention: ROBOT SYSTEM FOR REORIENTING A HELD WORKPIECE

Technical Field

[0001] The present invention relates to a robot system for holding and moving a workpiece and an apparatus, a method, and a program for controlling the robot system.

Background Art

[0002] For various purposes including a purpose of stably producing high-quality products and a purpose of relieving people of dangerous works and physically demanding works, industrial robots are used in production sites.

[0003] Robots having an arm and a hand for holding a workpiece which is attached to the arm have been proposed. Such a robot repeatedly performs a simple operation by moving the arm along a predetermined path and causing the hand to perform a holding operation. The simple operation is, for example, conveyance of a workpiece, rearrangement of a workpiece, or fitting or assembling of a workpiece to another workpiece.

[0004] For example, when a robot conveys a component placed at a predetermined position on a component supply palette, the robot moves an arm thereof to a position at which a hand thereof can hold the component, operates the hand to hold the component, moves the arm to convey the component to a predetermined position on a delivery palette, and operates the hand to release the component.

[0005] However, when a workpiece (the component) is not correctly disposed at the predetermined position on the component supply palette, the robot incompletely holds the workpiece and it is difficult for the robot to complete an operation (conveyance.) Japanese Patent Laid-Open No. 6-170771 discloses a method of measuring the position/posture of a workpiece with a distance detector provided at a hand immediately before the workpiece is held, adjusting the position/posture of a holding unit to the position/posture of the workpiece, and holding the workpiece.

[0006] However, even if such a method is performed, the position/posture of the workpiece may be changed on contact with the holding unit disposed at the hand when the workpiece is held by the holding unit.

[0007] In order to improve such a situation, after the workpiece has been held, the position/posture of the workpiece may be measured and corrected. Japanese Patent Laid-Open No. 2009-50921 discloses an apparatus for holding a workpiece, bringing the workpiece into contact with an object whose position/posture has been known, measuring the position/posture of the workpiece, correcting the deviation of the

position/posture of the workpiece from a reference position/posture, and moving a robot on the basis of a result of the correction of the deviation. Furthermore, the apparatus disclosed in Japanese Patent Laid-Open No. 2009-50921 detects a positional deviation of the workpiece held in a hand from a reference position and controls the movement of the hand to compensate for the positional deviation.

- [0008] However, since the apparatus disclosed in Japanese Patent Laid-Open No. 2009-50921 brings the held workpiece into contact with the object whose position/posture has been known when measuring the position/posture of the workpiece, a cycle time is increased.
- [0009] An apparatus disclosed in Japanese Patent Laid-Open No. 2000-71190 compensates for the positional deviation of a workpiece by correcting the target position/posture of a hand on the basis of the positional deviation. In general, multi-axis control arm robots for industrial use have a large moment of inertia in an arm portion thereof so as to maintain rigidity and also have a large time constant.
- [0010] In inverse kinematics calculation of a via point, the largest time constant in a normal system is used. Accordingly, in order to complete the correction of a position/posture without increasing an arm movement time, it is necessary to complete the determination of a corrected target position/posture a time corresponding to a time constant earlier than a target expected time of arrival. Thus, in order not to increase a cycle time in a system such as a multi-axis control arm robot for industrial use having a large time constant, it is necessary to reduce a time required for the measurement of a position/posture of a held workpiece and the determination of a corrected target position/posture.
- [0011] In the above-described method in the related art and the above-described apparatuses in the related art, when a workpiece is fitted or assembled to another workpiece, the positional deviation of another workpiece is not corrected while the positional deviation of the workpiece is corrected.
- [0012] Furthermore, in the above-described method in the related art and the above-described apparatuses in the related art, when the positional deviation of a held workpiece is large, the workpiece may hit against an obstacle while an arm moves or the holding of the workpiece may be performed again.

Citation List

Patent Literature

- [0013] PTL 1: Japanese Patent Laid-Open No. 6-170771
PTL 2: Japanese Patent Laid-Open No. 2009-50921
PTL 3: Japanese Patent Laid-Open No. 2000-71190

Summary of Invention

- [0014] The present invention has been made in consideration of the above situation, and has as its object to measure and correct the position/posture of a workpiece held by a hand without increasing a cycle time.
- [0015] According to the present invention, the foregoing object is attained by providing a robot system including an arm capable of adjusting a position/posture of an arm leading end portion thereof, a hand that is attached to the arm leading end portion, is provided with a holding mechanism for holding a workpiece, and is capable of adjusting a position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion, a first position/posture measurement unit configured to measure the position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion, and a control unit configured to perform measurement and correction of the position/posture of the workpiece held by the holding mechanism while the arm leading end portion moves after the holding mechanism has held the workpiece. In the measurement of the position/posture of the held workpiece, the control unit measures the position/posture of the workpiece relative to the arm leading end portion. In the correction of the position/posture of the held workpiece, the control unit corrects a position/posture of the hand relative to the arm leading end portion on the basis of a result of the measurement so that a predetermined position/posture of the workpiece relative to the arm leading end portion is set.
- [0016] Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof.

Brief Description of Drawings

- [0017] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.
- [fig.1A-1C] Figs. 1A to 1C are diagrams illustrating the configuration and operation states of a robot system according to a first embodiment of the present invention.
- [fig.2] Fig. 2 is a flowchart illustrating a control process according to the first embodiment.
- [fig.3] Fig. 3 is a diagram illustrating the operation state of a robot system according to a second embodiment of the present invention.
- [fig.4] Fig. 4 is a flowchart illustrating a control process according to the second embodiment.
- [fig.5] Fig. 5 is a flowchart illustrating a control process for correcting the position of a protrusion after the movement of an arm leading end portion has been completed.

[fig.6]Fig. 6 is a diagram illustrating the configuration and operation state of a robot system according to a third embodiment of the present invention.

[fig.7]Fig. 7 is a flowchart illustrating a control process according to the third embodiment.

[fig.8]Fig. 8 is a flowchart illustrating a control process according to a fourth embodiment of the present invention.

[fig.9]Fig. 9 is a flowchart illustrating a control process according to a fifth embodiment of the present invention.

[fig.10]Fig. 10 is a flowchart illustrating a control process according to a sixth embodiment of the present invention.

[fig.11]Fig. 11 is a flowchart illustrating a control process according to a seventh embodiment of the present invention.

[fig.12]Fig. 12 is a flowchart illustrating a control process according to an eighth embodiment of the present invention.

Description of Embodiments

[0018] Preferred embodiments of the present invention will be described in detail below with reference to the accompanying drawings.

First Embodiment

[0019] Fig. 1A is a diagram illustrating an exemplary configuration of a robot system according to an embodiment of the present invention. An arm 1 is a multi-joint serial link robot. Each joint is driven by a motor, so that the position/posture of an arm leading end portion 11 can be adjusted.

[0020] A hand 2 is attached to the arm leading end portion 11. The hand 2 is provided with a holding portion (holding mechanism) 21, and can hold and release a workpiece 3 with the holding portion 21. In addition, the hand 2 is provided with control mechanisms for correcting the position/posture of a held object. These control mechanisms include a rotating mechanism at a joint corresponding to a wrist and a multi-joint finger mechanism, and can also be achieved in a parallel link mechanism by combining X, Y, and Z stages and a 3-axis (pan, tilt, and roll) pan head.

[0021] The time constant of the arm 1 is large. The time constant of the hand 2 is smaller than that of the arm 1. Accordingly, the hand 2 can perform high-responsivity control processing.

[0022] In addition, the hand 2 is provided with a position/posture measurement device 22 for measuring the position/posture of the held workpiece 3 relative to the arm leading end portion 11. The position/posture measurement device 22 is, for example, a visual sensor including a camera and an image processing unit.

[0023] The arm 1 and the hand 2 are controlled by a robot control device 5. An application

control device 6 transmits an instruction to the robot control device 5 so as to operate the arm 1 and the hand 2 and can receive information about the position/posture of the workpiece 3 held by the holding portion 21 from the position/posture measurement device 22. An application used to perform control processing according to an embodiment of the present invention is stored in the application control device 6 for execution.

[0024] In this embodiment, the arm 1 is a multi-joint serial link robot and the hand 2 is a parallel link mechanism. However, the arm 1 and the hand 2 may be other mechanisms.

[0025] An operation for holding the workpiece 3 with the holding portion 21 and fitting the workpiece 3 into a hole portion 41 of a workpiece 4 will be described. Fig. 1A illustrates a state immediately after the holding portion 21 has held the workpiece 3. Fig. 1B illustrates a state immediately before the workpiece 3 is fitted into the hole portion 41 of the workpiece 4. In Fig. 1B, the illustration of the robot control device 5 and the application control device 6 is omitted. Fig. 1C illustrates the positional relationship among the hand 2, the workpiece 3, and the workpiece 4 obtained immediately before the workpiece 3 is fitted into the hole portion 41 of the workpiece 4.

[0026] Fig. 2 is a flowchart illustrating a control process performed by the application control device 6. As illustrated in Fig. 1A, it is determined that the holding portion 21 has held the workpiece 3 (step S1.) The workpiece 3 is in contact with a component supply palette or the like immediately after the workpiece 3 has been held. In this state, when the workpiece 3 is lifted and is apart from the component supply palette, the position/posture of the workpiece 3 may be slightly changed. When this change in the position/posture of the workpiece 3 becomes a problem, after the operation of step S1 has been performed, it may be determined whether the workpiece 3 has been lifted. The description of a process performed before the holding portion 21 holds the workpiece 3 is omitted.

[0027] Next, as illustrated in Fig. 1B, the arm leading end portion 11 is moved to a target position/posture PA1 (step S2.) The target position/posture PA1 is the position/posture of the arm leading end portion 11 in a robot standard coordinate system which is obtained immediately before the holding portion 21 fits the workpiece 3 held in a normal position/posture PO2 into the hole portion 41 of the workpiece 4. The normal position/posture PO2 is the position/posture of the workpiece 3 relative to the arm leading end portion 11. A position/posture PO1 of the workpiece 3 and a position/posture PH1 and a position/posture PH2 of the hand 2, which will be described later, are also a position/posture relative to the arm leading end portion 11.

[0028] The holding portion 21 does not always hold the workpiece 3 in the normal position/posture PO2. As represented by broken lines in Fig. 1C, when the holding portion 21

holds the workpiece 3 in the position/posture PO1 and then the workpiece 3 is subjected to a fitting operation, the workpiece 3 hits against the workpiece 4.

[0029] In steps S3 to S5, the position/posture of the workpiece 3 is measured and is corrected so that it is changed from the position/posture PO1 to the normal position/posture PO2. The measurement and correction of the position/posture of the workpiece 3 are performed in steps S3 to S5 while the arm leading end portion 11 moves in step S2. First, the position/posture measurement device 22 measures the position/posture PO1 of the workpiece 3 relative to the arm leading end portion 11 (step S3.)

[0030] The target position/posture PH2 of the hand 2 when the workpiece 3 is moved to the normal position/posture PO2 is calculated on the basis of the current position/posture PH1 of the hand 2 and the position/posture PO1 of the workpiece 3 (a result of the measurement of the position/posture) (step S4.)

[0031] The conversion from a coordinate system CO fixed on the workpiece 3 to another coordinate system will be described. It is assumed that coordinate conversion matrices corresponding to the position/posture PH1, the position/posture PH2, the position/posture PO1, and the position/posture PO2 are MHC1, MHC2, MVH1, and MVH2, respectively. Using these coordinate conversion matrices and a coordinate conversion matrix MOH between the coordinate system CO and a coordinate system fixed on the hand 2, the following equations are obtained under the assumption that the relationship between the position/posture of the holding portion 21 and the position/posture of the workpiece 3 is not changed when the holding portion 21 holds the workpiece 3.

[Math.1]

$$MVH1 \cdot CO = MHC1 \cdot MOH \cdot CO$$

$$MVH2 \cdot CO = MHC2 \cdot MOH \cdot CO$$

Accordingly, the following equation is obtained.

[Math.2]

$$MHC2 = MVH2 \cdot (MVH1 \cdot MHC1)^{-1}$$

[0032] When these conversion matrices are separated into translation components (Tx, Ty, and Tz) and rotation components (Rx, Ry, and Rz) around axes in the XYZ coordinate system, homogeneous coordinates represented by the following product of matrices are obtained. The order in which matrices are multiplied is changed in accordance with the type of a position/posture correction mechanism for the hand 2. In this embodiment, a Z axis, a Y axis, and an X axis are rotated and then translation is performed.

[Math.3]

$$\begin{pmatrix} 1 & 0 & 0 & Tx \\ 0 & 1 & 0 & Ty \\ 0 & 0 & 1 & Tz \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos Rx & -\sin Rx & 0 \\ 0 & \sin Rx & \cos Rx & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos Ry & 0 & \sin Ry & 0 \\ 0 & 1 & 0 & 0 \\ -\sin Ry & 0 & \cos Ry & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos Rz & -\sin Rz & 0 & 0 \\ \sin Rz & \cos Rz & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

- [0033] The hand 2 is moved from the current position/posture PH1 to the target position/posture PH2 (step S5.)
- [0034] By performing the above-described control method, even if the holding portion 21 holds the workpiece 3 in any position/posture, this does not affect the movement of the arm leading end portion 11. Accordingly, it is possible to perform a fitting operation without increasing a cycle time by completing the correction of the position/posture of the workpiece 3 before the arm leading end portion 11 moves to the target position/posture PA1.
- [0035] Since the correction of the position/posture of the workpiece 3 is performed after the holding portion 21 has held the workpiece 3, it is unnecessary to obtain information about the accurate position/posture of the workpiece 3 before the workpiece 3 is held. Accordingly, when a method of measuring the position/posture of the workpiece 3 before the workpiece 3 is held is used, it is unnecessary to accurately measure the position/posture of the workpiece 3.
- [0036] As described previously, while the arm leading end portion moves, the measurement of the position/posture of the workpiece held by the hand relative to the arm leading end portion and the correction of the position/posture of the hand relative to the arm leading end portion are performed. As a result, it is possible to perform the measurement and correction of the position/posture of the workpiece held by the hand without increasing a cycle time. Furthermore, it is possible to increase a time required to measure the position/posture of the held workpiece 3 and determine a corrected target position/posture of the hand 2 in a system having a large time constant. Still furthermore, it is unnecessary to accurately measure the position/posture of the workpiece 3 before the workpiece 3 is held.

Second Embodiment

- [0037] The workpiece 3 may not be a rigid body. For example, as illustrated in Fig. 3, the leading end of the workpiece 3 may be a flexible protrusion 31. An operation for fitting the flexible protrusion 31 into the hole portion 41 of the workpiece 4 will be described.
- [0038] Fig. 4 is a flowchart illustrating a control process according to the second embodiment. The operations of steps S1 to S5 are the same as those described with reference to Fig. 2. In this case, however, the position/posture measurement device 22 measures the position/posture of a leading end of the flexible protrusion 31 of the workpiece 3.
- [0039] After the process from steps S1 to S5 has been performed, the leading end of the flexible protrusion 31 is not necessarily in the normal position/posture because the flexible protrusion 31 deforms under its own weight. Accordingly, after the operation of step S5 has been performed, it is determined whether the arm leading end portion 11 has already moved to the target position/posture PA1 (step S6.) When it is determined

that the arm leading end portion 11 is moving, the measurement of the position/posture of the flexible protrusion 31 is performed (step S3), the correction of the position/posture of the hand 2 is performed (step S4), and the movement of the hand 2 is performed (step S5.)

[0040] By performing the above-described control process, even if the flexible protrusion 31 is not in the normal position/posture after the movement of the arm leading end portion 11 has been completed, it can be expected that the deviation from the normal position/posture is small. It is therefore possible to complete the position correction of the flexible protrusion 31 in a short time after the movement of the arm has been completed.

[0041] Fig. 5 is a flowchart illustrating a control process for correcting the position of the flexible protrusion 31 after the movement of the arm leading end portion 11 has been completed. Operations of steps S7 to S9 are the same as those of steps S3 to S5 in Fig. 4, respectively. It is determined whether the flexible protrusion 31 is in the normal position/posture (step S10.) When the flexible protrusion 31 is in the normal position/posture, the process ends. When the flexible protrusion 31 is not in the normal position/posture, the process from steps S7 to S9 is repeated.

[0042] As described previously, by repeatedly performing the measurement and correction of a position/posture while the arm leading end portion 11 moves, even if a deformable flexible workpiece is assembled to another workpiece, it is possible to appropriately correct the position/posture of the deformable flexible workpiece.

Third Embodiment

[0043] In the above-described embodiments, the deviation of the position/posture of the workpiece 4 from the normal position/posture does not occur. However, like the workpiece 3, the position/posture of the workpiece 4 may deviate from the normal position/posture.

[0044] Accordingly, a control process is performed in consideration of the deviation of the position/posture of the workpiece 4. Fig. 6 is a diagram illustrating an exemplary configuration of a robot system according to the third embodiment. In addition to the components illustrated in Fig. 1, a position/posture measurement device 7 is disposed. The position/posture measurement device 7 measures the position/posture of the workpiece 4 and notifies the application control device 6 of a result of the measurement. The position/posture measurement device 7 is, for example, a vision sensor using a camera. Any method capable of measuring the position/posture of the workpiece 4 can be used as a method performed by the position/posture measurement device 7.

[0045] Fig. 7 is a flowchart illustrating a control process according to the third embodiment. The difference between the control process illustrated in Fig. 7 and the control process

illustrated in Fig. 2 is that step S11 in which the position/posture of the workpiece 4 is measured is added before step S1.

[0046] The operation of Step S11 may be performed at any point before step S4.

[0047] In the control process illustrated in Fig. 2, in calculation of the corrected amount of movement of the hand 2 (step S4), the target position/posture PH2 of the hand 2 at the time of movement of the workpiece 3 to the normal position/posture PO2 is calculated on the basis of the current position/posture PH1 of the hand 2 and the position/posture PO1 of the workpiece 3. In this embodiment, the position/posture of the workpiece 4 is also used in the operation of step S4.

[0048] More specifically, the corrected amount of movement of the hand 2 calculated in step S4 is further corrected so that the deviation of the position/posture of the workpiece 4 from the normal position/posture is canceled. For example, when the position/posture PH1 and the position/posture PH2 are represented with six elements, that is, the amounts of translation in the X, Y, and Z directions and the amounts of rotation about axes, the corrected amount of movement of the hand 2 is obtained by subtracting PH1 from PH2 (PH2 - PH1.)

[0049] By performing the above-described control process, it is possible to correct the positional deviation of the workpiece 4 when a workpiece is fitted or assembled to the workpiece 4. The third embodiment has been described on the basis of the first embodiment. However, correction processing similar to the above-described correction processing according to the third embodiment may be performed when the corrected amount of movement of the hand 2 is calculated in step S4 illustrated in Fig. 4 and step S8 illustrated in Fig. 5.

Fourth Embodiment

[0050] While the arm leading end portion 11 moves after the holding portion 21 has held the workpiece 3, the workpiece 3 may hit against an obstacle. Accordingly, in order to prevent the collision, a plurality of movement paths of the arm leading end portion 11 are determined in advance. One of these movement paths is selected in accordance with the position/posture of the workpiece 3 held by the holding portion 21.

[0051] For example, in order to determine the movement paths of the arm leading end portion 11, a simulation is performed in advance. A movement path on which the workpiece 3 can move without hitting against an obstacle is obtained by the simulation and is then associated with the corresponding position/posture of the workpiece 3. More specifically, the relationship between the position/posture of the workpiece 3 and the movement path of the arm leading end portion 11 allowing the workpiece 3 to move without hitting against an obstacle is stored in the form of table. By referring to the table created at the time of the simulation, one of the movement paths of the arm leading end portion 11 is selected in accordance with the positions/postures of the

workpiece 3.

- [0052] Fig. 8 is a flowchart illustrating a control process according to the fourth embodiment. The difference between the control process illustrated in Fig. 8 and the control process illustrated in Fig. 2 is that the operation of step S3 is performed before a process branching point and an operation of step S12 for selecting one of movement paths of the arm leading end portion 11 is performed before step S2.
- [0053] The position/posture of the workpiece 3 relative to the arm leading end portion 11 is measured (step S3.) Subsequently, the process branches out into two ways. In one of two ways, the movement of the arm leading end portion 11 is performed. First, one of the movement paths of the arm leading end portion 11 determined in advance is selected on the basis of the position/posture of the workpiece 3 measured in step S3 (step S12.)
- [0054] The arm leading end portion 11 is moved to the target position/posture PA1 along the selected movement path (step S2.)
- [0055] In parallel to the movement of the arm leading end portion 11, in the other one of two ways, the position correction of the hand 2 is performed. Like in the control process illustrated in Fig. 2, first, the corrected amount of movement of the hand 2 is calculated (step S4.) The hand 2 is moved by the corrected amount of movement of the hand 2 (step S5.)
- [0056] By performing the above-described control process, when the deviation of the position/posture of a held workpiece is large, it is possible to prevent the held workpiece from hitting against an obstacle during movement of the arm leading end portion 11 or to avoid the need to perform a holding operation again.

Fifth Embodiment

- [0057] In the fourth embodiment, in order to prevent the workpiece 3 from hitting against an obstacle, a movement path of the arm leading end portion 11 is selected. However, a movement path of the hand 2 may be selected. Fig. 9 is a flowchart illustrating a control process according to the fifth embodiment. The difference between the control process illustrated in Fig. 9 and the control process illustrated in Fig. 2 is that an operation of step S13 for selecting a movement path of the hand 2 is performed instead of the operation of step S4. Like in the fourth embodiment, a simulation is performed so as to create a table. By referring to the table, a movement path of the hand 2 can be selected on the basis of the position/posture of the workpiece 3.

Sixth Embodiment

- [0058] In the fourth embodiment, in order to prevent the workpiece 3 from hitting against an obstacle, a movement path of the arm leading end portion 11 is selected on the basis of the position/posture of the workpiece 3 held by the holding portion 21. However, the

position/posture of the workpiece 4 measured by the position/posture measurement device 7 may be used for the selection of a movement path of the arm leading end portion 11.

[0059] Fig. 10 is a flowchart illustrating a control process according to the sixth embodiment. The difference between the control process illustrated in Fig. 10 and the control process illustrated in Fig. 8 is that the position/posture measurement device 7 measures the position/posture of the workpiece 4 first (step S11.)

[0060] When a movement path of the arm leading end portion 11 is selected (step S12), both the position/posture of the workpiece 3 relative to the arm leading end portion 11 and the position/posture of the workpiece 4 in a robot standard coordinate system are used. More specifically, the relationship between the combination of the position/posture of the workpiece 3 and the position/posture of the workpiece 4 and the movement path of the arm leading end portion 11 allowing the workpiece 3 to move without hitting against an obstacle is obtained by simulation and is then stored in the form of table. By referring to the table, a movement path of the arm leading end portion 11 is selected.

Seventh Embodiment

[0061] In the fifth embodiment, in order to prevent the workpiece 3 from hitting against an obstacle, a movement path of the hand 2 is selected on the basis of the position/posture of the workpiece 3 held by the holding portion 21. However, the position/posture of the workpiece 4 measured by the position/posture measurement device 7 may also be used for the selection of a movement path of the hand 2.

[0062] Fig. 11 is a flowchart illustrating a control process according to the seventh embodiment. The difference between the control process illustrated in Fig. 11 and the control process illustrated in Fig. 9 is that the position/posture measurement device 7 measures the position/posture of the workpiece 4 first (step S11.)

[0063] When a movement path of the hand 2 is selected (step S13), both the position/posture of the workpiece 3 relative to the arm leading end portion 11 and the position/posture of the workpiece 4 in a robot standard coordinate system are used. As described previously, the relationship between the combination of the position/posture of the workpiece 3 and the position/posture of the workpiece 4 and the movement path of the hand 2 allowing the workpiece 3 to move without hitting against an obstacle is obtained by simulation and is then stored in the form of table. By referring to the table, a movement path of the hand 2 is selected.

Eighth Embodiment

[0064] In the fourth to seventh embodiments, a movement path of the arm leading end portion 11 or a movement path of the hand 2 is selected. However, both of them may be selected. Fig. 12 is a flowchart illustrating a control process obtained by combining

a control process according to the sixth embodiment and a control process according to the seventh embodiment. The difference between the control process illustrated in Fig. 12 and the control process illustrated in Fig. 10 is that the operation of step S13 for selecting a movement path of the hand 2 is performed instead of the operation of step S4. By selecting both a movement path of the arm leading end portion 11 and a movement path of the hand 2, as compared with a case in which either a movement path of the arm leading end portion 11 or a movement path of the hand 2 is used to prevent collision with an obstacle, a time required to prevent the collision with an obstacle may be shortened.

- [0065] As described previously, a table used to select a movement path of the arm leading end portion 11 and a movement path of the hand 2 is created by performing a simulation and is then stored. A control process according to this embodiment obtained by combining a control process according to the sixth embodiment and a control process according to the seventh embodiment has been described. However, any combination of control processes according to embodiments may be used on condition that both a movement path of the arm leading end portion 11 and a movement path of the hand 2 are selected.

Other Embodiments

- [0066] Aspects of the present invention can also be realized by a computer of a system or apparatus (or devices such as a CPU or MPU) that reads out and executes a program recorded on a memory device to perform the functions of the above-described embodiment(s), and by a method, the steps of which are performed by a computer of a system or apparatus by, for example, reading out and executing a program recorded on a memory device to perform the functions of the above-described embodiment(s). For this purpose, the program is provided to the computer for example via a network or from a recording medium of various types serving as the memory device (e.g., computer-readable medium).
- [0067] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.
- [0068] This application claims the benefit of Japanese Patent Application No. 2009-289614, filed December 21, 2009, which is hereby incorporated by reference herein in its entirety.

Claims

- [Claim 1] A robot system comprising:
an arm capable of adjusting a position/posture of an arm leading end portion thereof;
a hand that is attached to the arm leading end portion, is provided with a holding mechanism for holding a workpiece, and is capable of adjusting a position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion;
a first position/posture measurement unit configured to measure the position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion; and
a control unit configured to perform measurement and correction of the position/posture of the workpiece held by the holding mechanism while the arm leading end portion moves after the holding mechanism has held the workpiece, and
wherein, in the measurement of the position/posture of the held workpiece, the control unit measures the position/posture of the workpiece relative to the arm leading end portion, and
wherein, in the correction of the position/posture of the held workpiece, the control unit corrects a position/posture of the hand relative to the arm leading end portion on the basis of a result of the measurement so that a predetermined position/posture of the workpiece relative to the arm leading end portion is set.
- [Claim 2] The robot system according to Claim 1, wherein the control unit completes the measurement and correction of the position/posture of the held workpiece before movement of the arm leading end portion is completed.
- [Claim 3] The robot system according to Claim 1, wherein the control unit repeatedly performs the measurement and correction of the position/posture of the held workpiece while the arm leading end portion moves.
- [Claim 4] The robot system according to Claim 1, further comprising a second position/posture measurement unit configured to measure a position/posture of another workpiece when the held workpiece is fitted or assembled to the other workpiece, and
wherein the control unit determines the predetermined position/posture of the workpiece relative to the arm leading end portion on the basis of both a result of measurement of the position/posture of the workpiece

performed by the first position/posture measurement unit and a result of measurement of the position/posture of the other workpiece performed by the second position/posture measurement unit.

[Claim 5] The robot system according to Claim 1, wherein the control unit selects a movement path of the arm leading end portion from among a plurality of movement paths determined in advance on the basis of a result of measurement of the position/posture of the held workpiece.

[Claim 6] The robot system according to Claim 1, wherein, in the correction of the position/posture of the held workpiece, the control unit selects a movement path of the workpiece from among a plurality of movement paths determined in advance on the basis of a result of measurement of the position/posture of the held workpiece.

[Claim 7] The robot system according to Claim 1, further comprising a second position/posture measurement unit configured to measure a position/posture of another workpiece when the held workpiece is fitted or assembled to the other workpiece, and wherein the control unit selects a movement path of the arm leading end portion from among a plurality of movement paths determined in advance on the basis of both a result of measurement of the position/posture of the held workpiece and a result of measurement of the position/posture of the other workpiece performed by the second position/posture measurement unit.

[Claim 8] The robot system according to Claim 1, further comprising a second position/posture measurement unit configured to measure a position/posture of another workpiece when the held workpiece is fitted or assembled to the other workpiece, and wherein the control unit selects a movement path of the workpiece from among a plurality of movement paths determined in advance on the basis of both a result of measurement of the position/posture of the held workpiece and a result of measurement of the position/posture of the other workpiece performed by the second position/posture measurement unit.

[Claim 9] A control apparatus for a robot system including an arm capable of adjusting a position/posture of an arm leading end portion thereof, a hand that is attached to the arm leading end portion, is provided with a holding mechanism for holding a workpiece, and is capable of adjusting a position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion, and a position/

posture measurement unit configured to measure the position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion, the control apparatus comprising a control unit configured to perform measurement and correction of the position/posture of the workpiece held by the holding mechanism while the arm leading end portion moves after the holding mechanism has held the workpiece, and

wherein, in the measurement of the position/posture of the held workpiece, the control unit measures the position/posture of the workpiece relative to the arm leading end portion, and

wherein, in the correction of the position/posture of the held workpiece, the control unit corrects a position/posture of the hand relative to the arm leading end portion on the basis of a result of the measurement so that a predetermined position/posture of the workpiece relative to the arm leading end portion is set.

[Claim 10]

A control method for a robot system including an arm capable of adjusting a position/posture of an arm leading end portion thereof, a hand that is attached to the arm leading end portion, is provided with a holding mechanism for holding a workpiece, and is capable of adjusting a position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion, and a position/posture measurement unit configured to measure the position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion, the control method comprising a controlling step of performing measurement and correction of the position/posture of the workpiece held by the holding mechanism while the arm leading end portion moves after the holding mechanism has held the workpiece, and

wherein, in the measurement of the position/posture of the held workpiece, the position/posture of the workpiece relative to the arm leading end portion is measured, and

wherein, in the correction of the position/posture of the held workpiece, a position/posture of the hand relative to the arm leading end portion is corrected on the basis of a result of the measurement so that a predetermined position/posture of the workpiece relative to the arm leading end portion is set.

[Claim 11]

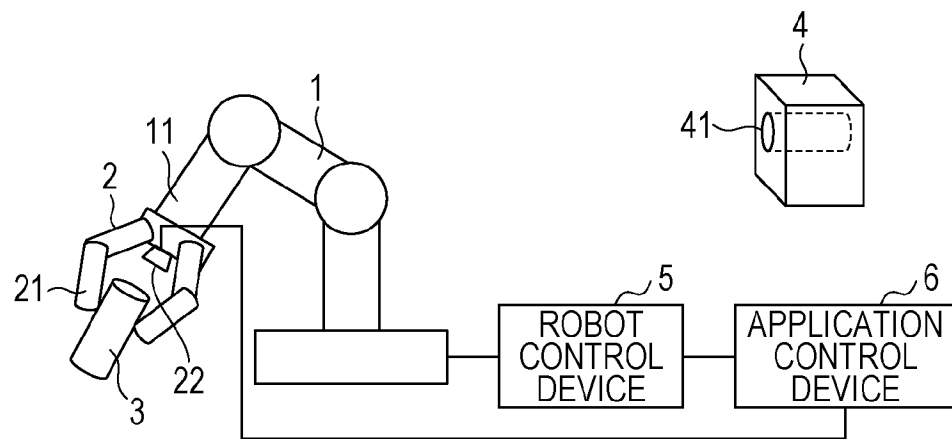
A program for controlling a robot system including an arm capable of adjusting a position/posture of an arm leading end portion thereof, a

hand that is attached to the arm leading end portion, is provided with a holding mechanism for holding a workpiece, and is capable of adjusting a position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion, and a position/posture measurement unit configured to measure the position/posture of the workpiece held by the holding mechanism relative to the arm leading end portion, the program causing a computer to execute control processing for performing measurement and correction of the position/posture of the workpiece held by the holding mechanism while the arm leading end portion moves after the holding mechanism has held the workpiece, and

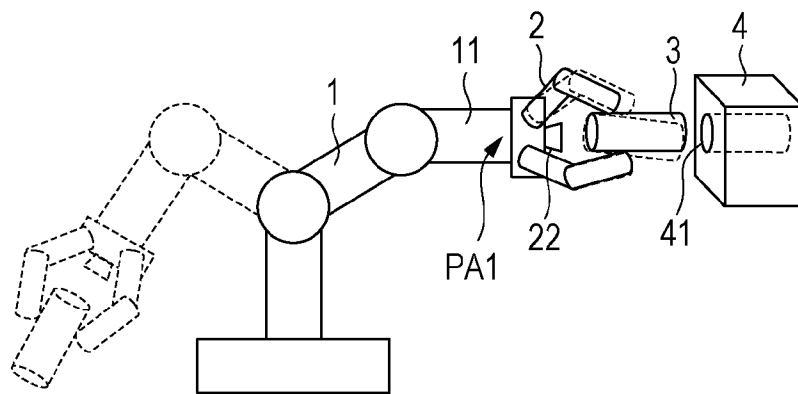
wherein, in the measurement of the position/posture of the held workpiece, the position/posture of the workpiece relative to the arm leading end portion is measured, and

wherein, in the correction of the position/posture of the held workpiece, a position/posture of the hand relative to the arm leading end portion is corrected on the basis of a result of the measurement so that a predetermined position/posture of the workpiece relative to the arm leading end portion is set.

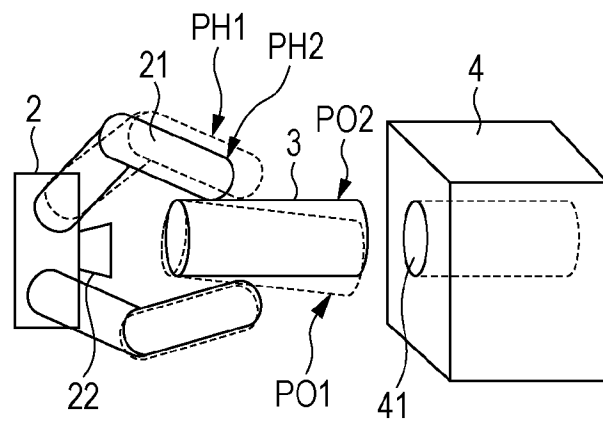
[Fig. 1A]



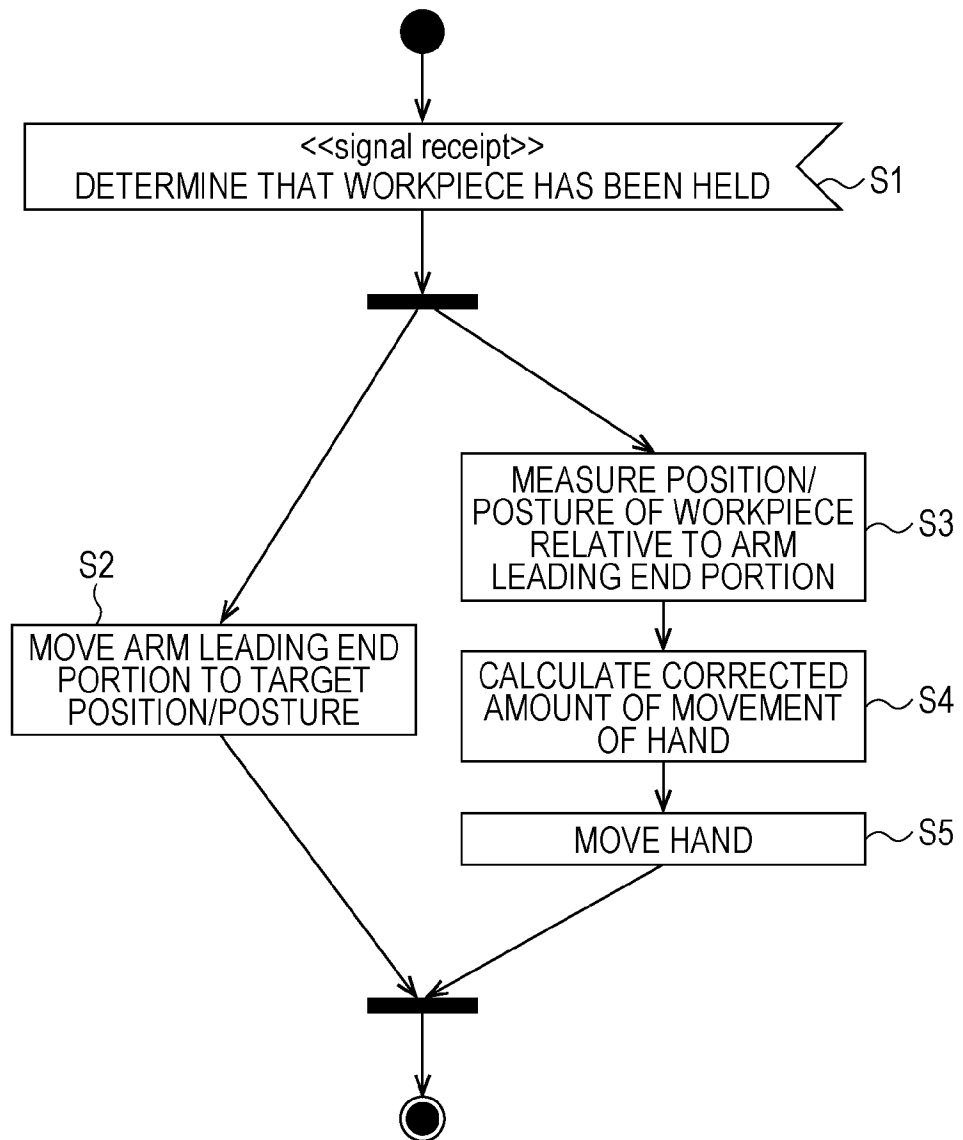
[Fig. 1B]



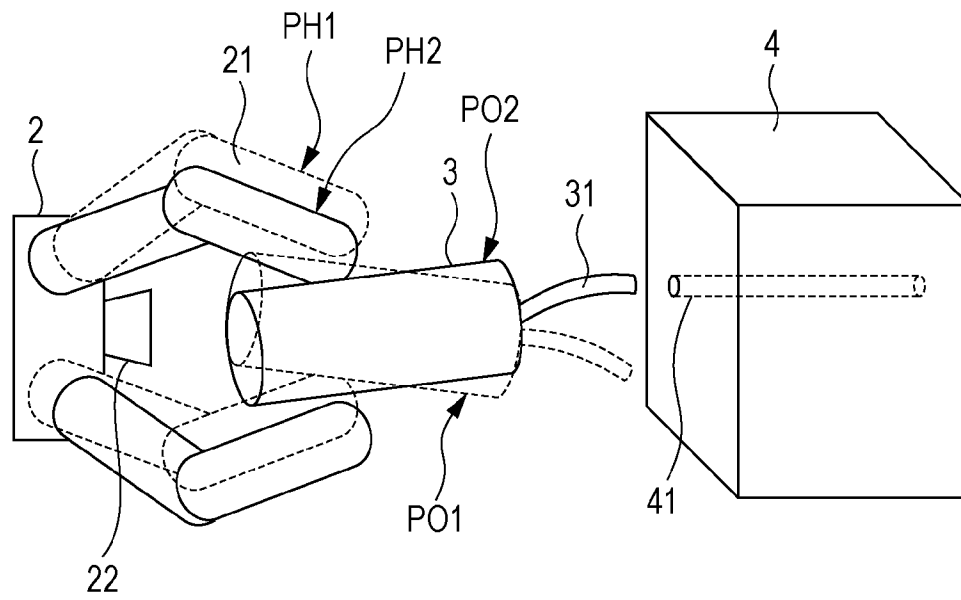
[Fig. 1C]



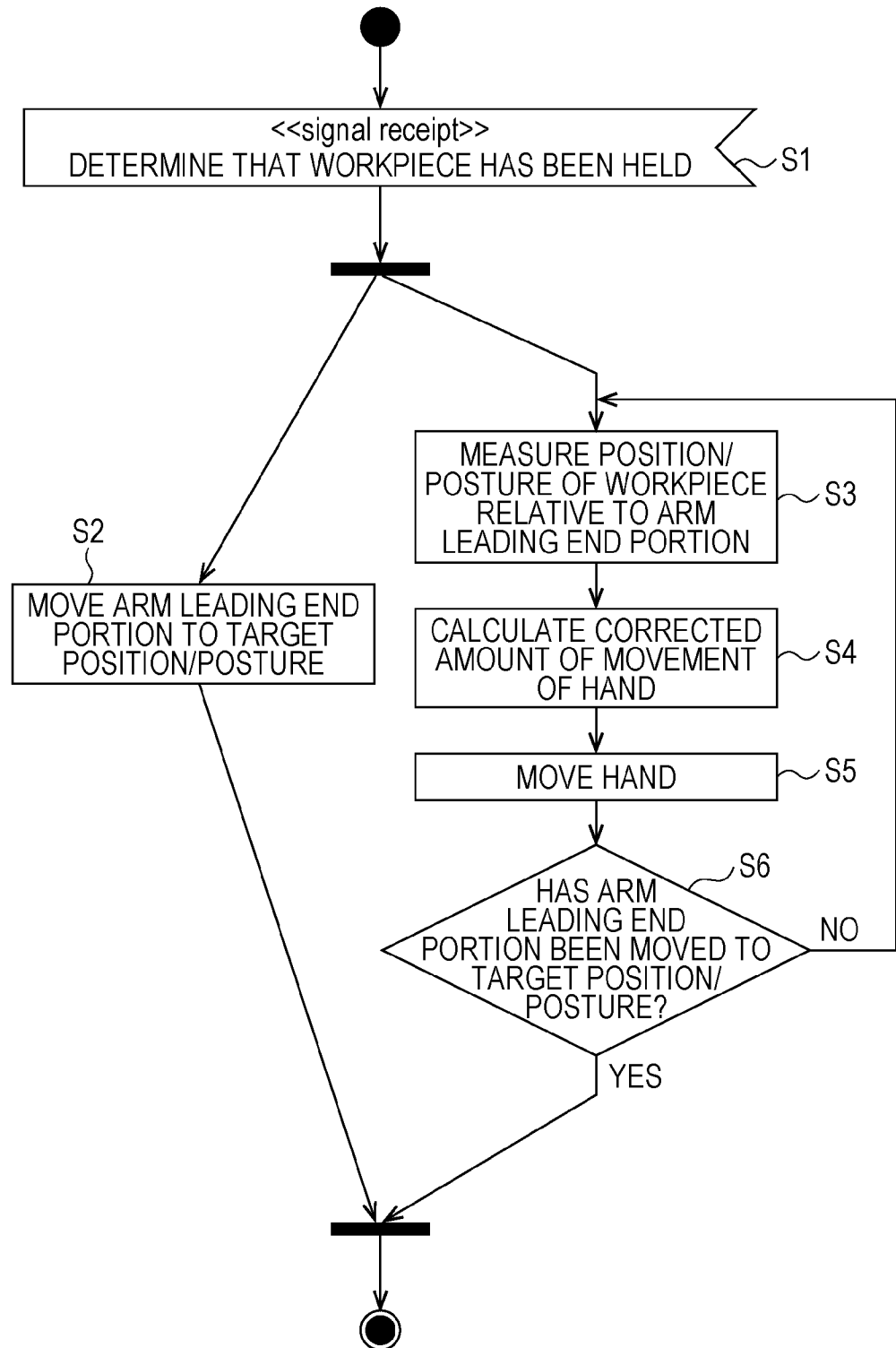
[Fig. 2]



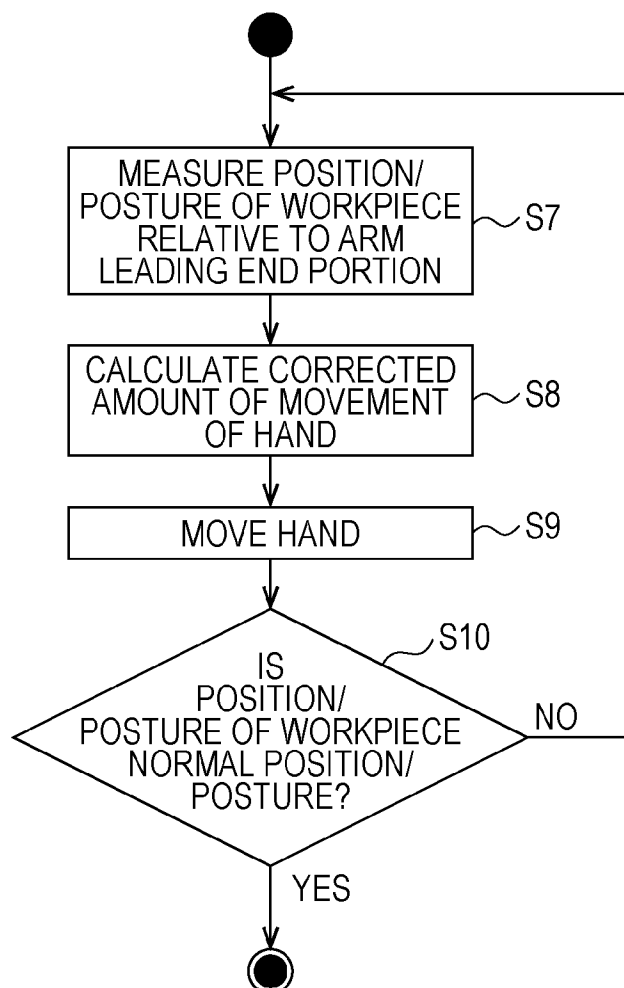
[Fig. 3]



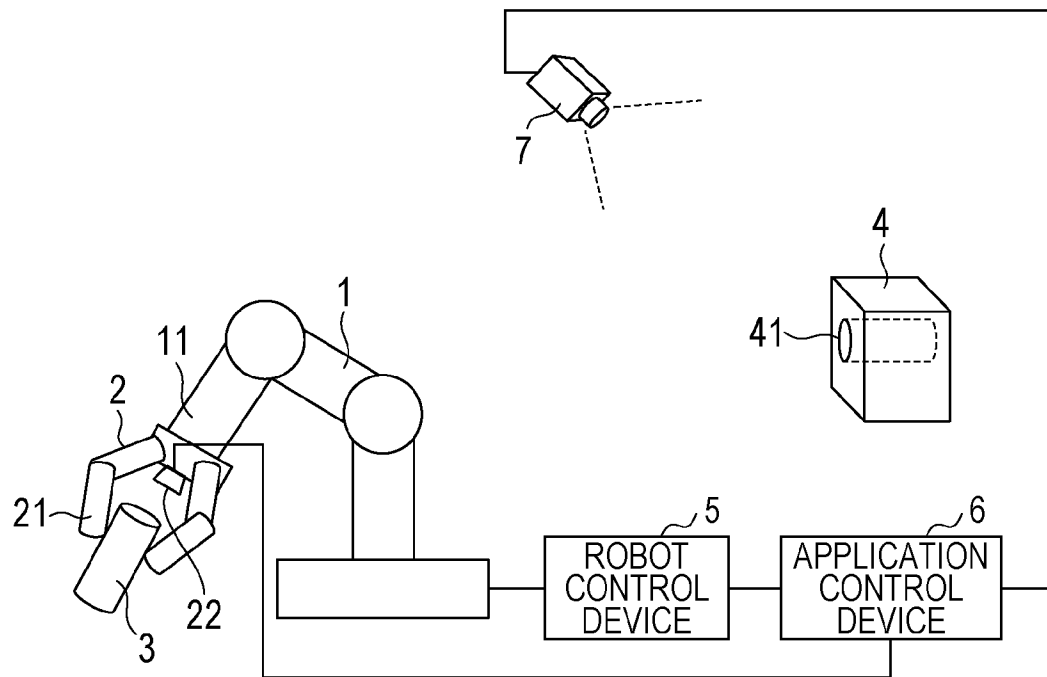
[Fig. 4]



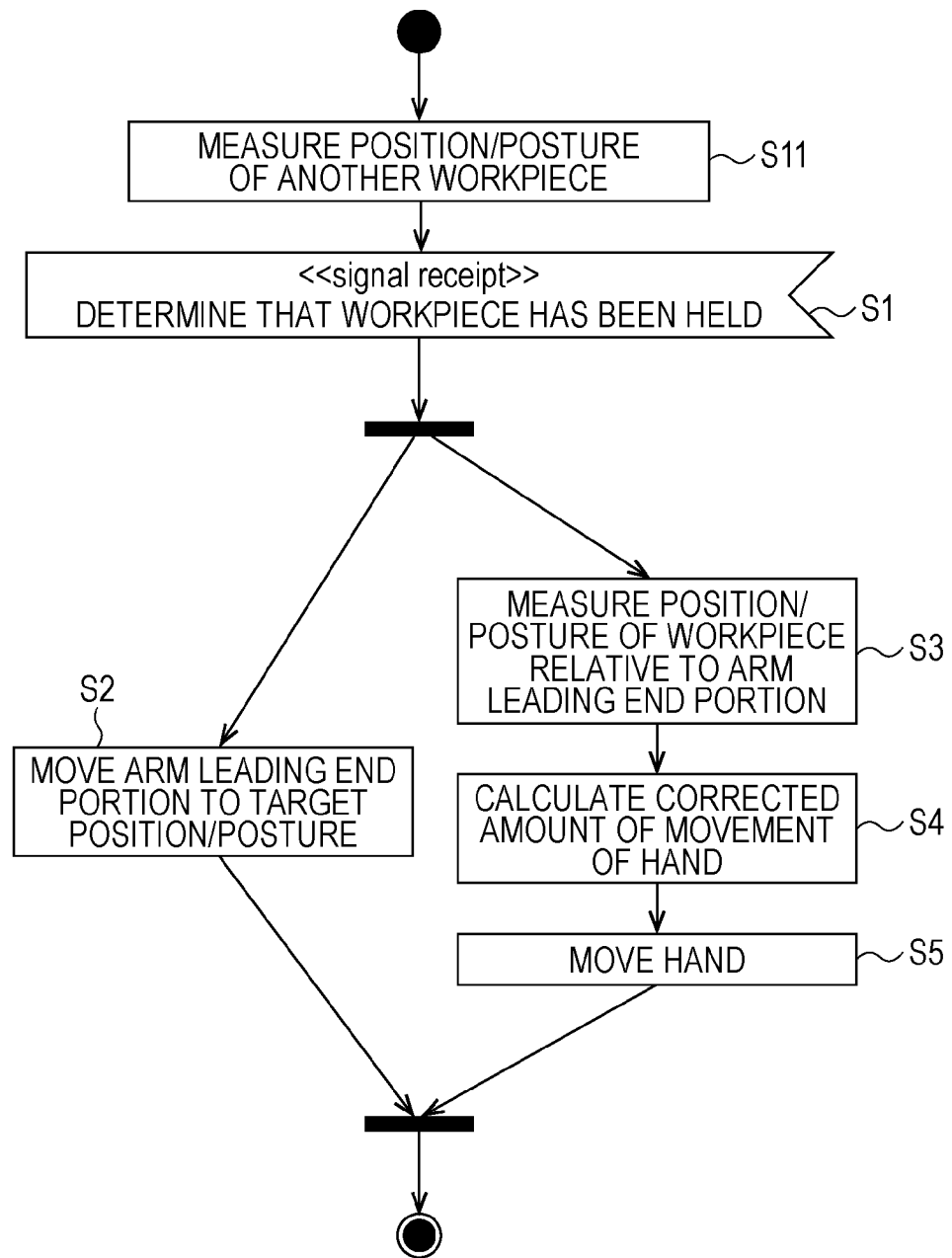
[Fig. 5]



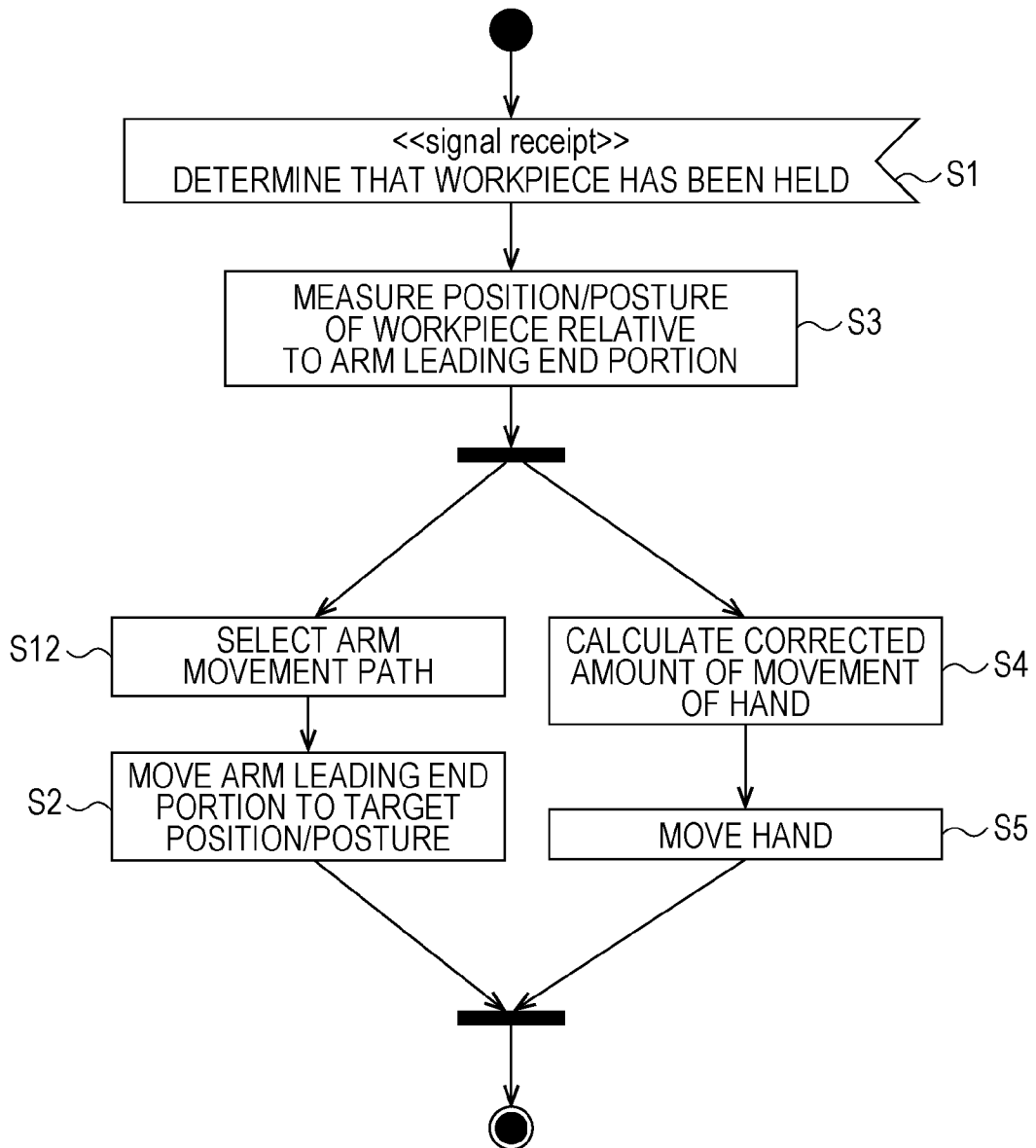
[Fig. 6]



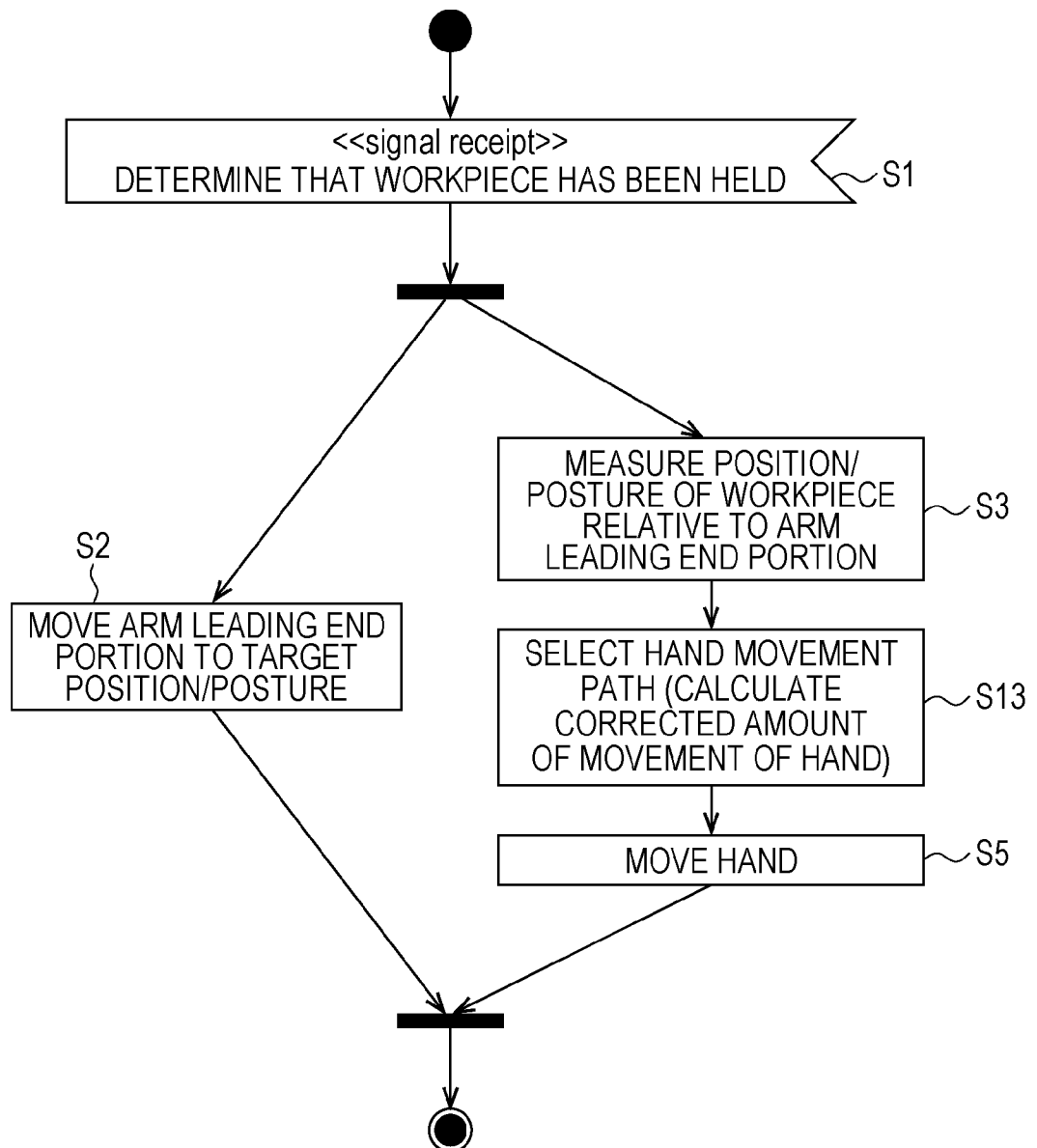
[Fig. 7]



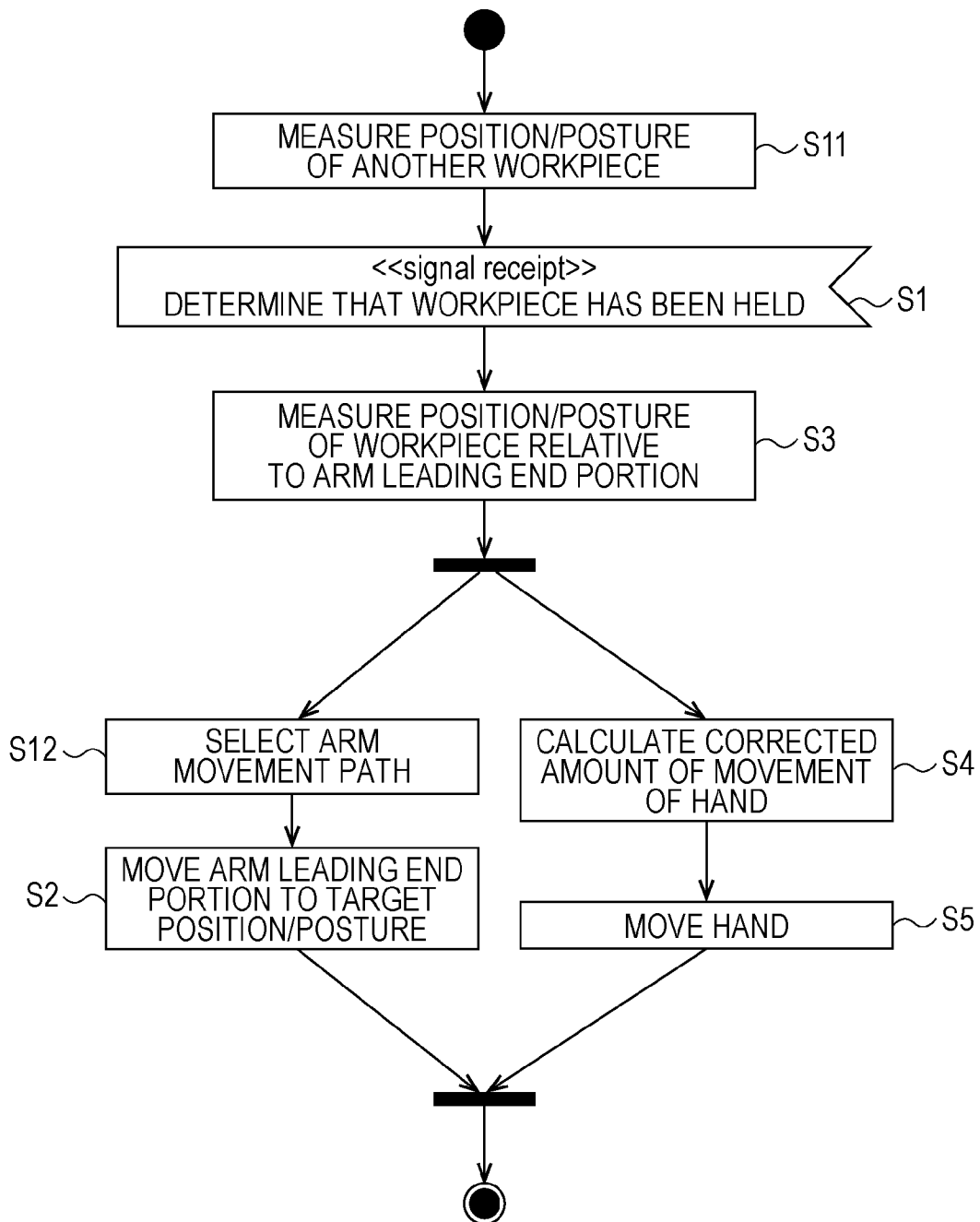
[Fig. 8]



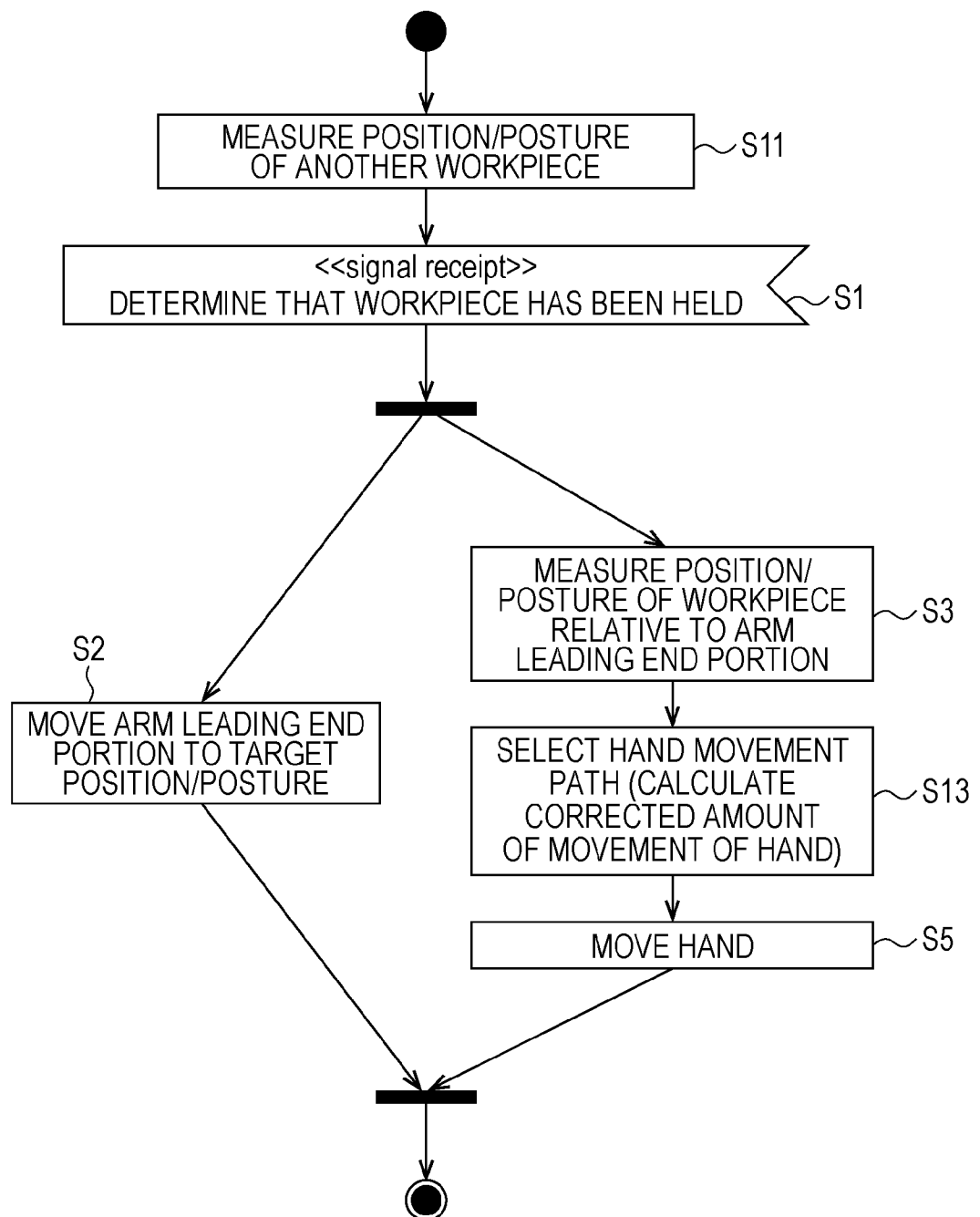
[Fig. 9]



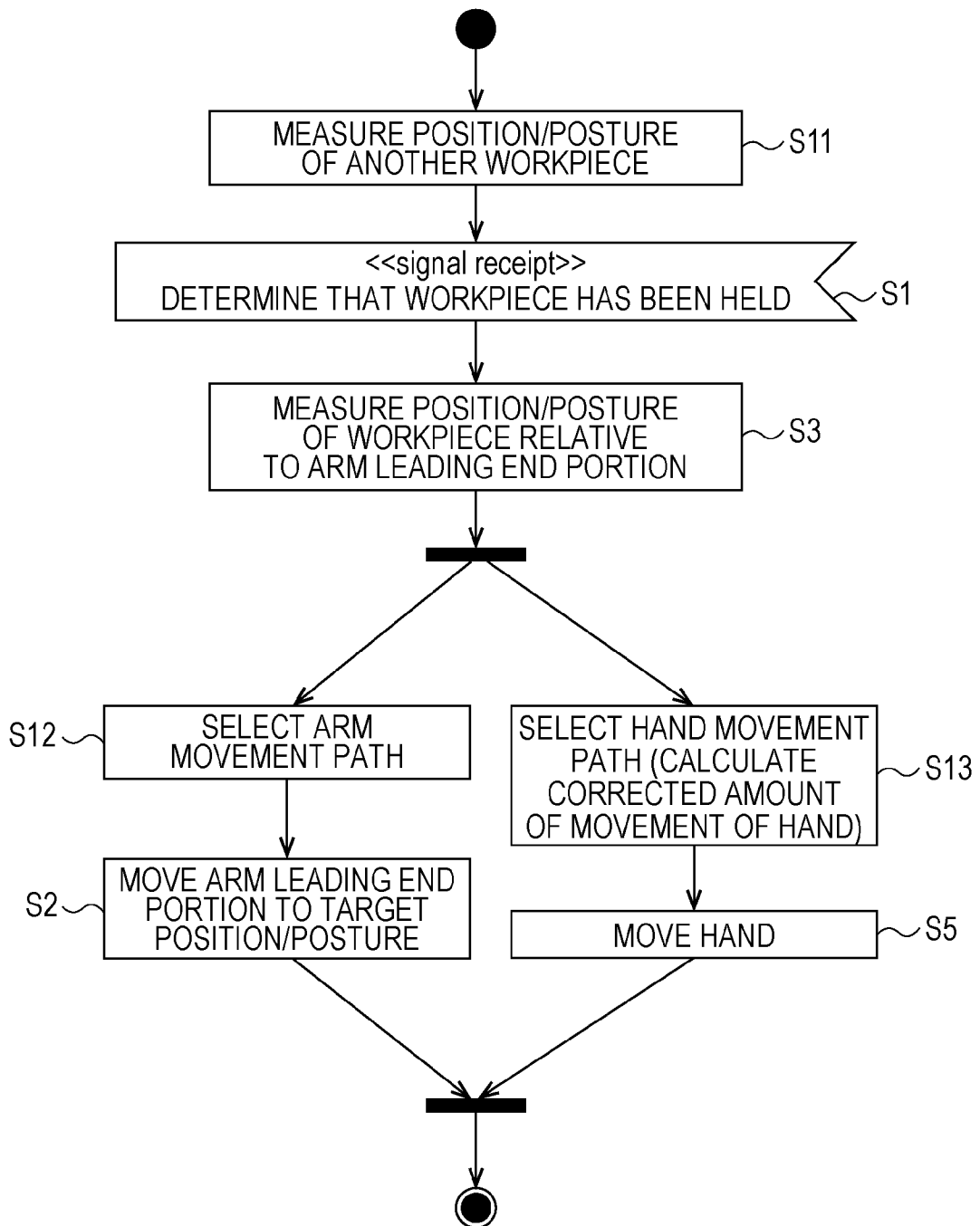
[Fig. 10]



[Fig. 11]



[Fig. 12]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2010/007367

A. CLASSIFICATION OF SUBJECT MATTER
INV. B25J9/16
ADD.

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)
B25J

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	----- EP 1 391 275 A2 (FANUC LTD [JP]) 25 February 2004 (2004-02-25) paragraph [0001] - paragraph [0035]; figure 1	1-11
A	----- JP 2008 279549 A (HONDA MOTOR CO LTD) 20 November 2008 (2008-11-20) abstract; figure 1	1,9-11
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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

15 April 2011

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26/04/2011

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INTERNATIONAL SEARCH REPORT

International application No

PCT/JP2010/007367

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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