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(54) **Title:** ROBOTIC PICKING OF PARTS FROM A PARTS HOLDING BIN

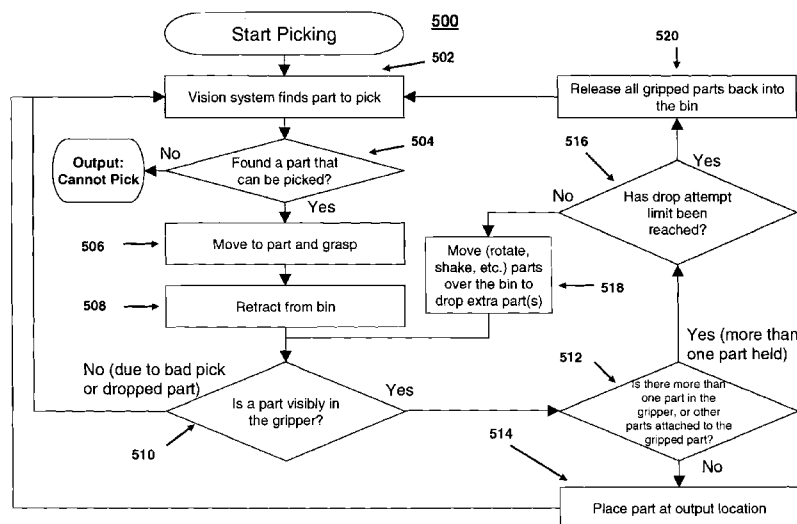


Fig. 5

(57) **Abstract:** A robot system for picking parts from a bin use the image from one or more cameras to determine if the robot gripper has picked one part or more than one part and uses one or more images from one or more cameras to determine the position / orientation of a picked part. If the robot has picked more than one part from the bin then an attempt is made to return the excess picked parts to the bin. The position / orientation of a picked part that does not meet a predetermined criteria is changed.

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Robotic Picking Of Parts From A Parts Holding Bin

1. Field of the Invention

The field is the use of a robot to pick parts from a bin that holds the parts to be picked by the robot.

2. Description of the Prior Art

Existing systems have used various contact or other non-vision sensing means such as force or proximity sensors to detect if one or more parts have been successfully picked from a bin that is holding the parts to be picked by the robot. These techniques can detect if only a single part has been picked by the robot from the bin, but cannot determine the orientation of the picked part or the nature of the interlocking if multiple entangled parts have been picked.

The term "bin" as used herein means, without limitation, any container, carton, box, tray or other structure that can receive and hold the parts to be picked by the robot.

Summary of the Invention

A method for using a robot to pick parts from a bin. The method uses an image from one or more cameras to determine if the robot is holding one or more parts after the robot is commanded to pick one part from the bin.

A method for using a robot to pick parts from a bin. The method uses an image from one or more cameras to determine the position / orientation of a part held by the robot after the robot is commanded to pick one part from the bin.

A robotic system for picking parts from a bin. The system has a robot having a gripper for picking a part from the bin when the robot is so commanded; one or more cameras mounted to provide one or more images that show what is held by the gripper after the robot is commanded to pick a part from the bin; a computing device programmed to use the one or more

images to determine if the robot is holding one or more parts after the robot is commanded to pick a part from the bin; and

the computing device further programmed to command the robot when the it is determined that the gripper is holding more than part to move the gripper and attempt to return to the bin all but one of the parts held by the gripper.

10 A robotic system for picking parts from a bin. The system has:

a robot having a gripper for picking a part from the bin when the robot is so commanded;

One or more cameras mounted to provide one or more images that show what is held by the gripper after the robot is commanded to pick a part from the bin;

20 a computing device programmed to use the one or more image to determine if the position / orientation of the part held by the gripper meets a predetermined criteria for the position / orientation of the part held by the gripper; and

the computing device further programmed to command the robot to move the gripper and return the picked part to the bin when it is determined that the part held by the gripper does not meet the predetermined criteria for the position / orientation of the part held by the gripper.

A robotic system for picking parts from a bin. The system has:

30 a robot having a gripper for picking a part from the bin when the robot is so commanded;

one or more cameras mounted to provide one or more images that show what is held by the gripper after the robot is commanded to pick a part from the bin;

a computing device programmed to use the one or more images to determine if the position / orientation of the part held by the gripper meets a predetermined criteria

for the position / orientation of the part held by the gripper; and

the computing device further programmed to command the robot either by itself or together with the gripper or only the gripper to adjust the part's position / orientation to be within the predetermined criteria when it is determined that the part held by the gripper does not meet the predetermined criteria for the position / orientation of the part held by the gripper.

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Description of the Drawing

Fig. 1 shows a prior art vision system for a robot to pick parts from a bin.

Figs. 2, 3 and 4 show embodiments for the present vision system for a robot to pick parts from a bin.

Fig. 5 shows a flowchart for the control flow for using a vision system to pick parts from a bin.

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Fig. 6 shows a flowchart for procedure to determine if the output position / orientation of the picked part is within predetermined limits so that the part can be used in a subsequent operation.

Detailed Description

Referring now to Fig. 1 there is shown one example of a prior art six-axis industrial robot manipulator system 10 that can be used for picking parts 41 from a bin 40.

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Robot systems such as system 10 typically include a manipulator assembly 12 and a computer-based controller 14. The robot manipulator assembly 12 includes an upper arm 16a and lower arm 16b. The manipulator assembly 12 has one end mounted through a first joint 18 to a base 20, and a wrist 22 on the opposite end. A grasping mechanism 24, also known as a gripper, is mounted to wrist 22 and is configured to receive a part. The grasping mechanism 24 and other devices such as a work-piece that are mounted to the robot wrist 22, are together known generally as an end-effector.

Fig. 1 also shows a vision system 36 having two cameras 38 not mounted on the robot and a bin 40 filled with parts 41 to be picked by robot 12 using grasping mechanism 24, also known as an end of arm tool. As is well known, vision system 36 also has a computing device which is not shown in Fig. 1.

The vision system 36 is used to determine the part location and orientation in the bin 40. The images from cameras 38 have not been previously used for post pick
10 analysis such as determining if the robot has picked more than one part 41 from the bin 40 or the orientation of the picked part 41. The vision system 36 shown in Fig. 1 is by way of example and not of limitation. That system could have more or less cameras, use laser lighting, have the cameras mounted on the robot 12 etc.

Many types of errors can occur when using an industrial robot 12 and machine vision system 36 to automate bin picking. Because parts 41 are randomly distributed in a bin 40, parts could become interlocked
20 with each other, entangled, and/or obstructed. When such interlocked, entangled and/or obstructed parts 41 are removed from the bin 40, several errors can occur. For example, a part 41 could be completely pulled out of the grasping mechanism (gripper) 24 during the extraction. Even if a part 41 is not pulled out of the gripper 24, its position and/or orientation could shift while it remains in the gripper 24. Such a shift can cause collision issues and other problems when the picked part 41 is presented for the next robotic procedure, such as
30 an incorrect placement of the gripped part 41 on a conveyor.

Another error that can be caused by interlocking and entangled parts 41 is the accidental picking of extra parts 41. This error can also cause problems for the next procedure that uses the picked part 41, because two or more parts 41 would be delivered to the station that

handles the picked part. For example, if the next procedure is for the robot that has picked the part to place a single picked part 41 on a conveyer, the accidental placement of additional parts 41 on the conveyer would likely cause a jam to occur. The additional parts 41 can also be a safety concern since the robot's quick motions could cause a partially entangled part 41 to loosen and fly in a random direction in the robot cell, causing damage and possible human injury.

The system in previously described Fig. 1 and the systems in Figs. 2, 3 and 4, which are described below, each have one or more cameras 38 that are either mounted on the robot 12 and/or in other locations in the work cell to view what is being held by the gripper 24. The images from the cameras 38 can be used to detect picking errors and the orientation of the picked part. Each robot or cell mounted camera 38 can be used either for only obtaining images for selecting parts to pick, or only for obtaining images for pick error and orientation analysis, or for obtaining images for both of these tasks.

The systems in Figs. 2, 3 and 4 each show the robot 12, cameras 38, gripper 24, and a bin 40 having parts 41 therein to be picked by robot 12.

Fig. 2 shows one camera 38 mounted on the robot 12 adjacent to and below the horizontal axis of the gripper 24. Fig. 3 shows two cameras 38 mounted on robot 12 on either side of the horizontal axis of gripper 24. Fig. 4 shows two cameras 38 mounted on robot 12 on either side of the horizontal axis of gripper 24 and two cameras 38 not mounted on robot 12. The camera(s) 38 shown in Figs. 2 and 3 may or may not be the same camera(s) 38 used to detect the location of parts 41 in the bin 40.

In the systems shown in Figs. 1-4, the software associated with the vision system uses the images from one or more of the cameras 38 to detect the presence

and/or position / orientation of the part 41 in the gripper 24 after the robot 12 has picked a part 41 from bin 40. This software could be part of the same software that detects the locations of the parts 41 in the bin 40, or completely separate from that software. This software may be in controller 14 which is a computing device or in a separate computing device such as a PC or in the camera(s) 38 if the camera(s) are smart cameras, that is, have a built in computing device.

10 If a part 41 is not visibly in the gripper 24 after the extraction motion is complete, then another pick 41 would be attempted. This check that the picked part 41 is visibly in the gripper 24 can be done immediately after the extraction of the part 41 from bin 40 should have been completed, and repeated just before the part 41 is used for the next operation (such as placement on a conveyor). The performing of this check for a second time is to ensure that a loosely grasped part 41 was not
20 extraction of the part 41 from bin 40 and the start of the next operation.

 The same vision software components used to locate parts 41 in the bin 40 or additional vision software components can also use the images from the cameras 38 to detect the presence of additional parts 41 attached to the gripper 24 and/or a part 41 that was intentionally picked by robot 12 from bin 40. If the robot 12 has picked additional parts 41 from bin 40, then the grasped parts 41 are moved over the bin 40 and then rotated or
30 shaken over the bin 40 to thereby return the extra picked parts 41 to the bin 40. After this operation, the additional vision software components need to recheck how many parts 41 are in the gripper 24, and, if necessary, repeat either the pick procedure or the procedure to return the extra picked parts 41 to the bin 40. This rechecking of how many parts 41 are in gripper 24 is

stopped if a predetermined drop attempt limit has been reached. This determination prevents the robot 12 from continuously repeating the foregoing operation. The predetermined drop attempt limit could, for example, be based either on the expiration of a predetermined period of time after the parts 41 were initially picked from bin 41 or reaching a predetermined number of attempts to return the excess picked parts 41 to the bin 40.

10 Referring now to Fig. 5, there is shown a flowchart 500 for the above described control flow to ensure that only one part 41 is picked by robot 12 from bin 40.

At block 502, the vision system 36 finds a part 41 that can be picked from bin 40. The process proceeds to decision block 504 where it is asked if the vision system 36 has found a part 41 that can be picked from bin 40. If the answer is no, a "cannot pick" signal is output to the controller 14 or other computing device. If the answer to the question in decision block 504 is yes, the process proceeds to block 506 where the gripping
20 mechanism 24 is commanded to move to and grasp the part 41.

At block 508, the gripper 24 is retracted from bin 40. The gripper 24 should be grasping a part 41 and thus at decision block 510 it is asked if the vision system sees that the gripper 24 is holding at least one part 41. If the answer is no, this means that gripper 24 has not grasped a part 41 either because of a bad pick or that the picked part 41 was dropped by the gripper 24. Therefore the procedure returns back to block 502 to
30 begin again the picking process.

If the answer to the question in decision block 510 is yes, then the gripper 24 is holding at least one part 41. The process then proceeds to decision block 512 where it is asked if the gripper 24 is either holding more than one part 41 or are other parts 41 attached to the gripped part 41. The answer to this question based on processing

the image from the cameras 38 determines if the gripper 24 is holding only one part 41 or has gripped two or more parts 41. If the answer to the question in decision block 512 is no, then the gripper 24 is holding only one part 41 that has no other parts attached to the gripped part and the process proceeds to block 514 where the gripped part 41 proceeds to where it can be used in another operation. The process then returns from block 514 to block 502 to find another part 41 to pick from bin 40.

10 If the answer to the question in decision block 512 is yes, then the process proceeds to decision block 516 where it is asked if the predetermined drop attempt limit has been reached. This question is asked to prevent the robot 12 from continuously repeating the process to drop off extra part(s). The predetermined drop attempt limit could, for example, be timed based or based on the number of attempts to shake the parts free. If the answer to question in block 516 is no, the process proceeds to block 518 where the grasped parts are moved or rotated or
20 shaken over the bin 40 so that the extra parts can be dropped back into bin 40. If the answer to the question of decision block 516 is yes, the process proceeds to block 520 where all of the gripped parts 41 are released back into bin 40.

 While the flowchart of Fig. 5 shows a decision block for the question asked in block 510 and another decision block for the question asked in block 512, it should be appreciated that both questions can be answered in a single decision block since determining how many parts 41
30 are held by the gripper 24 or that other parts 41 are attached to the gripped part 41 is dependent on the part(s) being visibly in the gripper 24.

 In addition to the above, the position and/or orientation of a picked part 41 may shift in the gripper 24 due to some obstructions during the extraction process, an imperfect grasp, or other errors. Cameras

38, mounted either on the robot shown in Figs. 2 and 3 or in other locations in the work cell where the robot is located such as the location of the fixed cameras 38 shown in Figs. 1 and 4, can detect the part's position and orientation, and then determine if a shift has occurred that is too large for the system to handle. In such a case, the part 41 would have to be returned to the bin 40 and another pick would be attempted. If a shift has occurred, but was not too large, the system can optionally perform a small transformation to the output position / orientation so that the part will be delivered to the correct output position / orientation.

Referring now to Fig. 6, there is shown a flowchart for one procedure 600 for determining if the output position / orientation of the picked part 41 is within predetermined limits so that the picked part can be used in the next operation. The procedure 600 can start either after the procedure 500 described above has determined that the gripper 24 has gripped only one part 41 or can operate in parallel with the operation of the combination of decision blocks 510 and 512..

At decision block 602, the procedure 600 asks if the position / orientation of the picked part 41 is within predetermined acceptable limits. This could be determined by comparing the difference between the current position and a pre-defined position of the picked part 41. The system will verify that this difference does not exceed predetermined acceptable limits. If the answer to the question asked in decision block 602 is no, then a pick error has occurred and the picked part 41 will be dropped back into the bin 40 and an appropriate error message can be displayed on the display terminal associated with the controller 14 or other computing device.

If the answer to the question asked in decision block 602 is yes, then the procedure 600 proceeds to decision block 604 where it is asked if it is required to

change the final position / orientation of the robot 12. This can be determined by comparing the difference between the current position / orientation of the picked part 41 and a pre-defined position / orientation of the picked part 41. The system verifies that this difference is within a predefined range of a predetermined required position / orientation. If the answer to the question asked in decision block 604 is no, then the gripped part 41 proceeds to where it can be used in another operation.

10 If the answer to this question is yes, then the procedure 600 proceeds to block 606 where the difference between the current and a pre-defined position / orientation of the picked part 41 is applied to cause the robot 12 either by itself or together with the gripper 24 or only by the gripper 24 to change the position / orientation of the picked part 41 so that the picked part 41 proceeds to the desired position / orientation for the next operation.

Some or all of the cameras 38 can be used for one or more of the vision-based aspects of the system, including: finding a part 41 in the bin 40, detecting if a part 41 was picked, detecting if extra parts 41 were picked, and/or detecting if a picked part's position/orientation has shifted significantly.

20

Part presence and part location can be implemented using industry standard vision libraries, or using commercially available vision applications. Examples of vision libraries include, but are not limited to, the libraries available from Matrox Graphics and Cognex. An example of a vision application, includes but is not limited to, ABB TrueView.

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It is to be understood that the description of the foregoing exemplary embodiment(s) is (are) intended to be only illustrative, rather than exhaustive, of the present invention. Those of ordinary skill will be able to make certain additions, deletions, and/or modifications to the

embodiment(s) of the disclosed subject matter without departing from the spirit of the invention or its scope, as defined by the appended claims.

What is claimed is:

1. A method for using a robot to pick parts from a bin comprising:

using an image from one or more cameras to determine if said robot is holding one or more parts after said robot is commanded to pick one part from said bin.

2. A method for using a robot to pick parts from a bin comprising:

using an image from one or more cameras to determine the position / orientation of a part held by said robot after said robot is commanded to pick one part from said bin.

3. A robotic system for picking parts from a bin comprising:

a robot having a gripper for picking a part from said bin when said robot is so commanded;

one or more cameras mounted to provide one or more images that show what is held by said gripper after said robot is commanded to pick a part from said bin;

a computing device programmed to use said one or more images to determine if said robot is holding one or more parts after said robot is commanded to pick a part from said bin; and

said computing device further programmed to command said robot when said it is determined that said gripper is holding more than part to move said gripper and attempt to return to said bin all but one of said parts held by said gripper.

4. A robotic system for picking parts from a bin comprising:

a robot having a gripper for picking a part from said bin when said robot is so commanded;

One or more cameras mounted to provide one or more images that show what is held by said gripper after said robot is commanded to pick a part from said bin;

a computing device programmed to use said one or

more image to determine if the position / orientation of said part held by said gripper meets a predetermined criteria for said position / orientation of said part held by said gripper; and

said computing device further programmed to command said robot to move said gripper and return said picked part to said bin when it is determined that said part held by said gripper does not meet said predetermined criteria for said position / orientation of said part held by said gripper.

5. A robotic system for picking parts from a bin comprising:

a robot having a gripper for picking a part from said bin when said robot is so commanded;

one or more cameras mounted to provide one or more images that show what is held by said gripper after said robot is commanded to pick a part from said bin;

a computing device programmed to use said one or more images to determine if the position / orientation of said part held by said gripper meets a predetermined criteria for said position / orientation of said part held by said gripper; and

said computing device further programmed to command said robot either by itself or together with said gripper or only said gripper to adjust said part's position / orientation to be within said predetermined criteria when it is determined that said part held by said gripper does not meet said predetermined criteria for said position / orientation of said part held by said gripper.

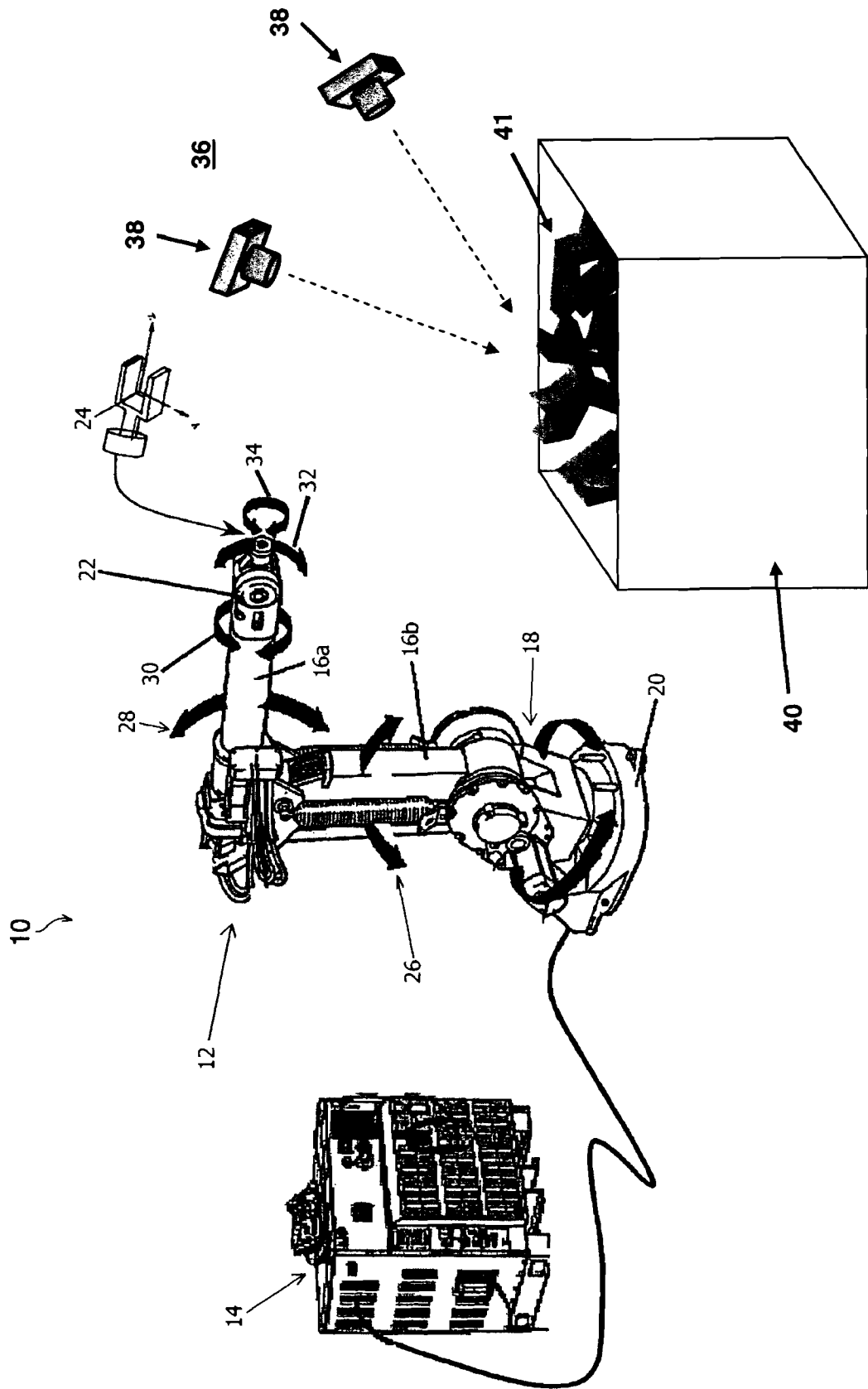


Fig. 1 (Prior Art)

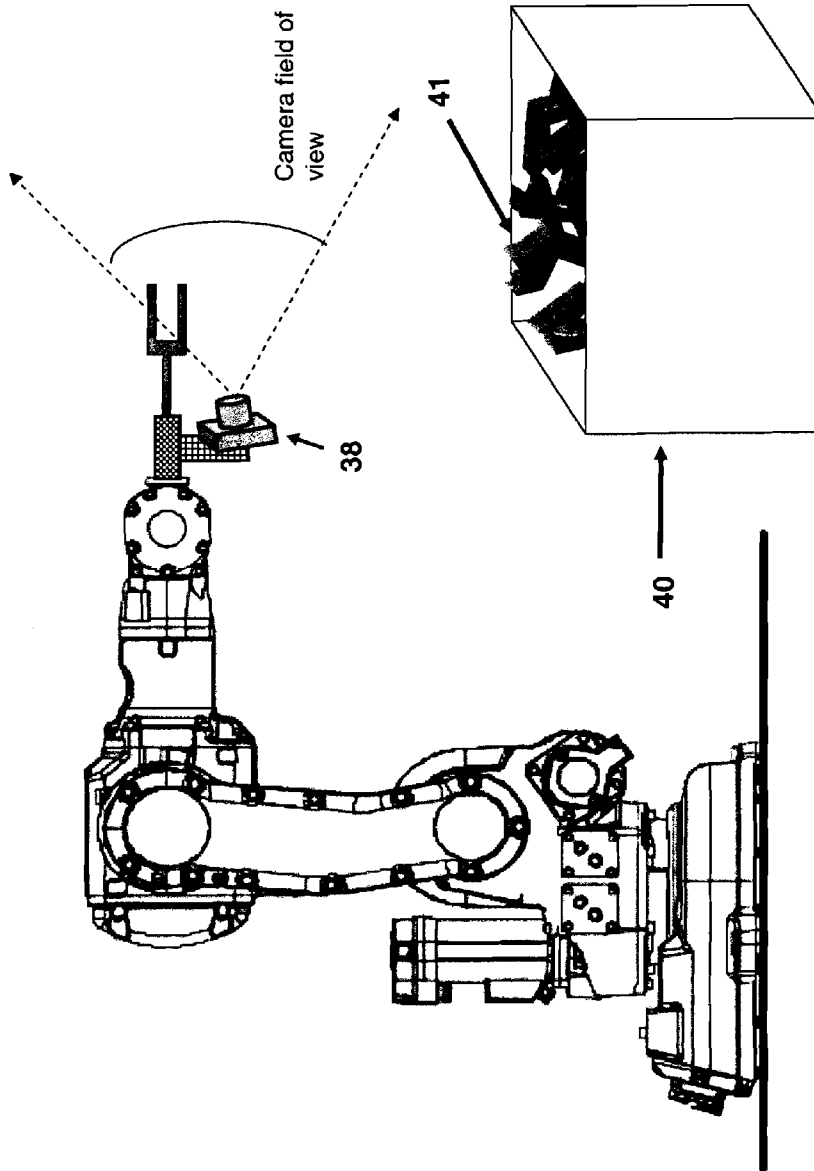


Fig. 2

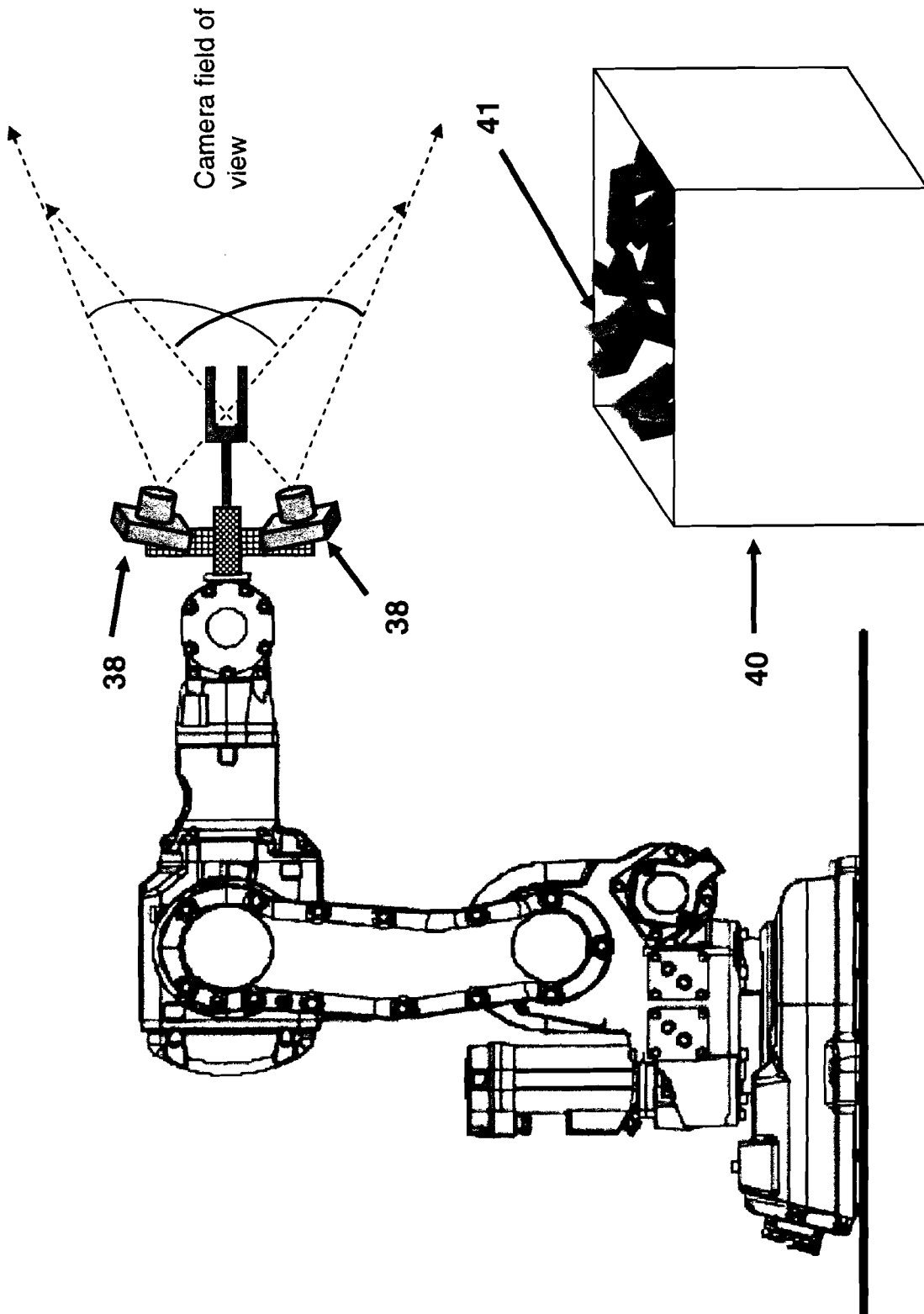


Fig. 3

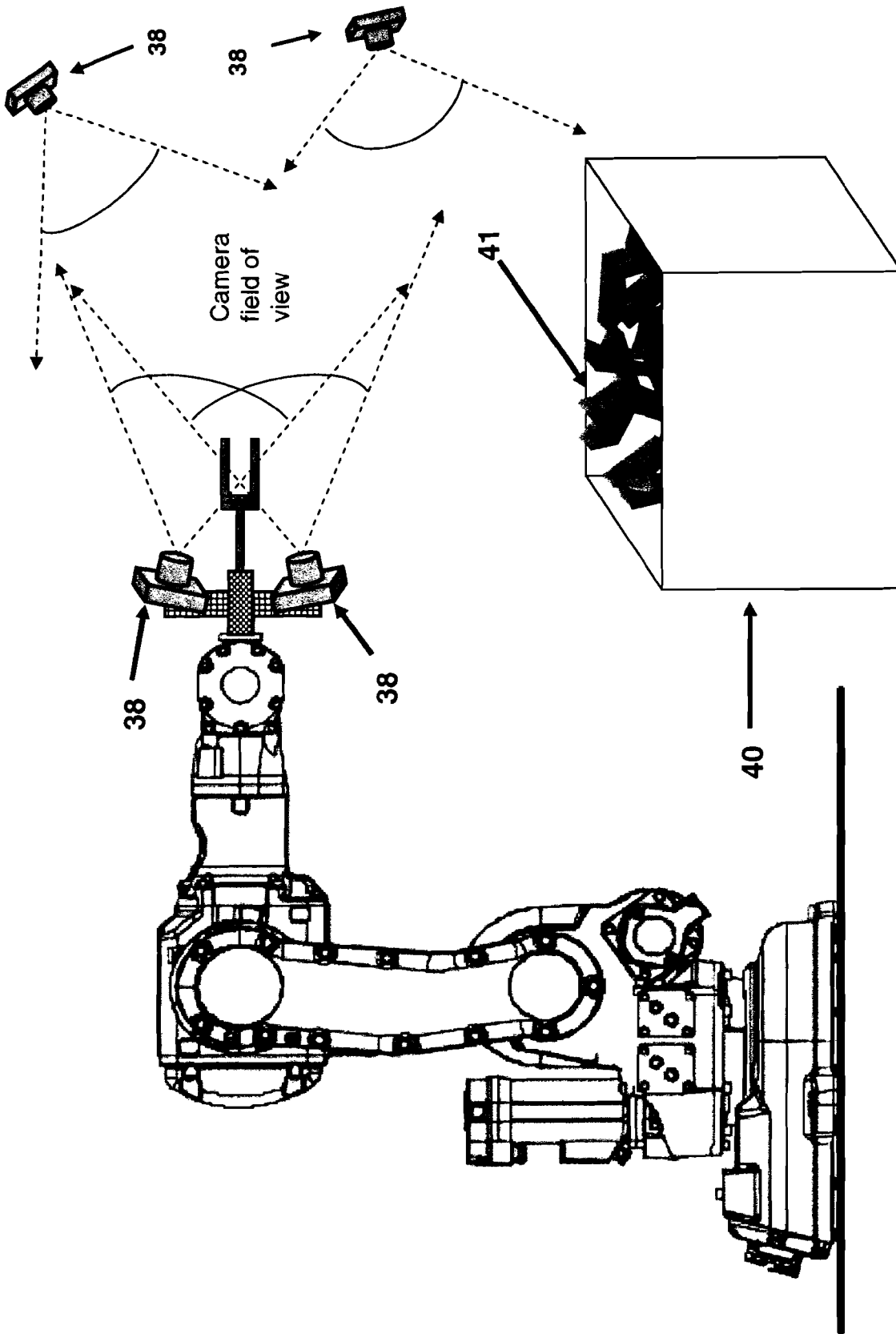


Fig. 4

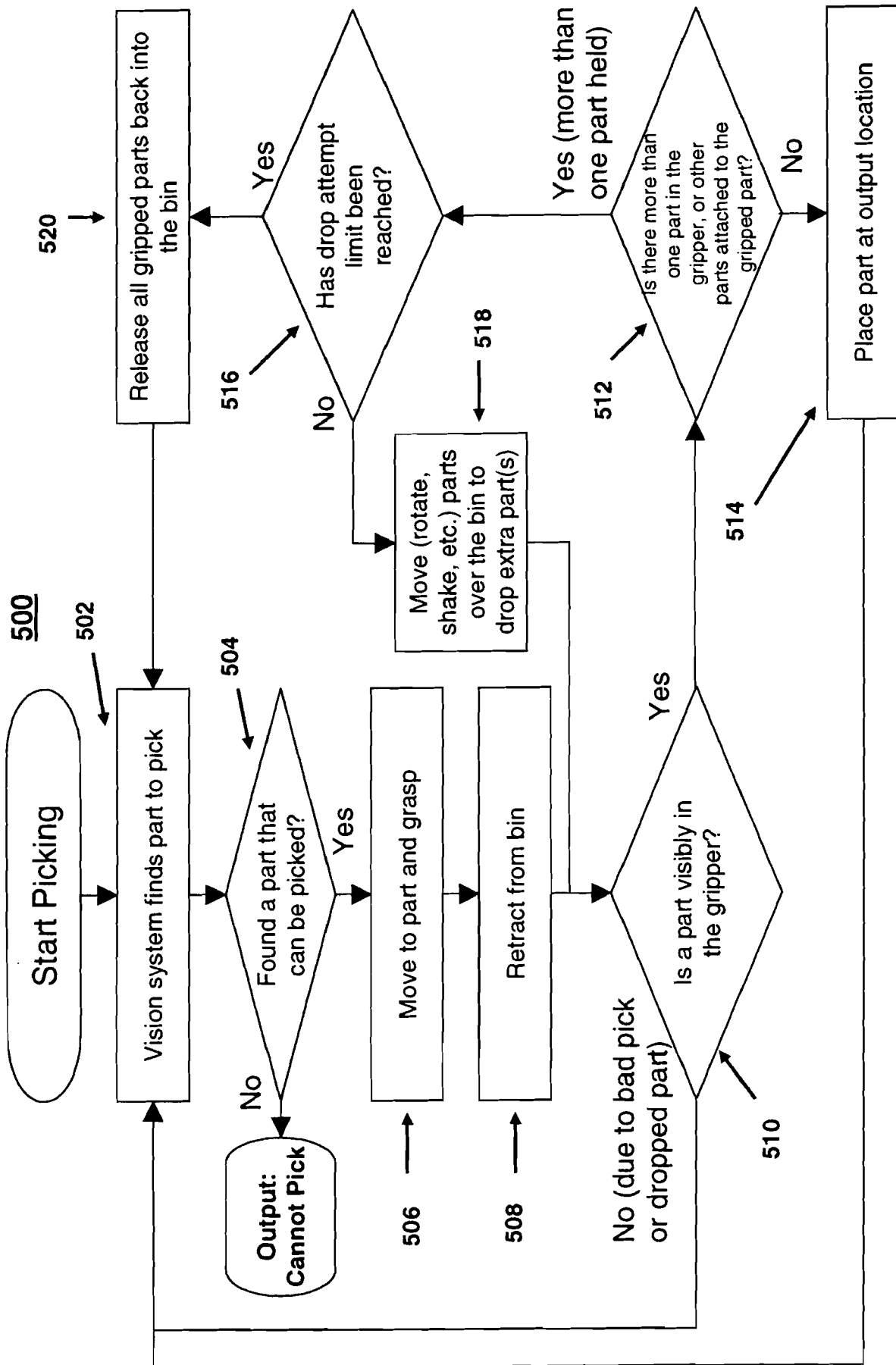


Fig. 5

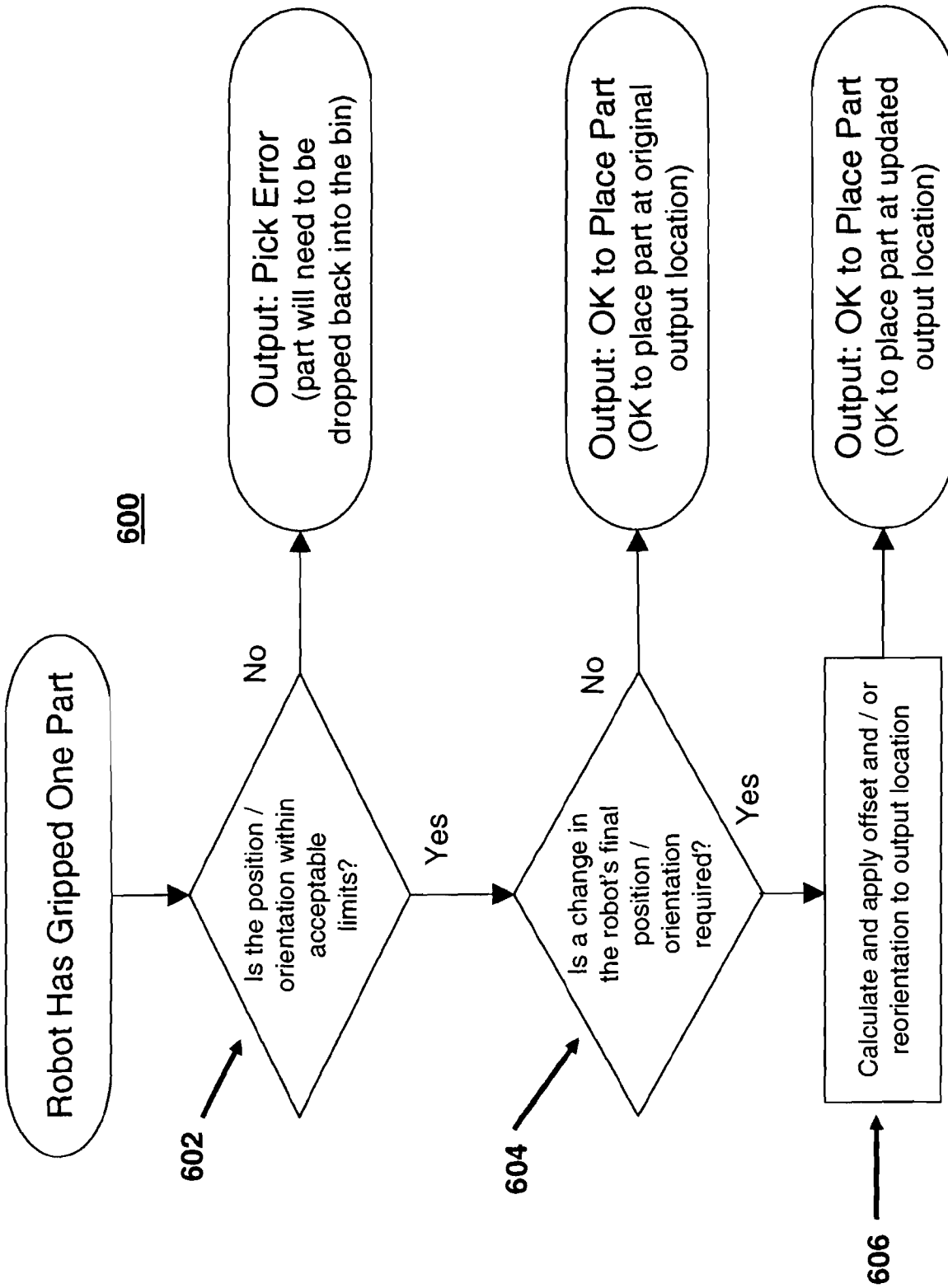


Fig. 6