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(54) **Title:** METHODS, SYSTEMS, AND APPARATUS FOR DYNAMIC PICK AND PLACE SELECTION SEQUENCE BASED ON SAMPLE RACK IMAGING DATA

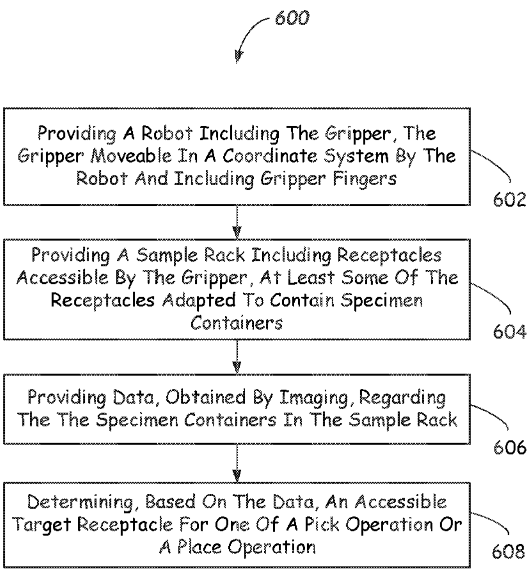

FIG. 6

(57) **Abstract:** Methods of operating a gripper are provided. The methods include providing a robot including the gripper, the gripper moveable by the robot and including gripper fingers, providing a sample rack including receptacles accessible by the gripper, at least some of the receptacles adapted to contain specimen containers, providing data, obtained by imaging, regarding the sample rack and the specimen containers therein, and determining, based on the data, an accessible target receptacle for one of a pick operation or a place operation. Apparatus and systems configured to carry out the methods are provided, as are other aspects.

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METHODS, SYSTEMS, AND APPARATUS FOR DYNAMIC PICK AND PLACE SELECTION SEQUENCE BASED ON SAMPLE RACK IMAGING DATA

CROSS-REFERENCE TO RELATED APPLICATIONS

[001] This application claims priority to U.S. provisional application Serial No. 62/362,535 filed on July 14, 2016, the contents of which is incorporated herein by reference in its entirety.

FIELD

[002] The present disclosure relates generally to methods and apparatus adapted to pick and place a specimen container from and to a sample rack in systems for processing biological liquids.

BACKGROUND

[003] In medical testing and processing, the use of robotics may minimize exposure to, or contact with, biological liquid samples (otherwise referred to herein as "specimens") and/or may significantly increase productivity. For example, in some automated testing and processing systems (e.g., clinical analyzers), specimen containers (such as test tubes) may be transported from and to sample racks (sometimes referred to as "cassettes") and from and to a testing or processing location of a testing or processing apparatus.

[004] Such transportation may be accomplished by the use of an automated mechanism, such as a robot having a coupled gripper. The gripper may have opposed gripper fingers that are configured to grasp respective specimen containers during transport. The specimens may be of varying size (e.g., height and/or diameter) or type. The gripper may be moved in two or more coordinate directions by the robot. In this way, specimen containers (containing a specimen to be tested or processed) may be gripped by the gripper, and then moved from one location to another.

[005] For example, in a pick operation, the robot gripper may be moved to above a theoretical center location of a receptacle of a sample rack and, with gripper fingers fully open, lowered to a specified height and then closed to grip the specimen container. This is followed by raising the gripper to pull the specimen container from the receptacle. In a place operation, the gripper, with specimen container in its grasp, may be moved over the center of a sample rack receptacle, and lowered towards the receptacle to place the specimen container to a desired depth, and then the gripper fingers are fully opened to release the specimen container. This is followed by raising the gripper. Thus, using these pick and place operations, specimen containers may be moved from and to numerous receptacles of the sample rack. However, to maximize machine footprint usage, the receptacles in such sample racks are very tightly spaced.

[006] Accordingly, methods and apparatus that may improve efficiency of pick and place operations in testing and processing systems are sought after.

SUMMARY

[007] In one method embodiment, an improved method of operating a gripper is provided. The method includes providing a robot including the gripper, the gripper moveable in a coordinate system by the robot and including gripper fingers, providing a sample rack including receptacles accessible by the gripper, at least some of the receptacles adapted to contain specimen containers, providing data, obtained by imaging, regarding the sample rack and the specimen containers, and determining, based on the data, an accessible target receptacle for one of a pick operation or a place operation.

[008] In a system embodiment, a gripper positioning system is provided. The gripper positioning system includes a robot including the gripper, the gripper moveable in a coordinate system by the robot and including gripper fingers, a sample rack including receptacles accessible by the gripper fingers, at least some of the receptacles containing specimen containers, and a controller coupled to the robot and operatively configured to: access data obtained from one or more images regarding the sample rack and the specimen containers, the data including population data and configuration data, and determine, based on the population data and configuration data, an accessible target receptacle for one of a pick operation or a place operation.

[009] In an apparatus embodiment, a gripper positioning apparatus is provided. The gripper positioning apparatus includes a robot including the gripper, the gripper moveable in a coordinate system by the robot and including gripper fingers, a controller coupled to the robot and operatively configured to access data obtained from one or more images, regarding the sample rack and the specimen containers, and determine, based on the data, an accessible target receptacle for one of a pick operation or a place operation.

[0010] Still other aspects, features, and advantages of the present disclosure may be readily apparent from the following detailed description illustrating a number of example embodiments, including the best mode contemplated for carrying out the present disclosure. The present disclosure may also be capable of different embodiments, and its several details may be modified in various respects, all without departing from the scope of the present disclosure. Accordingly, the disclosure is to cover all modifications, equivalents, and alternatives falling within the scope of the disclosure as defined in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 illustrates a schematic top view of a sample rack including specimen containers according to the prior art.

[0012] FIG. 2 illustrates a schematic side view of a gripper positioning system configured to perform a dynamic gripper finger positioning method according to one or more embodiments.

[0013] FIG. 3A illustrates a partial top plan view of a sample rack including a target specimen container surrounded by some empty and some full receptacles, shown in a configuration where the gripper fingers are opened (separated) by an intermediate distance according to one or more embodiments.

[0014] FIG. 3B illustrates a partial top plan view of a sample rack including specimen containers in receptacles, shown in a configuration where the gripper fingers are opened (separated) by an intermediate distance according to one or more embodiments.

[0015] FIGs. 4A-4E illustrate schematic diagrams showing various specimen container population scenarios according to one or more embodiments.

[0016] FIG. 5 illustrates a schematic top view of a specimen container transport system configured to perform a dynamic gripper finger positioning method according to one or more embodiments.

[0017] FIG. 6 illustrates a flowchart of a method of operating a gripper according to embodiments.

DETAILED DESCRIPTION

[0018] In robots, such as those used to accomplish robotic pick and place operations in clinical analyzers or other testing or processing systems (e.g., centrifuges, cold storage areas), jams, collisions, and/or jarring of specimen containers can occur from time-to-time.

[0019] In particular, as is shown in FIG. 1, specimen containers 102, 102L (e.g., blood collection tubes) used in automated in vitro diagnostics (IVD) equipment are typically provided in an open-topped (de-capped) condition and filled with a biological fluid specimen 105 (a few labeled), i.e., a bio-hazardous liquid (e.g., blood, blood serum or plasma, urine, interstitial fluid, cerebral fluid, spinal fluid, or other bodily fluids). The specimen containers 102, 102L are stored in a generally vertical orientation within receptacles 106R (a few labeled) within a sample rack 106 (the first two and a half rows populated with specimen containers 102, 102L).

[0020] To maximize the use of the equipment footprint, the receptacles 106R of the sample rack 106 are very closely spaced. To accommodate specimen containers 102 of various diameters, sometimes springs 108 (a few labeled), such as one or more leaf-type springs, can be placed in each receptacle 106R in an attempt to either center the specimen container 102, or to force the specimen container 102 against a defined wall of the receptacle 106R (as shown), all while generally maintaining the vertical orientation of the specimen container 102.

[0021] However, due to mechanical tolerances and placement of the specimen containers 102, each specimen container 102 may lean away from a true vertical orientation to some extent in one or more directions (e.g., X and/or Y as shown), thereby causing a reduction in the expected tube-to-tube clearance. Furthermore, because varying-diameter specimen containers 102 are often processed on a given piece of equipment at the same time (e.g., Row 3 shown containing some specimen containers 102L that have a relatively-larger diameter as compared to specimen containers 102 contained in Rows 1 and 2), the clearance between adjacent specimen containers 102, 102L in the sample rack 106 may vary from receptacle 106R to receptacle 106R based upon tube size and direction of lean. Furthermore, the offset due to the presence of springs 108 may place the center of the specimen container 102, 102L at a position other than the center of the receptacle 106R. Similarly, some receptacles 106R may be empty.

[0022] The close spacing of the receptacles 106R, combined with the desire for high throughput of the IVD equipment, may result in occasional unwanted contact between specimen containers 102, 102L (e.g., jams, collisions, and/or jarring) and the robot gripper and/or gripper fingers during processing. Such contact may slow down automated processing, as damage caused by the contact may have to be corrected by manual operator intervention. For example, such contact can, in the some extreme cases, result in tube breakage, spills, and/or loss of specimen, all possibly resulting in downtime for remediation/cleanup.

[0023] In the prior art, the order in which specimen containers 102 are picked and/or placed in the sample rack 106 is pre-determined using simple row-by-row sequential picking and/or placing based on simple picking algorithms. This pre-determined order of selection does not take into account possible differences in placement (e.g., offset), size (e.g., diameter or height), or even type of specimen containers 102, 102L that are resident within receptacles 106R of sample racks 106. These differences, if not accounted for, may result in contact or may cause obstruction of the gripper fingers and may make it more difficult for the gripper fingers to access the specimen containers 102, 102L in the pre-determined order without causing possible damage to the specimen (e.g., spillage) or requiring operator intervention.

[0024] In view of the foregoing, one or more embodiments of the disclosure provide methods, systems, and apparatus to dynamically (on the fly) determine a sequence of picking accessible specimen containers, or placing specimen containers in a target, accessible receptacle, based on data obtained by imaging the sample rack (i.e., dynamic selection of pick and/or place order). The data obtained by imaging may include sample rack population data and/or specimen container configuration data. Population data is data regarding the presence or absence of neighboring specimen containers in receptacles of the sample rack, and more particularly, around a particular target receptacle. Configuration data is data concerning the orientation and/or size of specimen containers surrounding the target receptacle, as well as the orientation and/or size of the target specimen container itself. Population data and/or configuration data is made available for each receptacle 106R in a sample rack 106 after the sample rack 106 has been imaged via a sample rack imaging system, wherein such sample rack imaging systems are known in the prior art.

[0025] According to one or more embodiments, vision data (e.g., configuration and/or population data) may be used to dynamically adjust a pick and/or place order or sequence. In one embodiment, the order in which specimen containers 102, 102L are picked by the gripper fingers may be adjusted based on configuration and/or population data obtained by imaging. In another embodiment, the order in which specimen containers 102, 102L are placed by the gripper fingers may be adjusted based on configuration and/or population data obtained by imaging.

[0026] Method, apparatus, and systems in accordance with one or more embodiments may take into account the population data of specimen containers 102 in the sample rack 106 and/or configuration data of specimen containers 102 in the sample rack 106 to dynamically determine a desired pick and/or place order.

[0027] For example, method, apparatus, and systems may take into account population data such as whether or not surrounding receptacles 106R contain specimen containers 102 or are empty. Similarly, one or more embodiments may take into account configuration data regarding size (e.g., diameter and/or height) of one or more of the surrounding specimen containers, offset of neighboring specimen containers towards or away from a certain target specimen container, the tube type of the target specimen container (e.g., capped tube, uncapped tube, tube top sample cup, and the like), and any offset of a target specimen container (in the case of a pick operation).

[0028] This ability to dynamically choose the order in which specimen containers 102 are picked and/or placed by the gripper may dramatically reduce the propensity for contact (e.g., jams, collisions, and/or jarring) and thus reduce damage to the specimen container 102, 102L and/or reduce biological fluid specimen 105 spillage and loss. This may reduce IVD instrument downtime as well as the need for operator intervention.

[0029] These and other aspects and features of embodiments of the disclosure will be described with reference to FIGs. 2-6 herein.

[0030] In accordance with one or more system embodiments, referring to FIG. 2, a gripper positioning system 200 is shown and described. The gripper positioning system 200 includes a robot 210 that is useful for grasping and transferring a target specimen container 102T, such as blood collection vessel, vial, or the like, from a first location to a second location. The gripper positioning system 200 may be used in any testing instrument or device, such as an automated clinical analyzer, assaying instrument, or other processing device such as a centrifuge, where specimen containers 102, 102L containing biological fluid specimen 105 are moved to or from a sample rack 106.

[0031] For example, the robot 210 may move the target specimen container 102T from the sample rack 106 to a specimen container carrier 532 (e.g., a puck - FIG. 5) moveable on a track 540, which moves the specimen container 102 to an instrument or equipment for testing or processing. In one or more embodiments, the testing instrument or equipment may be used for determining a constituent component (e.g., an analyte concentration) in the biological fluid specimen 105 contained in the specimen container 102 or otherwise performing processing thereon. The track 540 may include one or more offshoots 540A providing the opportunity for specimen container carriers 532 to branch off from a main channel 540B.

[0032] Again referring to FIG. 2, the robot 210 includes a gripper 212 coupled to a moveable part of the robot 210, such as a moveable arm or portion of a gantry. For example, the robot 210 may be an R, theta, Z robot as shown in FIG. 2. Alternatively, the robot may be a gantry robot 510 as shown and described relative to FIG. 5 herein. In each case, the robot 210, 510 moves a gripper 212 in a coordinate system (e.g., in X, Y, and Z). The robot 210 shown in FIG. 2 may include a base 210B that may be coupled to a frame 214 of the testing instrument or equipment, an upright portion 210U configured to move vertically (in the +Z and -Z directions) along a vertical axis 211Z, a telescoping portion 210T configured to move radially (in the +R and -R directions), and a rotary portion 210R configured to move rotationally about the vertical axis 211Z (in the $+\theta$ and $-\theta$ directions). "Gripper" as used herein means any member coupled to a robot component (e.g., coupled to a robot arm or gantry member) that is used in robotic operations to grasp and move an article (e.g., a specimen container 102) from one location to another, so as to carry out a pick and/or a place operation. For example, the robot 210, 510 may be used to place the target specimen container 102T into a target receptacle 106T in the sample rack 106, or pick the target specimen container 102T from the target receptacle 106R in the sample rack 106.

[0033] The gripper 212 may include two gripper fingers 212A, 212B that are moveable relative to one another, may be generally opposed to one another, and are adapted to grasp articles, such as specimen containers 102 (e.g., blood collection tubes or vials). The gripper fingers 212A, 212B may be driven to open and close by an actuation mechanism 212L coupled to each of the gripper fingers 212A, 212B. Actuation mechanism 212L may be any suitable mechanism that moves the gripper fingers 212A, 212B in opposite directions. The actuation mechanism 212L may be linearly acting to move each gripper finger 212A, 212B in linear translation or otherwise pivot the gripper fingers 212A, 212B. The relative amount of movement of the gripper fingers 212A, 212B may be the same (but in opposite directions) or a different amount. The gripper fingers 212A, 212B may open and close along any suitable direction in an X-Y plane (e.g., in the X or Y direction or combinations thereof).

[0034] In some embodiments, a rotary actuator 212R may be provided that is configured and operable to rotate the gripper fingers 212A, 212B to any prescribed rotational position/orientation. Thus, a line of action of opening and closing of the gripper fingers 212A, 212B can be rotated to coincide with areas on the sample rack 106 that meet a threshold minimum clearance. The areas in the sample rack 106 that are determined to meet the threshold minimum clearance may be determined by imaging. In particular, receptacles 106R that meet the threshold minimum clearance may be selected as target receptacles 106T for pick and/or place operations thereat. The selection may be based on population and/or configuration data obtained by imaging. The +X, -X, +Y and -Y directions as referred to herein may be as shown. The Y direction is into and out of the paper, as shown.

[0035] In more detail, the actuation mechanism 212L may be driven by an electric, pneumatic, or hydraulic servo motor, or the like, that is coupled to the gripper fingers 212A, 212B. The gripper fingers 212A, 212B may move along any slide mechanism so that they may be constrained to linear motion. Other suitable mechanisms for causing gripping action of the gripper fingers 212A, 212B may be used. Likewise, in some embodiments where rotational capability is provided, the rotary actuator 212R may be configured and operable to rotate the gripper fingers 212A, 212B. The rotary actuator 212R may be an electric, pneumatic, or hydraulic servo motor, or the like.

[0036] The actuation mechanism 212L and the rotary actuator 212R may be driven responsive to drive signals from a robot controller 216. One or more linear position encoders 212LE and/or rotational encoders 212RE may be included to provide position feedback concerning the extent of opening of the gripper fingers 212A, 212B and/or the rotational orientation of the gripper fingers 212A, 212B. Furthermore, although two gripper fingers 212A, 212B are shown, embodiments of the present disclosure are equally applicable to a gripper 212 having more than two gripper fingers 212A or 212B. Other gripper 212 types may be used, as well. The robot 210, 510 may be any suitable robot type capable of moving the gripper 212 in space (e.g., three-dimensional space) to transport the specimen containers 102.

[0037] Again referring to FIG. 2, in one or more embodiments, the robot 210 may include a rotational motor 218R adapted to rotate a rotary portion 210R to a desired angular orientation in a rotational direction (e.g., +/- θ). The robot 210 may also include a vertical motor 218Z coupled to the upright portion 210U and that may be adapted to move the gripper 212 in a vertical direction (e.g., along the vertical axis 211Z, shown dotted). In one or more embodiments, the robot 210 may include a translational motor 218T adapted to impart translational motion to the gripper 212 coupled to the rotary portion 210R (e.g., along the +/- R direction). However, although an R, theta, Z robot is shown, other suitable robot types, robot motors and mechanisms for imparting X, Y, R, θ, and/or Z motion or other combinations may be provided. Suitable position feedback mechanisms may be provided for each degree of motion (X, Y, R, θ, and/or Z) such as from linear and/or rotation encoders.

[0038] In one or more embodiments, the robot 210 may be used to accomplish three-dimensional motion of the gripper 212 in a coordinate system (e.g., X, Y, and Z) so that the specimen containers 102, 102L may be placed in, or removed from, target receptacles 106T of the sample rack 106 or placed in or removed from other positions in testing instrument or processing equipment. Optionally, the robot 210 may accomplish rotation of the gripper 212 about the gripper rotational axis 220, so that the gripper fingers 212A, 212B may be precisely rotationally oriented relative to a target receptacle 106T of the sample rack 106.

[0039] The robot controller 216 may include a suitable microprocessor, memory, power supply, conditioning electronics, circuitry and drivers adapted to carry out and control the robot motions and to control position of the gripper 212 in the X,Y,Z coordinate system, as well as control an extent of gripper finger 212A, 212B opening distance and/or rotational orientation.

[0040] In FIG. 2, a sample rack imaging system 221 may be provided in the gripper positioning system 200 to capture images of the sample rack 106. Sample rack imaging system 221 may include a rack image capture apparatus 222 and an image capture controller 224. In particular, the rack image capture apparatus 222 (e.g., a digital camera) may be placed at any suitable location. In one or more embodiments, multiple images of the sample rack 106 may be obtained from multiple perspectives. For example, the rack image capture apparatus 222 may be placed above a moveable sample rack loading drawer 225, which may be moveable relative to the frame 214. The sample rack 106 may be supported by the moveable sample rack loading drawer 225 and moved into the testing instrument or processing equipment to a position accessible by the robot 210. During that movement, the rack image capture apparatus 222 may take multiple digital images of a top of the sample rack 106. Other means for capturing images may be used.

[0041] Image processing software stored in the image capture controller 224 may receive and process the multiple digital images. From the images, data may be produced including population data and/or configuration data. The population data and/or configuration data may be accessed by the robot controller 216. Access may be either through a download of the data from the image capture controller 224 or by gaining access to a database resident on the image capture controller 224.

[0042] Optionally, the robot controller 216 and image capture controller 224 may be combined in one common controller and configured to process the images captured by the rack image capture apparatus 222 and also control the motion and operation of the robot 210 and gripper 212. Further details of the sample rack imaging system 221 and image capture controller 224 may be found in U.S. Pat. Pub. No. US2016/0025757 filed March 14, 2014, to Pollack et al. entitled "Tube Tray Vision System"; PCT Application Pub. No. WO2015/191702 filed June 10, 2015, and entitled "Drawer Vision System"; PCT Application No. PCT/US2016/018100 filed February 16, 2016, and entitled "Locality-Based Detection Of Tray Slot Types And Tube Types In A Vision System"; PCT Application No. PCT/US2016/018112 filed February 16, 2016, and entitled "Locality-Based Detection Of Tray Slot Types And Tube Types In A Vision System"; and PCT Application No. PCT/US2016/018109 filed February 16, 2016, and entitled "Image-Based Tube Slot Circle Detection For A Vision System."

[0043] In more detail, population data refers to data on which of the receptacles 106R in the sample rack 106 are empty, and which contain a specimen container 102 therein. For example, as shown in FIG. 2, population data would indicate that target receptacle 106T labeled "B" is empty, and receptacles 106R labeled "A," "C," "D," and "E" all contain specimen containers 102, 102L. Population data, alone or in combination with configuration data, may be used to select the next target specimen container 102T for a pick operation or target receptacle 106T for a place operation.

[0044] Configuration data is defined herein as information on the geometry and/or orientation of one or more specimen containers 102, 102L resident in the sample rack 106. Configuration data may include maximum specimen container outer diameter, offset distance of a top of the specimen container 102, 102L relative to a center of the receptacle 106R where it resides, height of the specimen container 102, 102L, or tube type (e.g., capped tube, uncapped tube, including a tube top sample cup, and the like).

[0045] For example, configuration data may indicate that specimen container 102L has a relatively large diameter, that the specimen container 102 is offset in the X and/or Y directions due to the action of a spring (e.g., spring 108) or because the specimen container 102, 102L is leaning in the receptacle 106R. The configuration data obtained from imaging may also indicate a specimen container 102 having a relatively small diameter or intermediate diameter, and may provide a distance between the centers of the target specimen container 102T and any neighboring specimen containers 102, 102L, for example. The sizes, offsets, and clearances may be obtained by first identifying the geometrical features in the image and then counting pixels.

[0046] Population data, configuration data, or combinations of the two are at least partially used to determine a target receptacle 106T that is deemed to be accessible by the gripper fingers 212A, 212B. The target receptacle 106T may be selected by preliminarily surveying the available receptacles 106R prior to either a pick operation or a place operation.

[0047] An accessible target receptacle is a receptacle (e.g., target receptacle 106T) which has been determined to meet a threshold minimum clearance. The threshold minimum clearance is predetermined and measured along an available line of action relative to the target specimen container 102T. For example, referring to FIG. 3A, consider that specimen container 102T in the target receptacle 106T is the "target specimen container," i.e., in a pick operation, the specimen container 102 that is desired to be picked by the gripper fingers 212A, 212B. Before the specimen container 102T is picked by the gripper fingers 212A, 212B, though, the method may determine whether or not the target receptacle 106T, in which the target specimen container 102T is received, is accessible. By determining this, the risk of jams, contact between neighboring specimen containers, spillage, etc. is reduced, thus increasing efficiency of the automated testing instrument or processing equipment.

[0048] To determine if the target receptacle 106T is accessible (i.e., if it meets the threshold minimum clearance), population data and/or configuration data for the target specimen container 102T and the surrounding specimen containers 102 and receptacles 106R may be accessed and used. In this case, as shown in FIG. 3A, configuration data for the specimen containers 102 located in the number 2, 4, 6, and 8 receptacles 106R in the sample rack 106, is obtained and analyzed. Likewise, population data may be used to determine that number 1, 3, 7 and 9 receptacles 106R are empty.

[0049] The analysis can be carried out by selecting a first receptacle as a potential target receptacle 106T and testing whether the threshold minimum clearance is available along any available line of action. For example, in a fixed gripper design, i.e., without rotational capability, only the clearance along the line of action 325A for that receptacle 106R will be surveyed.

[0050] The method of selection of the receptacle for testing against the threshold may be as simple as moving from receptacle to receptacle until one that meets the threshold minimum clearance is found. In the case where multiple lines of action (e.g., lines of action 325A-325C) are available because the gripper 212 has rotation capability, each line of action (325A-325C) for a test receptacle 106R may be tested individually against the threshold minimum clearance. As soon as one clearance value falls above the threshold, the pick or place may be carried out. If the receptacle 106R does not meet the threshold minimum clearance, then another receptacle 106R is surveyed to see if it meets the threshold minimum clearance. This continues until a target receptacle 106T is found to meet the minimum threshold clearance.

[0051] The population data for receptacles 106R surrounding the target receptacle 106T may indicate which of the receptacles 106R surrounding the target receptacle 106T contain a specimen container 102, 102L. In cases where there is an empty receptacle 106R along a line of action 325A, such as at numbers 1, 2, 3, 7 and 9, those clearances on that side of the target specimen container 102T may be determined to be above the threshold, automatically. Thus, immediately, that line of action 325A may be selected. The opening distance measured between the specimen container contact surfaces of the gripper fingers 212A, 212B may be set to a maximum. Line of action 325A may be selected over line of action 325C because the direction of offset of the top of the specimen container is such that gripping it along line of action 325A may have a high probability of righting the orientation from leaning to a vertical orientation, i.e., to right a leaning target specimen container 102T.

[0052] Moreover, the configuration data may indicate which ones of the neighboring specimen containers 102, 102L is a specimen container 102L of a relatively large diameter. The configuration data may also indicate that the target specimen container 102T is leaning (i.e., is offset from the center of the target receptacle) or otherwise offset, thus reducing or increasing a clearance between the target specimen container 102T and any surrounding specimen containers 102, 102L.

[0053] The configuration data may also indicate the tube type of the target specimen container 102T. Knowing the tube type is important in situations where the clearance between two specimen containers 102 is very close to the minimum threshold clearance, making it difficult to determine whether the receptacle 106R is actually accessible or not. For certain tube types, smaller threshold clearances may be allowed as that tube type is sturdier, and for other tube types, such as tube-top sample cups, larger threshold clearances may be used as the tube type is more delicate. Thus, the threshold clearance may be selected based on the type of specimen container 102 present in the target receptacle 106T or in the surrounding receptacles 106R in some embodiments.

[0054] From the imaging data, it may be determined if a target receptacle 106T is accessible, i.e., that it can be properly accessed by the gripper fingers 212A, 212B (e.g., without contact therewith) or if it is blocked from access. Blocked from access means that the gripper fingers 212A, 212B cannot be inserted without substantial possibility of contact with one or more specimen containers 102, 102L surrounding the target specimen container 102T. For a pick operation, a receptacle 106R can be determined to be blocked after all possible lines of action have been analyzed and none allow for the minimum threshold clearance between the specimen container 102 within the receptacle 106R and one of the neighboring specimen containers 102. A receptacle 106R can be determined to be accessible if one of the lines of action provides a minimum threshold clearance between the receptacle 106R and the neighboring specimen containers 102. The minimum threshold clearance may be provided in some instances by adjusting the gripper 212 in X and/or Y directions. In other instances, the minimum threshold clearance may be provided by adjusting the opening distance between the gripper fingers 212A, 212B. In some embodiments, adjustments to both the location of the gripper 212 in X and/or Y directions together with adjustments the opening distance between the gripper fingers 212A, 212B may be carried out to provide the minimum clearance.

[0055] If the target receptacle 106T is not accessible, a strategy may be developed, based upon the imaging data, wherein the strategy involves selecting neighboring specimen containers 102, 102L that are accessible and removing them first, so as to make the target receptacle 106T accessible. For example, as shown in FIG. 3B, specimen container 102B shown in the receptacle 106RB labeled C7 is effectively blocked. Blocking is determined when no available line of action includes the minimum clearance regardless of gripper rotational orientation, gripper opening distance, or X or Y positioning. Specimen container 102B is deemed blocked because specimen containers 102, 102L in receptacles 106R labeled B7, B6, C6, D6 are too close to meet the minimum clearance on one side of the blocked specimen container 102B. Thus, to be able to pick blocked specimen container 102B, it must first be unblocked.

[0056] By removing an unblocked specimen container 102 in an adjacent neighboring receptacle labeled A7 along line of action 325E, this may effectively “unblock” the target receptacle 106RB. The target receptacle 106RB may then be made accessible and may then be able to be picked along a line of action (e.g., along line of action 325F, for example). Optionally, specimen container 102 in receptacle 106R labeled B6 may have been removed to provide unblocking the blocked specimen container 102B. In each case, there may be many options for unblocking a blocked receptacle 106RB.

[0057] The method may, in one embodiment, test in a round robin fashion whether each removal may unblock the target receptacle 106RB. As soon as one is found that will unblock, it may be removed and the previously blocked specimen container 102B, now being unblocked, may be picked. In other embodiments, where multiple unblocking options are available, removal of a specimen container 102, 102L that will reveal a line of action with the greatest clearance may be selected.

[0058] For each blocked receptacle 106RB, embodiments of the method may search in a sequence, going clockwise or counterclockwise from any starting location, and survey whether any of the neighboring specimen containers 102, 102L may be removed, and if so, would that free up a line of action effectively enabling the unblocking the blocked specimen container 102B by removal thereof. In some embodiments, all of the blocked receptacles 106RB in the sample rack 106 may be identified based on the imaging data, and each blocked receptacle 106RB may be given precedence over unblocked receptacles 106R so that a neighboring specimen container 102, 102L may be selected in an effort to unblock the blocked condition. Any number of schemes may be implemented to unblock blocked receptacles.

[0059] In some embodiments, pick operations may take place in an ordered sequence, such as row-by-row, column-by-column, or in any other ordered pattern, and when a blocked receptacle 106RB is detected, then a pick move may be made to attempt to unblock the blocked receptacle 106RB. If no move is available at that time, then the ordered sequence simply continues until a move is available.

[0060] In some embodiments, after a first pick or place is made, the system and method can be used to analyze the rest of the sample rack 106 and create a comprehensive pick and place strategy that takes into account population and/or configuration data. This pick or place order may be determined rapidly, and while the first accessible specimen container 102 is being picked. The system may determine all accessible specimen containers 102 and all "blocked" specimen containers 102. In some embodiments, all the accessible specimen containers 102 may be picked first, and then it may be determined which of the specimen containers 102 that were once considered "blocked" have become "unblocked." These "unblocked" specimen containers 102 are now accessible, and may be picked. This may be repeated until all of the specimen containers 102 have been "unblocked," deemed accessible, and picked.

[0061] In some embodiments, rank ordering the receptacles 106R may also be used to determine the order in which specimen containers 102 are picked. Referring now to FIGs. 4A-4E, several possible configurations of a target specimen container, indicated with a T, and its neighboring specimen containers 102 to the left and right along a line of action are shown. The line of action is shown horizontal, but vertical and diagonal lines of action may also use this rank order method. In rank ordering, some of these configurations may be given a relatively high numerical score (i.e., indicating a target specimen container T involved in this configuration should be picked first or given precedence), and some configurations are given a relatively lower numerical score (i.e., indicating a target specimen container T involved in this configuration should be picked later or last). For example, in FIG. 4A, a best possible configuration is shown wherein the receptacles 106R on either side of the target specimen container T are empty (indicated with an X). This configuration may be given a numerical score of 10, or another relatively high numerical score. This target specimen container T may be selected first for a pick operation.

[0062] However, the configuration shown in FIG. 4B may be given a relatively lower numerical score, such as of 9. The target specimen container T has only one neighboring specimen container, and the neighboring specimen container 102 is offset away (indicated by "OA"), so the clearance between the target specimen container T and its neighbor may still meet the minimum threshold clearance and the target specimen container T may still be quite accessible.

[0063] In FIG. 4C, a configuration is shown which includes the target specimen container T having one empty receptacle (X) to its left and one receptacle 106R to its right containing a specimen container 102 which is offset towards the target specimen container T (indicated with an "OT"). This may be given a relatively lower score such as 8.

[0064] In FIG. 4D, a configuration is shown which includes the target specimen container T having two full receptacles 106R on both its right and left, and both of the receptacles 106R contain centered specimen containers 102 of a relatively larger diameter (indicated with an "LD"). The configuration in FIG. 4D may be given a relatively lower score compared to the configuration in FIGs. 4A-4C, such as a score of 7 because of the lower clearance offered by the larger diameter specimen containers LD.

[0065] In cases like in FIGs. 4B and 4C, biasing the gripper fingers 212A, 212B in X and/or Y may create the minimum threshold clearance for the target specimen container T to be considered accessible. In the configuration in FIG. 4E, the gripper fingers 212A, 212B may not be biased because the target specimen container T is surrounded by two specimen containers LOT that are leaning and offset towards the target specimen container T. Thus, there may not be the minimum threshold clearance between the target specimen container T and its neighboring specimen containers LOT, and the target specimen container T may be considered "blocked." This configuration may be assigned a relatively lower score, such as of a 1, or any other relatively lower score, that may indicate a "blocked" condition. Accordingly, the target specimen container T may be picked after other specimen containers LOT have been picked, thus freeing up area surrounding it.

[0066] Using rank ordering, a dynamic order in which to pick specimen containers 102 may be determined based on the "most accessible" receptacles 106R i.e., receptacles 106R given a higher rank value being picked first. Likewise, a dynamic order in which to pick specimen containers 102 may be determined without rank ordering and simply by determining which of the receptacles 106R meet a minimum threshold clearance between the specimen container 102 contained in the receptacle 106R and neighboring specimen containers 102, i.e., which of the receptacles 106R are accessible, and which receptacles 106R are blocked. The dynamic order may be determined by surveying all of the available receptacles, those in a region, or by surveying each one individually and determining if they meet the minimum clearance criteria set for the gripper fingers 212A, 212B and sample rack 106 used. In some embodiments, the minimum clearance threshold may be set based upon experimental runs to ensure lack of contact on a high percentage of pick and place operations.

[0067] Dynamic selections of accessible target receptacles for sequential place operations may be made using the system and method described above. To determine if the receptacle 106R is accessible, population data, configuration data, or a combination of the two may be used, in a similar manner as with place operations. Population data refers to data on which of the receptacles 106R are empty, and may be used to determine a target receptacle 106R into which a specimen container 102 is desired to be placed. Configuration data refers to information on a specific neighboring specimen container 102, including maximum specimen container diameter, specimen container offset distance, or tube type (e.g., capped tube, uncapped tube, tube-top sample cup, and the like). Configuration information from a previous pick operation may also be stored in the image capture controller 224 and may be able to be accessed by the robot controller 216 during a subsequent place operation. This allows the place strategy to be configured in a way that allows for maximum clearance between neighboring specimen containers 102. For example, the place strategy can be configured to avoid placing two specimen containers 102 of a relatively larger diameter in receptacles 106R next to each other. Likewise, specimen containers 102 including tube-top specimen containers may be placed away from large specimen containers 102L. Similarly, dynamic placement may be made in every other row or column to initially increase placement clearance.

[0068] Consider the sample rack 106 in FIG. 3B, having multiple rows of receptacles 106R (rows 6 through 9 shown), some of which contain specimen containers 102, 102L. For example, a pre-determined order may comprise starting at the first receptacle 106R (A6) in row 6. Population data indicates that receptacles 106R labeled A6 and E6 are empty, and that the receptacles 106R labeled B6, C6, D6 and E6 contain specimen containers 102, 102L. Thus, from the population and configuration data, it can be determined that receptacles 106R labeled A6 and E6 are both accessible. Accessibility can be determined by ensuring that both sides along a particular line of action practicable by the gripper 212 meet the minimum clearance. Therefore, a place order can be determined based on whether a receptacle 106R is accessible. In some embodiments, if a receptacle 106R is not accessible, the place operation may skip over that receptacle 106R and be placed in the next accessible receptacle 106R based on imaging data. The next pick move may attempt to unblock the receptacle 106R found not to be accessible.

[0069] FIG. 5 illustrates a specimen container transport system 500 in which the dynamic selection method may be practiced. The specimen container transport system 500 includes a sample rack 106 provided within the access of a gripper 212 (shown dotted). The gripper 212 may be mounted to a cross slide 510C of a gantry robot 510, which can be moved back and forth on a cross beam 510B to access any column of the sample rack 106. Likewise, the cross beam 510B may move forward and backward along the left and right slide rails 510L, 510R to allow access to any row of the sample rack 106. The gripper may be moved vertically (into and out of the paper) to raise and lower the specimen containers 102. Thus, the gripper 212 may be moveable in an X, Y, Z coordinate system. A dynamic pick operation may be made according to the method described above to pick specimen containers 102 from the sample rack 106 and transport them to specimen container carriers 532 (e.g., pucks) that reside on, and move around, track 540 based on imaging data obtained from the rack image capture apparatus 222 and image capture controller 224. Likewise, the specimen containers 102 may be placed, using a dynamic place operation, back into the sample rack 106 upon returning from testing and/or processing. The selection of pick and place sequences may be as described above and may be based on population data, configuration data, or both. Track 540 may transport the specimen containers 102 to various pieces of equipment or instrument(s) to preform testing or otherwise process specimens contained in the specimen containers 102. Track 540 may include one or more offshoots 540A from a main channel 540B to all loading and unloading. In some embodiments, dynamic placement may include a strategy that returns certain specimen container carriers 532 in a specified order so that a placement strategy that increases placement clearance in the sample rack is provided.

[0070] In accordance with another embodiment of the disclosure, a method 600 of operating a gripper (e.g., gripper 212) is provided. The method 600 includes, in 602, providing a robot (e.g., robot 210, 510) including the gripper (e.g., gripper 212), the gripper moveable in a coordinate system (e.g., in X, Y and Z) by the robot and including gripper fingers (e.g., gripper fingers 212A, 212B), and in 604, providing a sample rack (e.g., sample rack 106) including receptacles (e.g., 106R, 106T) accessible by the gripper, at least some of the receptacles adapted to contain specimen containers (e.g., 102, 102L, 102T).

[0071] Further, in 606, the method 600 includes providing data, obtained by imaging, regarding the sample rack (e.g., sample rack 106) and the specimen containers (e.g., specimen containers 102, 102L), and lastly, in 608, determining, based on the data, an accessible target receptacle (e.g., 106T) for one of a pick operation or a place operation. The data, obtained by imaging, may be population data and/or configuration data. Determining an accessible target receptacle (e.g., 106T) may include testing a clearance between the target specimen container 102T and a surrounding specimen container 102, 102L in the case of a pick operation to make sure the minimum threshold clearance is provided. In the case of a place operation, accessibility involves determining a clearance around the target receptacle (e.g., 106T) and comparing that clearance to a target threshold value based on the type of specimen container 102 being placed and possibly the type of specimen containers surrounding the target receptacle 106T.

[0072] While specific apparatus, system, and methods have been shown by way of example embodiments herein, it should be understood that other and different embodiments are possible. It is intended that the disclosure is to cover all modifications, equivalents, and alternatives falling within the scope of the appended claims.

CLAIMS

WHAT IS CLAIMED IS:

1. A method of operating a gripper, comprising:

providing a robot including the gripper, the gripper moveable in a coordinate system by the robot and including gripper fingers;

providing a sample rack including receptacles accessible by the gripper, at least some of the receptacles adapted to contain specimen containers;

providing data, obtained by imaging, regarding the sample rack and the specimen containers; and

determining, based on the data, an accessible target receptacle for one of a pick operation or a place operation.

2. The method of claim 1, wherein for the place operation the accessible target receptacle is empty.

3. The method of claim 2, comprising placing a target specimen container in the accessible target receptacle.

4. The method of claim 1, wherein for the pick operation the accessible target receptacle contains a target specimen container.

5. The method of claim 4, wherein the accessible target receptacle is a receptacle which meets a threshold minimum clearance along a line of action relative to the target specimen container.

6. The method of claim 5, comprising the gripper having rotational capability and more than one line of action.

7. The method of claim 6, including determining whether one or more line of action meets the threshold minimum clearance.

8. The method of claim 1, further comprising:

determining if one or more of the receptacles is blocked.

9. The method of claim 1, wherein the data comprises population data, which is data on which of the receptacles include specimen containers.

10. The method of claim 9, wherein the accessible target receptacle is at least partially determined based on population data.

11. The method of claim 1, wherein the data comprises configuration data.

12. The method of claim 11, wherein the configuration data comprises one or more from a group of: maximum specimen container diameter, specimen container offset distance, or tube type.

13. The method of claim 12, wherein the accessible target receptacle is at least partially determined based on configuration data.

14. The method of claim 1, wherein the accessible target receptacle is determined based on population data and configuration data.

15. The method of claim 1, comprising making further dynamic selections of additional accessible target receptacles for subsequent pick or place operations based on the data.

16. The method of claim 1, wherein the accessible target receptacle is determined by rank ordering at least some of the receptacles, based on both configuration data and population data.

17. The method of claim 1, wherein the accessible target receptacle is selected to include a first empty receptacle and a second empty receptacle on opposite sides of the accessible target receptacle.

18. The method of claim 1, further comprising blocked receptacles, wherein surrounding specimen containers are removed to unblock the blocked receptacles.

19. A gripper positioning system, comprising:

a robot including the gripper, the gripper moveable in a coordinate system by the robot and including gripper fingers;

a sample rack including receptacles accessible by the gripper fingers, at least some of the receptacles containing specimen containers; and

a controller coupled to the robot and operatively configured to:

access data obtained from one or more images regarding the sample rack and the specimen containers, the data including population data and configuration data, and

determine, based on the population data and configuration data, an accessible target receptacle for one of a pick operation or a place operation.

20. A gripper positioning apparatus, comprising:

a robot including the gripper, the gripper moveable in a coordinate system by the robot and including gripper fingers; and

a controller coupled to the robot and operatively configured to:

access data obtained from one or more images, regarding a sample rack and specimen containers contained therein, and

determine, based on the data, an accessible target receptacle for one of a pick operation and a place operation.

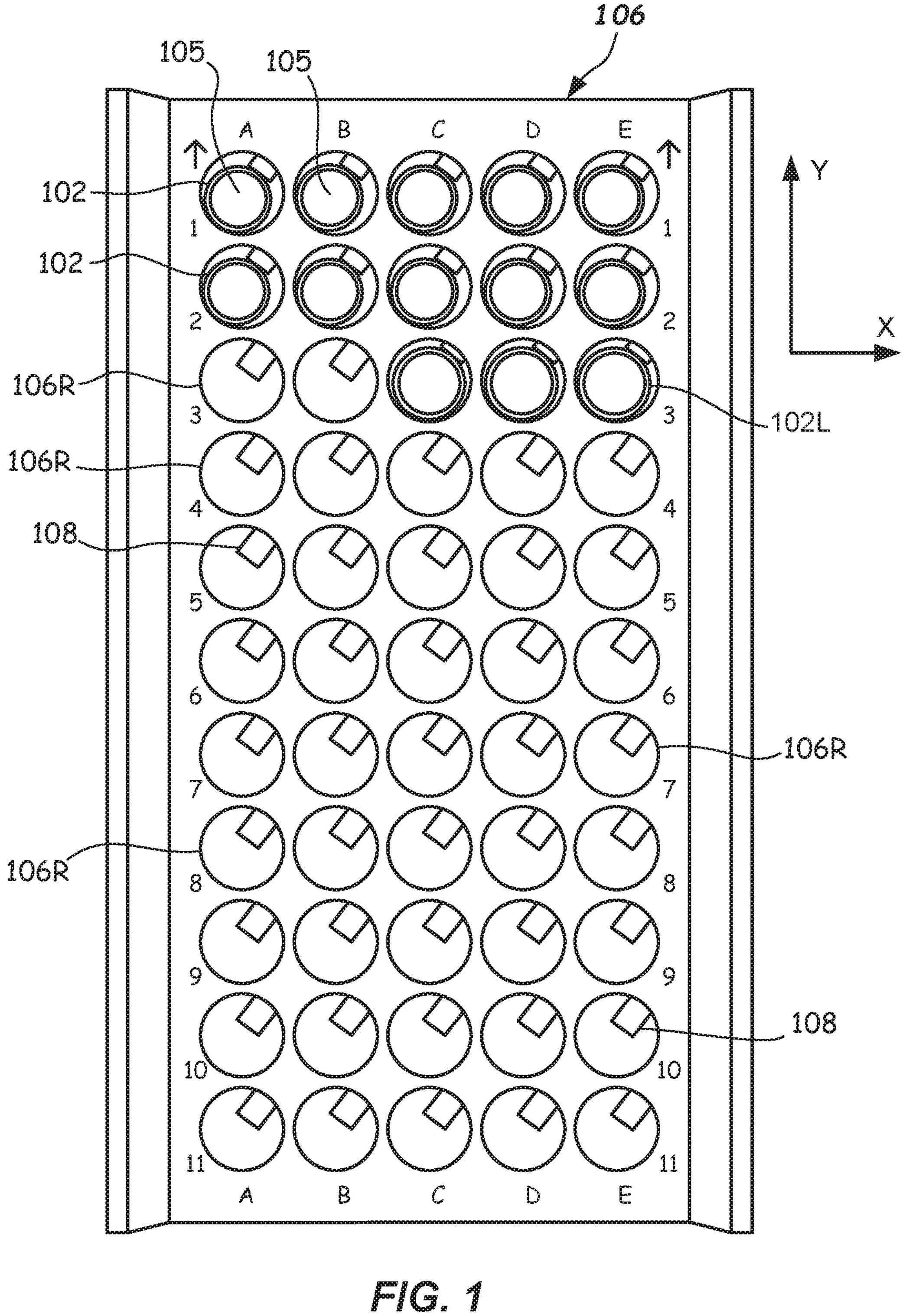

FIG. 1
Prior Art

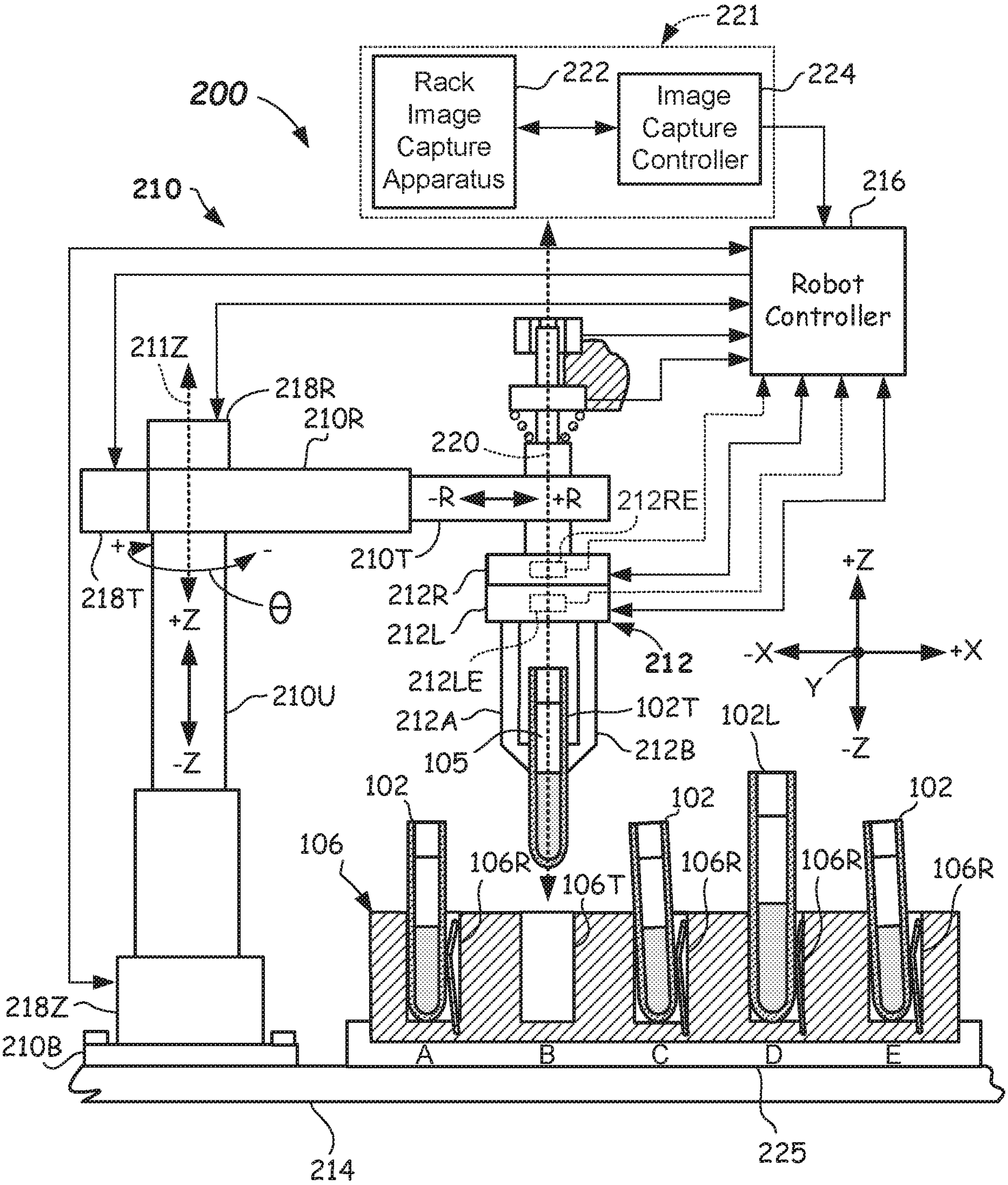
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Image Capture Controller
224
210
216
Robot Controller
211Z
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210R
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+R
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210T
218T
θ
212R
212L
212
+Z
-X
+X
Y
-Z
212LE
210U
212A
102T
102L
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212B
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106T
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214
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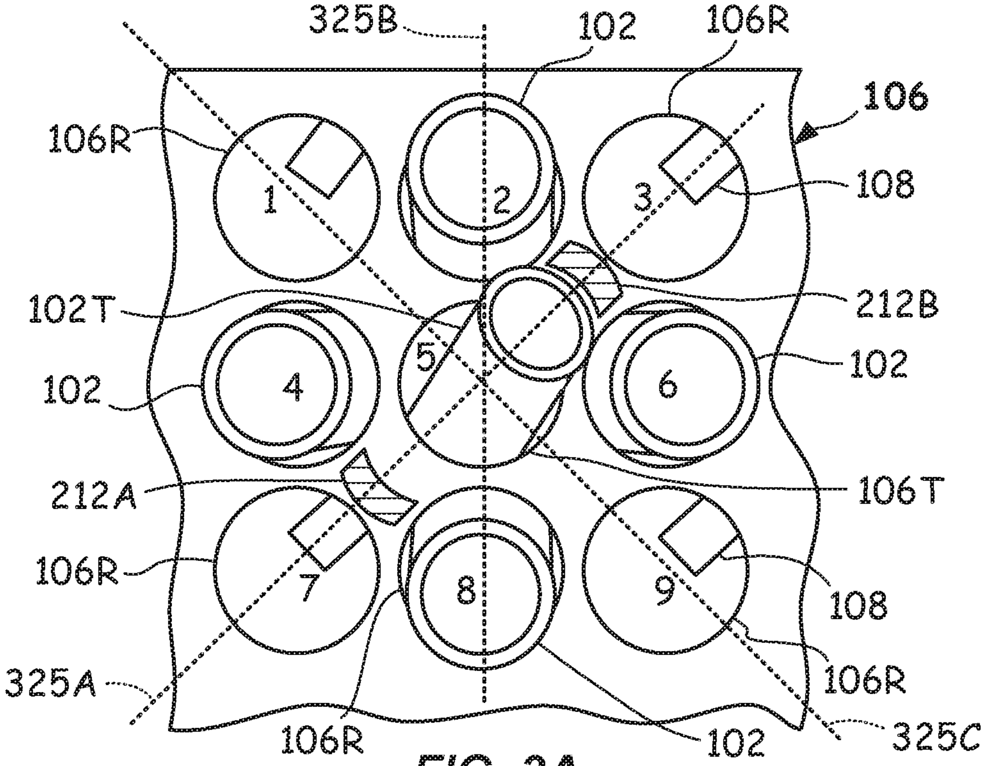
FIG. 2


325B
102
106R
106
106R
1
2
3
108
212B
102T
5
4
6
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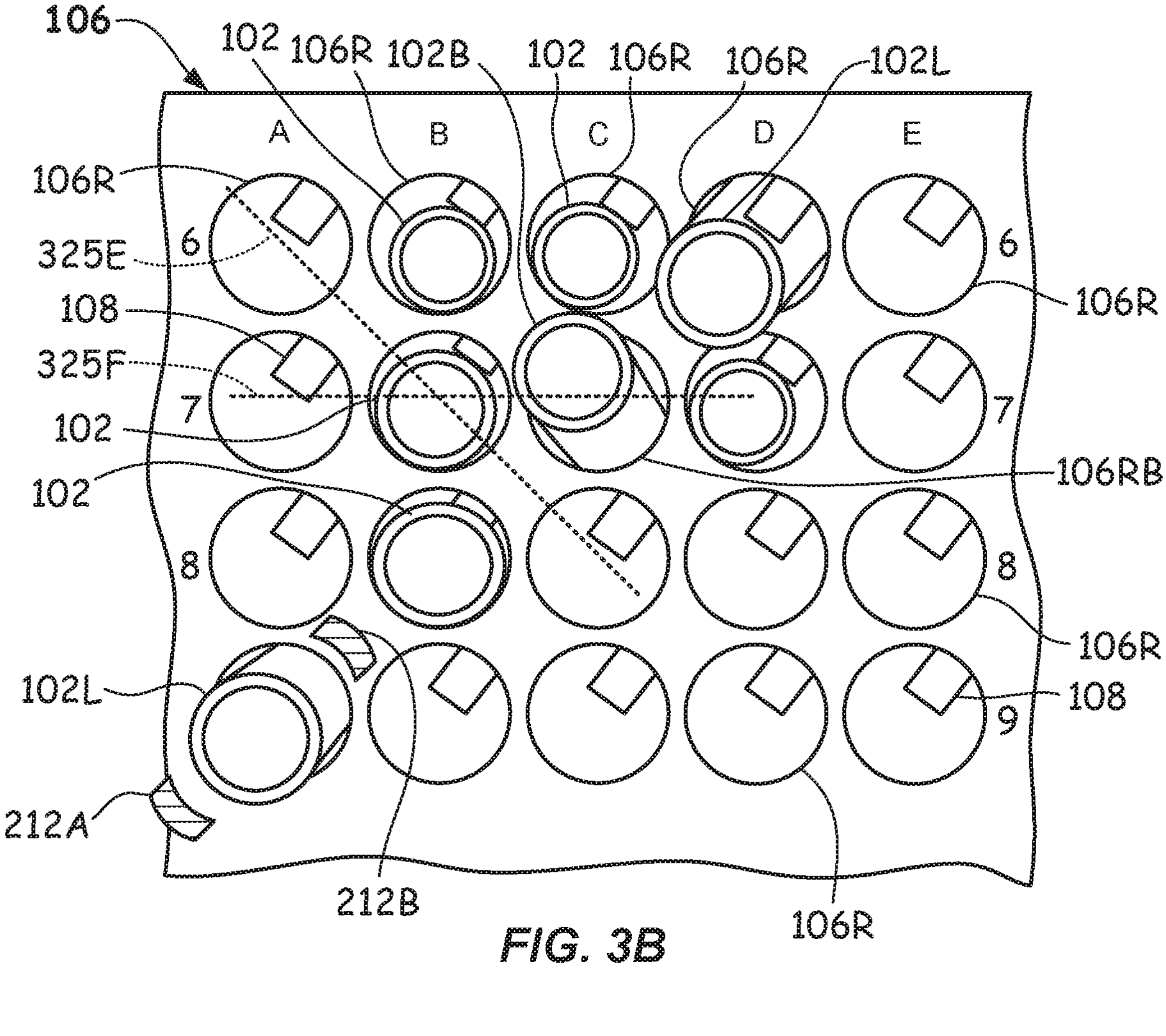
212A
106T
106R
7
8
9
108
106R
325A
106R
102
325C

FIG. 3A


106
102
106R
102B
102
106R
106R
102L
A
B
C
D
E
106R
6
6
325E
106R
108
325F
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106RB
102
8
8
106R
102L
9
108
212A
212B
106R

FIG. 3B

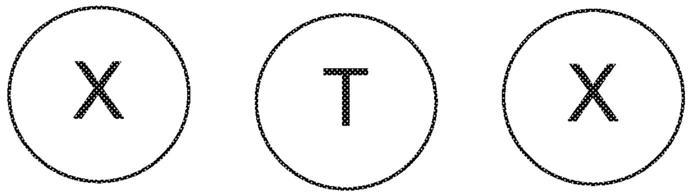


FIG. 4A

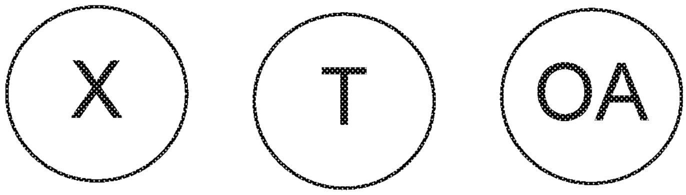


FIG. 4B

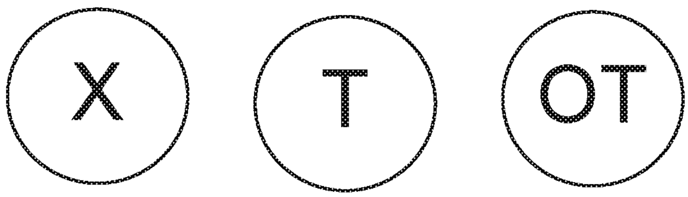


FIG. 4C

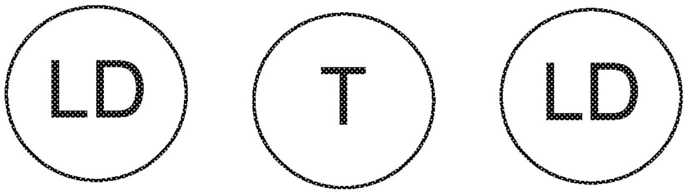


FIG. 4D

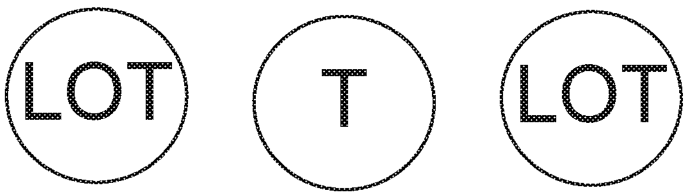
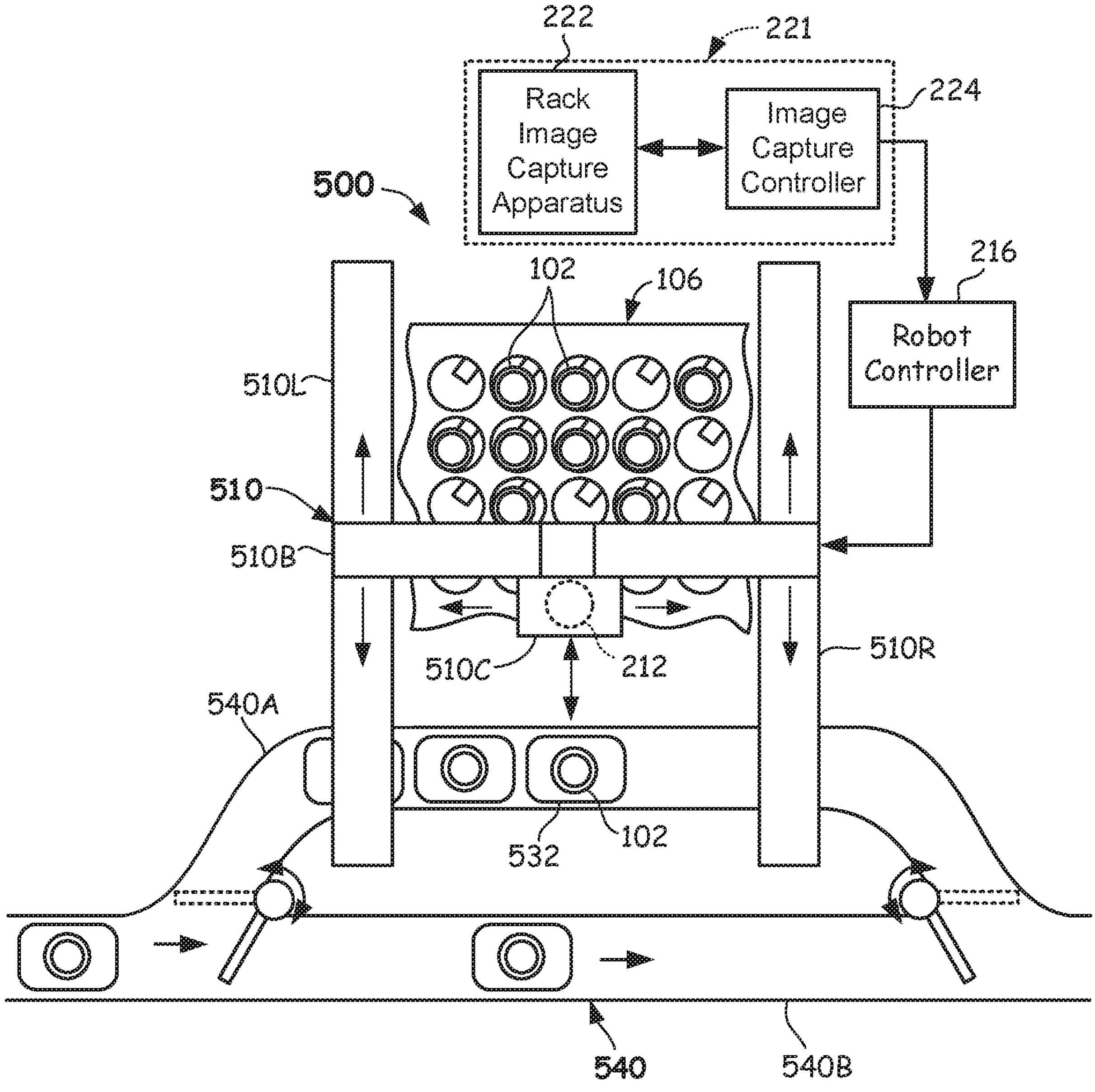


FIG. 4E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Rack Image Capture Apparatus
Image Capture Controller
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216
Robot Controller
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106
510L
510
510B
510C
212
510R
540A
532
102
540
540B

FIG. 5

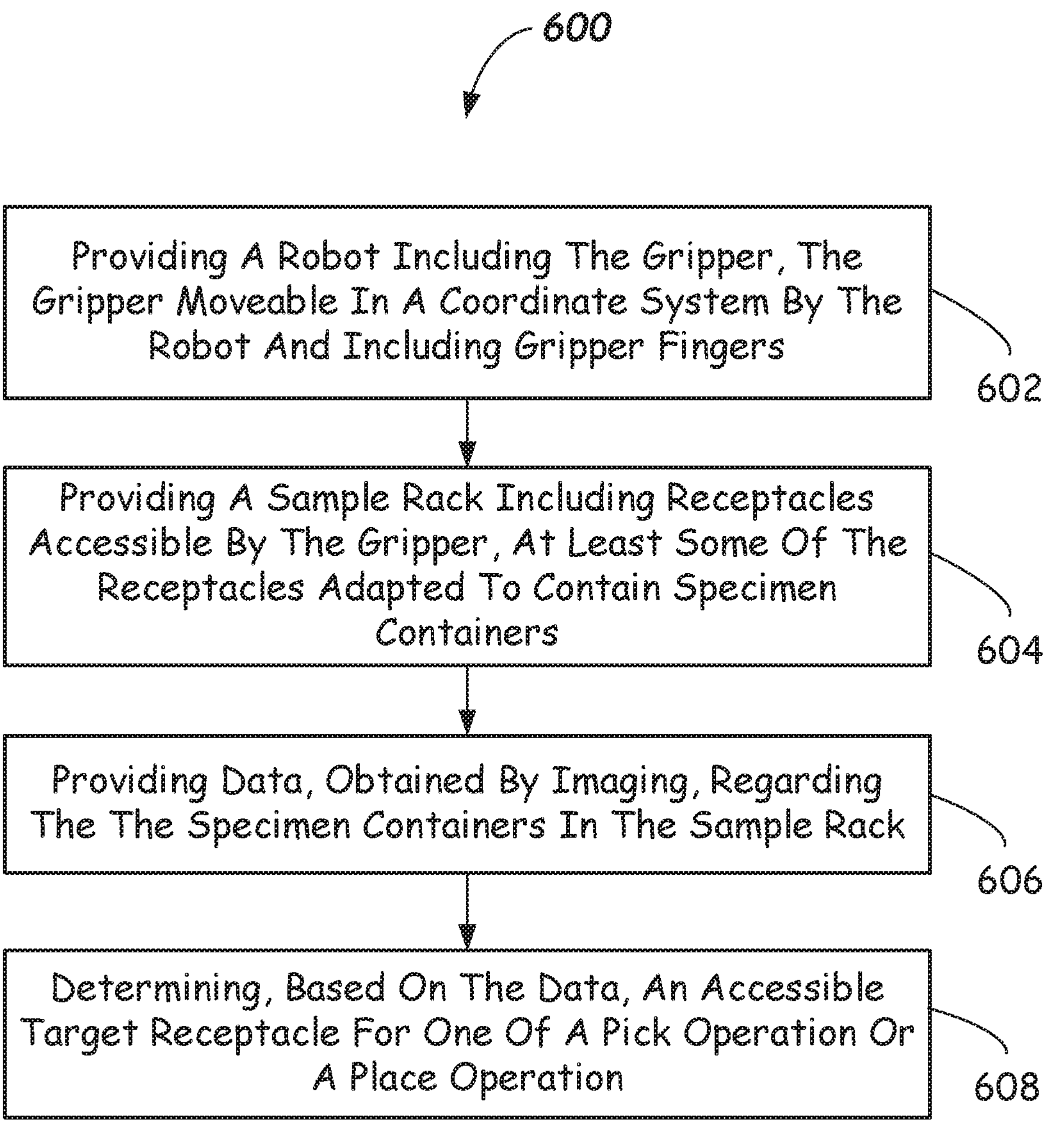
600
Providing A Robot Including The Gripper, The Gripper Moveable In A Coordinate System By The Robot And Including Gripper Fingers
602
Providing A Sample Rack Including Receptacles Accessible By The Gripper, At Least Some Of The Receptacles Adapted To Contain Specimen Containers
604
Providing Data, Obtained By Imaging, Regarding The The Specimen Containers In The Sample Rack
606
Determining, Based On The Data, An Accessible Target Receptacle For One Of A Pick Operation Or A Place Operation
608

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/039588

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B25J 19/04; B25J 9/16; B25J 15/00; B25J 15/08; G01N 35/10; G05B 19/401 (2017.01)
CPC - B25J 19/04; B25J 9/16; B25J 15/00; B25J 15/08; G01N 35/10; G05B 19/401; G05B 2219/36412; G05B 2219/45063 (2017.08)

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)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 436/180; 700/245; 700/251; 901/31; 901/47 (keyword delimited)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/0305227 A1 (BECKMAN COULTER, INC) 16 October 2014 (16.10.2014) entire document	1-4, 8-20
A	US 2015/0142171 A1 (LI et al) 21 May 2015 (21.05.2015) entire document	1-20
A	US 2006/0047363 A1 (FARRELLY et al) 02 March 2006 (02.03.2006) entire document	1-20
A	US 2015/0290795 A1 (OLEYNIK) 15 October 2015 (15.10.2015) entire document	1-20

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 August 2017	08 SEP 2017

Name and mailing address of the ISA/US	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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B25J 9/16(2006.01)
B25J 15/00(2006.01)
B25J 15/08(2006.01)
G01N 35/10(2006.01)
G05B 19/401(2006.01)

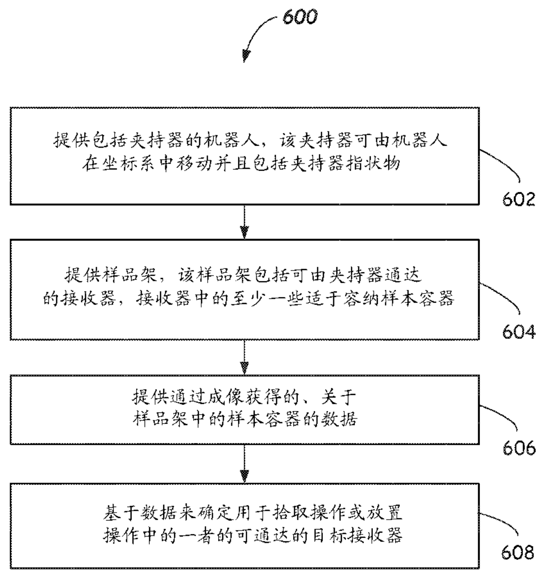
权利要求书2页 说明书11页 附图7页

(54)发明名称

用于基于样品架成像数据的动态拾取和放置选择顺序的方法、系统和装置

(57)摘要

提供了操作夹持器的方法。该方法包括:提供包括夹持器的机器人,该夹持器可由机器人移动并且包括夹持器指状物;提供样品架,该样品架包括可由夹持器通达的接收器,接收器中的至少一些适于容纳样本容器;提供通过成像获得的、关于样品架和样品架中的样本容器的数据;以及基于该数据来确定用于拾取操作或放置操作中的一者的可通达的目标接收器。提供了被构造为执行该方法的装置和系统以及其他方面。



CN 109414826 A

1.一种操作夹持器的方法,所述方法包括:

提供包括所述夹持器的机器人,所述夹持器能够由所述机器人在坐标系中移动并且包括夹持器指状物;

提供样品架,所述样品架包括能够由所述夹持器通达的接收器,所述接收器中的至少一些适于容纳样本容器;

提供通过成像获得的、关于所述样品架和所述样本容器的数据;以及

基于所述数据来确定用于拾取操作或放置操作中的一者的可通达的目标接收器。

2.根据权利要求1所述的方法,其中,对于所述放置操作,所述可通达的目标接收器是空的。

3.根据权利要求2所述的方法,所述方法包括:将目标样本容器放置在所述可通达的目标接收器中。

4.根据权利要求1所述的方法,其中,对于所述拾取操作,所述可通达的目标接收器容纳有目标样本容器。

5.根据权利要求4所述的方法,其中,所述可通达的目标接收器是沿着相对于所述目标样本容器的作用线满足阈值最小间隙的接收器。

6.根据权利要求5所述的方法,所述方法包括具有旋转能力和多于一个作用线的夹持器。

7.根据权利要求6所述的方法,所述方法包括确定一个或多个作用线是否满足所述阈值最小间隙。

8.根据权利要求1所述的方法,所述方法还包括:

确定所述接收器中的一个或多个是否被阻挡。

9.根据权利要求1所述的方法,其中,所述数据包括群体数据,所述群体数据是关于所述接收器中的哪些包括样本容器的数据。

10.根据权利要求9所述的方法,其中,至少部分地基于群体数据来确定可通达的目标接收器。

11.根据权利要求1所述的方法,其中,所述数据包括构造数据。

12.根据权利要求11所述的方法,其中,所述构造数据包括如下的组中的一者或多者:最大样本容器直径、样本容器偏移距离或管类型。

13.根据权利要求12所述的方法,其中,至少部分地基于构造数据来确定所述可通达的目标接收器。

14.根据权利要求1所述的方法,其中,基于群体数据和构造数据来确定所述可通达的目标接收器。

15.根据权利要求1所述的方法,所述方法包括:基于所述数据进行进一步动态选择附加的可通达的目标接收器以用于随后的拾取或放置操作。

16.根据权利要求1所述的方法,其中,基于构造数据和群体数据两者,通过对所述接收器中的至少一些进行排序来确定所述可通达的目标接收器。

17.根据权利要求1所述的方法,其中,所述可通达的目标接收器被选择成包括在所述可通达的目标接收器的相对侧上的第一空接收器和第二空接收器。

18.根据权利要求1所述的方法,所述方法还包括被阻挡的接收器,其中,移除周围的样

本容器以将所述被阻挡的接收器解除阻挡。

19.一种夹持器定位系统，所述夹持器定位系统包括：

包括所述夹持器的机器人，所述夹持器能够由所述机器人在坐标系中移动并且包括夹持器指状物；

样品架，所述样品架包括能够由所述夹持器指状物通达的接收器，所述接收器中的至少一些容纳有样本容器；以及

控制器，所述控制器联接到所述机器人并且被可操作地构造为：

访问从一个或多个图像获得的、关于所述样品架和所述样本容器的数据，所述数据包括群体数据和构造数据，并且

基于所述群体数据和构造数据，来确定用于拾取操作或放置操作中的一者的可通达的目标接收器。

20.一种夹持器定位装置，所述夹持器定位装置包括：

包括所述夹持器的机器人，所述夹持器能够由所述机器人在坐标系中移动并且包括夹持器指状物；以及

控制器，所述控制器联接到所述机器人并且被可操作地构造为：

访问从一个或多个图像获得的、关于样品架和被容纳在样品架中的样本容器的数据，并且

基于所述数据来确定用于拾取操作和放置操作中的一者的可通达的目标接收器。

用于基于样品架成像数据的动态拾取和放置选择顺序的方法、系统和装置

[0001] 相关申请的交叉引用

本申请要求于2016年7月14日提交的美国临时申请序列号62/362,535的优先权,所述文献的内容通过引用以其整体并入本文。

技术领域

[0002] 本公开总体上涉及适于在用于处理生物液体的系统中从样品(sample)架拾取样本(specimen)容器和将样本容器放置到样品架的方法和装置。

背景技术

[0003] 在医学测试和处理中,机器人技术的使用可以最小化暴露于生物液体样品(在本文中另外称为“样本”)或与生物液体样品接触和/或可以显著提高生产率。例如,在一些自动化测试和处理系统(例如,临床分析仪)中,样本容器(诸如,试管)可以从样品架被运输和被运输到样品架(有时称为“盒”),以及从测试或处理装置的测试或处理位置被运输和被运输到测试或处理装置的测试或处理位置。

[0004] 这种运输可以通过使用自动化机构(诸如,具有联接的夹持器的机器人)来实现。夹持器可以具有相对的夹持器指状物,其被构造为在运输期间抓取相应的样本容器。样本可以具有不同的尺寸(例如,高度和/或直径)或类型。夹持器可以由机器人在两个或更多个坐标方向上移动。以这种方式,可以通过夹持器来夹持样本容器(容纳有待测试或待处理的样本),然后将样本容器从一个位置移动到另一位置。

[0005] 例如,在拾取操作中,机器人夹持器可以被移动到样品架的接收器的理论中心位置上方,并且在夹持器完全打开的状态下降低到指定高度,并且然后闭合以夹持样本容器。在此之后升高夹持器以将样本容器从接收器中拉出。在放置操作中,夹持器与其所抓取的样本容器可以一起在样品架接收器的中心上方移动,并且朝向接收器降低以将样本容器放置到期望的深度,并且然后夹持器指状物完全打开以释放样本容器。在此之后升高夹持器。因此,使用这些拾取和放置操作,样本容器可以移动到样品架的多个接收器中和从样品架的多个接收器移动。然而,为了最大化机器占用面积使用,这种样品架中的接收器间隔非常紧密。

[0006] 因此,寻求可以改进测试和处理系统中的拾取和放置操作的效率的方法和装置。

发明内容

[0007] 在一个方法实施例中,提供了操作夹持器的改进方法。该方法包括:提供包括夹持器的机器人,该夹持器可由机器人在坐标系中移动并且包括夹持器指状物;提供样品架,该样品架包括可由夹持器通达的接收器,接收器中的至少一些适于容纳样本容器;提供通过成像获得的、关于样品架和样本容器的数据;以及基于该数据来确定用于拾取操作或放置操作中的一者的可通达的目标接收器。

[0008] 在系统实施例中，提供了夹持器定位系统。该夹持器定位系统包括：机器人，该机器人包括夹持器，该夹持器可由机器人在坐标系中移动并且包括夹持器指状物；样品架，该样品架包括可由夹持器指状物通达的接收器，接收器中的至少一些容纳有样本容器；以及控制器，该控制器联接到机器人并且可操作地构造为：访问从一个或多个图像获得的、关于样品架和样本容器的数据，该数据包括群体(population)数据和构造数据，并且基于群体数据和构造数据来确定用于拾取操作或放置操作中的一者的可通达的目标接收器。

[0009] 在装置实施例中，提供了夹持器定位装置。该夹持器定位装置包括：机器人，该机器人包括夹持器，夹持器可由机器人在坐标系中移动并包括夹持器指状物；控制器，其联接到机器人并且可操作地构造为：访问从一个或多个图像获得的、关于样品架和样本容器的数据，并且基于该数据来确定用于拾取操作或放置操作中的一者的可通达的目标接收器。

[0010] 从示出包括所想到的用于实施本公开的最佳模式的多个示例实施例的以下详细描述，本公开的又其他方面、特征和优点可以容易地显而易见。本公开还能够具有不同的实施例，并且可以在各个方面修改其多种细节，所有这些都不脱离本公开的范围。因此，本公开将覆盖落入如所附权利要求中所限定的本公开的范围内的所有修改、等同物和替代物。

附图说明

[0011] 图1示出了根据现有技术的包括样本容器的样品架的示意性顶视图。

[0012] 图2示出了根据一个或多个实施例的夹持器定位系统的示意性侧视图，该夹持器定位系统被构造为执行动态夹持器指状物定位方法。

[0013] 图3A示出了根据一个或多个实施例的样品架的局部俯视平面图，该样品架包括被一些空的接收器和一些满的接收器包围的目标样本容器，以其中夹持器指状物被打开(分离)达中间距离的构造示出。

[0014] 图3B示出了根据一个或多个实施例的样品架的局部俯视平面图，该样品架包括接收器中的样本容器，以其中夹持器指状物被打开(分离)达中间距离的构造示出。

[0015] 图4A-图4E示出了示出根据一个或多个实施例的各种样本容器群体场景的示意图。

[0016] 图5示出了根据一个或多个实施例的被构造为执行动态夹持器指状物定位方法的样本容器运输系统的示意性顶视图。

[0017] 图6示出了根据实施例的操作夹持器的方法的流程图。

具体实施方式

[0018] 在机器人中可能会不时地发生样本容器的堵塞、碰撞和/或震动，所述机器人诸如是用于在临床分析仪或其他测试或处理系统(例如，离心机，冷藏区域)中实现机器人拾取和放置操作的机器人。

[0019] 特别地，如图1中所示出，在自动化体外诊断(IVD)设备中使用的样本容器102、102L(例如，血液收集管)通常以敞顶(去盖)状态被提供并且被填充有生物流体样本105(一些被标记)，即，生物有害(bio-hazardous)液体(例如，血液、血清或血浆、尿液、间质流体、脑流体、脊髓流体或其他身体流体)。样本容器102、102L以大致竖直取向被存储在样品架106内的接收器106R(一些被标记)内(样本容器102、102L填充前两行半)。

[0020] 为了最大化设备占用面积的使用，样品架106的接收器106R间隔非常紧密。为了容纳各种直径的样本容器102，有时可以在每个接收器106R中放置弹簧108（一些被标记），诸如一个或多个叶片型(leaf-type)弹簧，以试图要么使样本容器102居中，要么迫使样本容器102抵靠接收器106R的限定的壁（如所示出的），所有这些同时大致维持样本容器102的竖直取向。

[0021] 然而，由于机械公差和样本容器102的放置，每个样本容器102可能会在一个或多个方向（例如，如所示出的X和/或Y）上在一定程度上远离真正的竖直取向倾斜，从而导致预期的管到管间隙减小。此外，因为不同直径的样本容器102通常同时在给定的设备上进行处理（例如，所示出的行3容纳有与行1和行2中所容纳的样本容器102相比具有相对较大直径的一些样本容器102L），所以样品架106中的相邻样本容器102、102L之间的间隙可能会基于管尺寸和倾斜方向而从接收器106R到接收器106R不同。此外，由于弹簧108的存在而引起的偏移可能会将样本容器102、102L的中心放置于除接收器106R的中心之外的位置处。类似地，一些接收器106R可能是空的。

[0022] 接收器106R的紧密间隔与对IVD设备的高吞吐量的期望相组合，可能会导致在处理期间样本容器102、102L与机器人夹持器和/或夹持器指状物之间偶尔的不期望的接触（例如，堵塞，碰撞和/或震动）。这种接触可能会减慢自动化处理，因为由接触导致的损坏可能必须通过操作者手动干预来校正。例如，在一些极端情况下，这种接触可能会导致管破裂、溢出和/或样本损失，所有这些都可能会导致用于修复/清理的停机时间。

[0023] 在现有技术中，使用基于简单拾取算法的简单逐行顺序拾取和/或放置来预先确定样本容器102被拾取和/或被放置在样品架106中的次序。该预先确定的选择次序没有考虑放置（例如，偏移）、尺寸（例如，直径或高度）或者甚至驻留于样品架106的接收器106R内的样本容器102、102L的类型的可能差异。如果不加以考虑，这些差异可能会导致接触或者可能会导致夹持器指状物的阻碍，并且可能会使得夹持器指状物更难以在不导致对样本的可能的损坏（例如，溢出）或不需要操作者干预的情况下以预先确定的次序通达样本容器102、102L。

[0024] 鉴于前述内容，本公开的一个或多个实施例提供了基于通过对样品架成像获得的数据，来动态地（实时地）确定拾取可通达的样本容器或将样本容器放置在目标可通达的接收器中的顺序（即，拾取和/或放置次序的动态选择）的方法、系统和装置。通过成像获得的数据可以包括样品架群体数据和/或样本容器构造数据。群体数据是关于样品架的接收器中的相邻样本容器（并且更特别地，围绕特定目标接收器的相邻样本容器）的存在或不存在的数据。构造数据是关于目标接收器周围的样本容器的取向和/或尺寸以及目标样本容器本身的取向和/或尺寸的数据。在已经经由样品架成像系统对样品架106成像之后，群体数据和/或构造数据被使得对于样品架106中的每个接收器106R可获得，其中，这种样品架成像系统在现有技术中是已知的。

[0025] 根据一个或多个实施例，视觉数据（例如，构造数据和/或群体数据）可用于动态地调整拾取和/或放置次序或顺序。在一个实施例中，可以基于通过成像获得的构造和/或群体数据来调整由夹持器指状物拾取样本容器102、102L的次序。在另一实施例中，可以基于通过成像获得的构造和/或群体数据来调整由夹持器指状物放置样本容器102、102L的次序。

[0026] 根据一个或多个实施例的方法、装置和系统可以考虑样品架106中的样本容器102的群体数据和/或样品架106中的样本容器102的构造数据，以动态地确定期望的拾取和/或放置次序。

[0027] 例如，方法、装置和系统可以考虑群体数据，诸如，周围的接收器106R是否容纳有样本容器102或者是否是空的。类似地，一个或多个实施例可以考虑关于周围的样本容器中的一个或多个的尺寸(例如，直径和/或高度)、相邻样本容器朝向或远离特定目标样本容器的偏移、目标样本容器的管类型(例如，加盖的管、未加盖的管、管顶样品杯(tube top sample cup)等)、以及目标样本容器的任何偏移(在拾取操作的情况下)的构造数据。

[0028] 动态地选择由夹持器拾取和/或放置样本容器102的次序的这种能力可以显著降低接触(例如，堵塞、碰撞和/或震动)的倾向，并且因此减少对样本容器102、102L的损坏和/或减少生物流体样本105的溢出和损失。这可以减少IVD仪器的停机时间以及对于操作者干预的需要。

[0029] 本文将参考图2-图6来描述本公开这些方面和其他方面以及实施例的特征。

[0030] 根据一个或多个系统实施例，参考图2，示出并描述了夹持器定位系统200。夹持器定位系统200包括机器人210，该机器人用于将目标样本容器102T(诸如，血液收集容器、瓶等)从第一位置抓取并传送到第二位置。夹持器定位系统200可以用于任何测试仪器或设备，诸如，自动化临床分析仪、测定仪器或诸如离心机的其他处理设备，其中含有生物流体样本105的样本容器102、102L被移动到样品架106或从样品架106移动。

[0031] 例如，机器人210可以将目标样本容器102T从样品架106移动到可在轨道540上移动的样本容器载体532(例如，定位盘(puck)-图5)，轨道540将样本容器102移动到用于测试或处理的仪器或设备。在一个或多个实施例中，测试仪器或设备可以用于确定被容纳在样本容器102中的生物流体样本105中的组成成分(例如，分析物浓度)或以其他方式在其上执行处理。轨道540可以包括一个或多个分支540A，从而为样本容器载体532提供从主要通道540B分出来的机会。

[0032] 再次参考图2，机器人210包括联接到机器人210的可移动部分的夹持器212，所述可移动部分诸如可移动臂或机架(gantry)的部分。例如，机器人210可以是如图2中所示出的R，θ，Z机器人。替代性地，机器人可以是如本文中关于图5所示出并描述的机架(gantry)机器人510。在每种情况下，机器人210、510在坐标系中(例如，在X，Y和Z中)移动夹持器212。图2中所示出的机器人210可以包括：基座210B，其可以联接到测试仪器或设备的框架214；直立部分210U，其被构造为沿竖直轴线211Z竖直地(沿+Z和-Z方向)移动；伸缩部分210T，其被构造为径向地(沿+R和-R方向)移动；以及旋转部分210R，其被构造为围绕竖直轴线211Z旋转地(沿+θ和-θ方向)移动。如本文所使用的“夹持器”意味着联接到机器人部件(例如，联接到机器人臂或机架构件)的这样的任何构件：其用于机器人操作中以将物品(例如，样本容器102)从一个位置抓取和移动到另一位置，以便执行拾取和/或放置操作。例如，机器人210、510可以用于将目标样本容器102T放置到在样品架106中的目标接收器106T中，或者从样品架106中的目标接收器106R中拾取目标样本容器102T。

[0033] 夹持器212可以包括两个夹持器指状物212A、212B，它们可相对于彼此移动、可大致彼此相对、并适于抓取物品，诸如，抓取样本容器102(例如，血液收集管或瓶)。夹持器指状物212A、212B可以由联接到夹持器指状物212A、212B中的每者的致动机构212L驱动以打

开和闭合。致动机构212L可以是使夹持器指状物212A、212B沿相反方向移动的任何合适机构。致动机构212L可以线性地作用以使每个夹持器指状物212A，212B以线性平移的方式移动，或以其他方式使夹持器指状物212A、212B枢转。夹持器指状物212A、212B的相对移动量可以是相同的(但是沿相反的方向)或是不同的量。夹持器指状物212A、212B可沿X-Y平面中的任何合适方向(例如，沿X方向或Y方向或其组合)打开和闭合。

[0034] 在一些实施例中，可以提供旋转致动器212R，其被构造为并可操作以将夹持器指状物212A、212B旋转到任何规定的旋转位置/取向。因此，夹持器指状物212A、212B的打开和闭合作用线可以被旋转以与样品架106上的满足阈值最小间隙的区域重合。可以通过成像来确定样品架106中被确定为满足阈值最小间隙的区域。特别地，可以选择满足阈值最小间隙的接收器106R作为目标接收器106T，以用于在那里进行拾取和/或放置操作。选择可以基于通过成像获得的群体数据和/或构造数据。如本文所提到的+ X、-X、+ Y和-Y方向可以是如所示出的。如所示出的，Y方向进出纸张。

[0035] 更详细地，致动机构212L可以由联接到夹持器指状物212A、212B的电动、气动或液压伺服马达等驱动。夹持器指状物212A、212B可以沿着任何滑动机构移动，以使得它们可以被约束为线性运动。可以使用用于引起夹持器指状物212A、212B的夹持作用的其他合适的机构。同样地，在提供了旋转能力的一些实施例中，旋转致动器212R可以被构造为并可操作以旋转夹持器指状物212A、212B。旋转致动器212R可以是电动、气动或液压伺服马达等。

[0036] 可以响应于来自机器人控制器216的驱动信号来驱动致动机构212L和旋转致动器212R。可以包括一个或多个线性位置编码器212LE和/或旋转编码器212RE以提供关于夹持器指状物212A、212B的打开程度和/或夹持器指状物212A、212B的旋转取向的位置反馈。此外，尽管示出了两个夹持器指状物212A、212B，但是本公开的实施例同样适用于具有多于两个夹持器指状物212A或212B的夹持器212。也可以使用其他夹持器212类型。机器人210、510可以是能够在空间(例如，三维空间)中移动夹持器212以运输样本容器102的任何合适的机器人类型。

[0037] 再次参考图2，在一个或多个实施例中，机器人210可以包括旋转马达218R，其适于将旋转部分210R沿旋转方向(例如，+/-θ)旋转到期望的角度取向。机器人210还可以包括竖直马达218Z，竖直马达218Z联接到直立部分210U并且可以适于沿竖直方向(例如，沿竖直轴线211Z，以虚线示出)移动夹持器212。在一个或多个实施例中，机器人210可以包括平移马达218T，平移马达218T适于将平移运动施加至联接到旋转部分210R的夹持器212(例如，沿+/-R方向)。然而，尽管示出了R、θ、Z机器人，但是可以提供其他合适的机器人类型、机器人马达和用于施加X、Y、R、θ和/或Z运动或其他组合的机构。可以为每个运动度(X、Y、R、θ和/或Z)提供合适的位置反馈机构，诸如，从线性和/或旋转编码器。

[0038] 在一个或多个实施例中，机器人210可以用于实现夹持器212在坐标系(例如，X、Y和Z)中的三维运动，使得样本容器102、102L可以被放置在样品架106的目标接收器106T中或从样品架106的目标接收器106T被移除，或者被放置在测试仪器或处理设备中的其他位置中或从测试仪器或处理设备中的其他位置被移除。可选地，机器人210可以实现夹持器212围绕夹持器旋转轴线220的旋转，使得夹持器指状物212A，212B可以相对于样品架106的目标接收器106T精确地旋转取向。

[0039] 机器人控制器216可包括合适的微处理器、存储器、电源、调节电子器件、电路和驱

动器，其适于执行和控制机器人运动并适于控制夹持器212在X、Y、Z坐标系中的位置，以及控制夹持器指状物212A，212B的旋转取向和/或打开距离的程度。

[0040] 在图2中，样品架成像系统221可以被设置在夹持器定位系统200中以捕获样品架106的图像。样品架成像系统221可以包括架图像捕获装置222和图像捕获控制器224。特别地，架图像捕获装置222(例如，数字相机)可以被放置在任何合适的位置处。在一个或多个实施例中，可以从多个视角获得样品架106的多个图像。例如，架图像捕获装置222可以被放置在可以能够相对于框架214移动的可移动样品架装载抽屉(drawer)225上方。样品架106可以由可移动样品架装载抽屉225支撑并被移动到测试仪器或处理设备中到达可被机器人210通达的位置。在该移动期间，架图像捕获装置222可以采集样品架106的顶部的多个数字图像。可以使用用于捕获图像的其他装置。

[0041] 存储在图像捕获控制器224中的图像处理软件可以接收和处理多个数字图像。从图像中，可以产生包括群体数据和/或构造数据的数据。群体数据和/或构造数据可以由机器人控制器216访问。访问可以是通过从图像捕获控制器224下载数据或通过获得对驻留在图像捕获控制器224上的数据库的访问。

[0042] 可选地，机器人控制器216和图像捕获控制器224可以被组合在一个公共控制器中，并且被构造为处理由架图像捕获装置222捕获的图像，并且还控制机器人210和夹持器212的运动和操作。样品架成像系统221和图像捕获控制器224的进一步细节可以在如下中发现：2014年3月14日提交的Pollack等人的题为“Tube Tray Vision System”的美国专利公布US2016/0025757号；2015年6月10日提交的、并且题为“Drawer Vision System”的PCT申请公布 WO2015/191702号；2016年2月16日提交的、并且题为“Locality-Based Detection Of Tray Slot Types And Tube Types In A Vision System”的PCT申请PCT/US2016/018100号；2016年2月16日提交的、并且题为“Locality-Based Detection Of Tray Slot Types And Tube Types In A Vision System”的PCT申请PCT/US2016/018112号；以及2016年2月16日提交的、并且题为“Image-Based Tube Slot Circle Detection For A Vision System”的PCT申请PCT/US2016/018109号。

[0043] 更详细地，群体数据是指关于样品架106中的哪些接收器106R是空的、以及哪些接收器在其中容纳有样本容器102的数据。例如，如图2中所示出，群体数据将指示被标记为“B”的目标接收器106T是空的，并且被标记为“A”、“C”、“D”和“E”的接收器106R都容纳有样本容器102、102L。群体数据单独或与构造数据组合可以用于选择用于拾取操作的下一目标样本容器102T或用于放置操作的目标接收器106T。

[0044] 构造数据在本文中被限定为关于驻留在样品架106中的一个或多个样本容器102、102L的几何形状和/或取向的信息。构造数据可以包括最大样本容器外直径、样本容器102、102L的顶部相对于其所驻留的接收器106R的中心的偏移距离、样本容器102、102L的高度或管类型(例如，加盖的管，未加盖的管，包括管顶样品杯等)。

[0045] 例如，构造数据可以指示样本容器102L具有相对大的直径、样本容器102由于弹簧(例如，弹簧108)的作用或者因为样本容器102、102L在接收器106R中倾斜而在X和/或Y方向上偏移。从成像获得的构造数据还可以指示具有相对小直径或中间直径的样本容器102，并且可以提供例如目标样本容器102T的中心与任何相邻样本容器102、102L之间的距离。可以通过首先识别图像中的几何特征并且然后对像素计数来获得尺寸、偏移和间隙。

[0046] 群体数据、构造数据或两者的组合至少部分地用于确定被认为可由夹持器指状物212A,212B通达的目标接收器106T。可以通过在拾取操作或放置操作之前预先调查可用接收器106R来选择目标接收器106T。

[0047] 可通达的目标接收器是已经被确定为满足阈值最小间隙的接收器(例如,目标接收器106T)。阈值最小间隙是预先确定的,并且沿着相对于目标样本容器102T的可用作用线测量。例如,参考图3A,考虑如下情形:目标接收器106T中的样本容器102T是“目标样本容器”,即,在拾取操作中期望由夹持器指状物212A、212B拾取的样本容器102。然而,在通过夹持器指状物212A,212B拾取样本容器102T之前,该方法可以确定是否可通达目标样本容器102T被接收在其中的目标接收器106T。通过确定这一点,降低了堵塞、相邻样本容器之间的接触、溢出等的风险,从而提高了自动化测试仪器或处理设备的效率。

[0048] 为了确定目标接收器106T是否可通达(即,其是否满足阈值最小间隙),可以访问并使用目标样本容器102T和周围的样本容器102以及接收器106R的群体数据和/或构造数据。在这种情况下,如图3A中所示出,获得并分析位于样品架106中的编号为2、4、6和8的接收器106R中的样本容器102的构造数据。同样地,群体数据可以用于确定编号为1、3、7和9的接收器106R是空的。

[0049] 可以通过选择第一接收器作为潜在目标接收器106T并测试是否沿任何可用的作用线可获得阈值最小间隙来执行分析。例如,在固定的夹持器设计中(即,没有旋转能力),将仅调查沿着用于该接收器106R的作用线325A的间隙。

[0050] 选择用于针对阈值进行测试的接收器的方法可以简单到从接收器到接收器移动直到发现满足阈值最小间隙的接收器。在由于夹持器212具有旋转能力而多个作用线(例如,作用线325A-325C)可用的情况下,可以针对阈值最小间隙来单独地测试用于测试接收器106R的每个作用线(325A-325C)。一旦一个间隙值落入高于阈值的范围,就可以执行拾取或放置。如果接收器106R不满足阈值最小间隙,则调查另一接收器106R以查看其是否满足阈值最小间隙。这继续直到发现满足最小阈值间隙的目标接收器106T为止。

[0051] 目标接收器106T周围的接收器106R的群体数据可以指示目标接收器106T周围的接收器106R中的哪些容纳有样本容器102、102L。在沿着作用线325A存在空接收器106R的情况下,诸如,在编号1、2、3、7和9处,可以自动地确定在目标样本容器102T的该侧上的那些间隙高于阈值。因此,可以立即选择该作用线325A。在夹持器指状物212A、212B的样本容器接触表面之间测量的打开距离可以被设定为最大。可以选择作用线325A而不是作用线325C,因为样本容器顶部的偏移方向使得沿着作用线325A夹持样本容器可以具有将取向从倾斜取向纠正到竖直取向的高概率,即,以纠正倾斜的目标样本容器102T。

[0052] 此外,构造数据可以指示相邻样本容器102、102L中的哪些样本容器是具有相对大直径的样本容器102L。构造数据还可以指示目标样本容器102T倾斜(即,从目标接收器的中心偏移)或以其他方式偏移,从而减小或增加在目标样本容器102T与任何周围的样本容器102,102L之间的间隙。

[0053] 构造数据还可以指示目标样本容器102T的管类型。在两个样本容器102之间的间隙非常接近最小阈值间隙而使得难以确定接收器106R是否实际上可通达的情形中,知道管类型是重要的。对于某些管类型,因为该管类型更加坚固,所以可以允许较小的阈值间隙,并且对于其他管类型,诸如管顶样品杯,因为该管类型更加脆弱,所以可以使用更大的阈值

间隙。因此，在一些实施例中，可以基于存在于目标接收器106T中或周围的接收器106R中的样本容器102的类型来选择阈值间隙。

[0054]　从成像数据，可以确定目标接收器106T是否可通达，即，目标接收器106T可以被夹持器指状物212A、212B适当地通达(例如，在不与其接触的情况下)，或者确定目标接收器106T是否被阻止通达。被阻止通达意味着夹持器指状物212A、212B不能在不非常可能与目标样本容器102T周围的一个或多个样本容器102、102L接触的情况下被插入。对于拾取操作，在已经分析了所有可能的作用线、并且没有作用线允许在接收器106R内的样本容器102与相邻的样本容器102中的一个之间的最小阈值间隙之后，可以确定接收器106R被阻挡。如果其中一个作用线在接收器106R与相邻的样本容器102之间提供最小阈值间隙，则可以确定接收器106R是可通达的。在一些情况下，可通过在X和/或Y方向上调整夹持器212来提供最小阈值间隙。在其他情况下，可以通过调整夹持器指状物212A、212B之间的打开距离来提供最小阈值间隙。在一些实施例中，可以执行对夹持器212在X和/或Y方向两者上的位置的调整以及调整夹持器指状物212A、212B之间的打开距离以提供最小间隙。

[0055]　如果目标接收器106T不可通达，则可以基于成像数据开发策略，其中，该策略涉及选择可通达的相邻样本容器102、102L并首先移除它们，以便使目标接收器106T可通达。例如，如图3B中所示出，被标记为C7的在接收器106RB中示出的样本容器102B被有效地阻挡。当无论夹持器旋转取向、夹持器打开距离或X或Y定位如何都没有可用的作用线包括最小间隙时，阻挡被确定。样本容器102B被认为被阻挡，因为被标记为B7、B6、C6、D6的接收器106R中的样本容器102、102L过于接近以致不能满足被阻挡的样本容器102B的一侧上的最小间隙。因此，为了能够拾取被阻挡的样本容器102B，必须首先将其解除阻挡。

[0056]　通过沿着作用线325E移除被标记为A7的邻近的相邻接收器中的未被阻挡的样本容器102，这可以有效地将目标接收器106RB“解除阻挡”。然后可以使目标接收器106RB可通达，并且然后可以能够沿着作用线(例如像沿着作用线325F)拾取目标接收器106RB。可选地，可已经移除被标记为B6的接收器106R中的样本容器102以提供对被阻挡的样本容器102B的解除阻挡。在每种情况下，可以存在用于将被阻挡的接收器106RB解除阻挡的许多选项。

[0057]　在一个实施例中，该方法可以以轮询(round robin)方式测试每次移除是否可以将目标接收器106RB解除阻挡。一旦发现将解除阻挡的对象，则可以将其移除并且可以拾取先前被阻挡的、现在被解除阻挡的样本容器102B。在其他实施例中，在多个解除阻挡选项可用的情况下，可以选择将揭示具有最大间隙的作用线的样本容器102、102L的移除。

[0058]　对于每个被阻挡的接收器106RB，该方法的实施例可以从任何开始位置沿顺时针方向或逆时针方向按顺序搜索，并且调查相邻的样本容器102、102L中的任何是否可以被移除，并且如果可以被移除，那么是否将通过其移除而有效地释放作用线从而使得能够将被阻挡的样本容器102B解除阻挡。在一些实施例中，可以基于成像数据来识别样品架106中的所有被阻挡的接收器106RB，并且每个被阻挡的接收器106RB可以被给定相对于未被阻挡的接收器106R的优先(precedence)，使得可以选择相邻的样本容器102、102L以便将被阻挡状态解除阻挡。可以实施任何数量的方案以将被阻挡的接收器解除阻挡。

[0059]　在一些实施例中，拾取操作可以以有序的顺序发生，诸如，逐行、逐列或以任何其他有序模式，并且当检测到被阻挡的接收器106RB时，则可以进行拾取移动以试图将被阻挡

的接收器106RB解除阻挡。如果此时没有可用的移动,则有序顺序将简单地继续,直到移动可用为止。

[0060] 在一些实施例中,在进行第一次拾取或放置之后,该系统和方法可以用于分析样品架106的其余部分并产生考虑群体数据和/或构造数据的综合拾取和放置策略。可以快速地确定并且在拾取第一可通达的样本容器102的同时确定该拾取或放置次序。系统可以确定所有可通达的样本容器102和所有“被阻挡的”样本容器102。在一些实施例中,可以首先拾取所有可通达的样本容器102,并且然后可以确定曾经被认为是“被阻挡的”样本容器102中的哪些已经变得被“解除阻挡”。这些“解除阻挡”的样本容器102现在是可通达的,并且可以被拾取。这可以重复,直到所有样本容器102已经被“解除阻挡”,被认为可通达并被拾取。

[0061] 在一些实施例中,对接收器106R进行排序也可用于确定拾取样本容器102的次序。现在参考图4A-图4E,示出了用T指示的目标样本容器以及沿着作用线向左和向右的其相邻样本容器102的多种可能的构造。作用线被示出为是水平的,但竖直和对角作用线也可以使用此排序方法。在排序中,这些构造中的一些可以被给定相对高的数值分数(即,指示该构造中涉及的目标样本容器T应当首先被拾取或被给定优先),并且一些构造被给定相对较低的数值分数(即,指示该构造中涉及的目标样本容器T应更迟或最后被拾取)。例如,在图4A中,示出了最佳可能构造,其中,在目标样本容器T的任一侧上的接收器106R是空的(用X指示)。该构造可以被给定10的数值分数,或者另一相对高的数值分数。可以首先选择该目标样本容器T以用于拾取操作。

[0062] 然而,图4B中所示出的构造可以被给定相对较低的数值分数,诸如为9的数值分数。目标样本容器T具有仅一个相邻样本容器,并且相邻样本容器102向远处偏移(用“OA”指示),所以在目标样本容器T与其相邻样本容器之间的间隙可仍然满足最小阈值间隙,并且目标样本容器T可以仍然相当可通达。

[0063] 在图4C中,示出了包括目标样本容器T的构造,该目标样本容器T在其左侧具有一个空的接收器(X)并且在其右侧具有一个容纳有朝向目标样本容器T偏移(用“OT”指示)的样本容器102的接收器106R。这可以被给定相对较低的分数,诸如8。

[0064] 在图4D中,示出了包括目标样本容器T的构造,该目标样本容器T在其右侧和左侧两者上具有两个满的接收器106R,并且这两个接收器106R两者都容纳有具有相对较大直径(用“LD”指示)的居中的样本容器102。与图4A-图4C中的构造相比,图4D中的构造可以被给定4D相对较低的分数,诸如7的分数,这是因为由较大直径的样本容器LD提供的较低间隙。

[0065] 在类似于图4B和图4C中的情况下,将夹持器指状物212A、212B沿X和/或Y偏置可以产生使目标样本容器T被认为可通达的最小阈值间隙。在图4E中的构造中,夹持器指状物212A、212B可以不被偏置,这是因为目标样本容器T被两个样本容器LOT包围,这两个样本容器LOT朝向目标样本容器T倾斜和偏移。因此,在目标样本容器T和其相邻的样本容器LOT之间可能不存在最小阈值间隙,并且目标样本容器T可以被认为“被阻挡”。这种构造可以被分配相对较低的分数,诸如1的分数或任何其他相对较低的分数,其可以指示“被阻挡”的状态。因此,可以在已经拾取其他样本容器LOT从而释放其周围的区域之后拾取目标样本容器T。

[0066] 使用排序,可以基于“最可通达的”接收器106R来确定拾取样本容器102的动态次序,所述“最可通达的”接收器即首先被拾取的被给定较高排序值的接收器106R。同样地,可

以在没有排序的情况下并且简单地通过如下来确定拾取样本容器102的动态次序：确定接收器106R中的哪些满足被容纳在接收器106R中的样本容器102与相邻样本容器102之间的最小阈值间隙，即，接收器106R中的哪些可通达、以及哪些接收器106R被阻挡。可以通过如下来确定动态次序：调查所有可用的接收器、区域中的可用的接收器、或者单独地调查每个接收器并确定它们是否满足针对所使用的夹持器指状物212A、212B和样品架106设定的最小间隙标准。在一些实施例中，可以基于实验运行来设定最小间隙阈值，以确保在高百分比的拾取和放置操作中没有接触。

[0067] 可以使用上文描述的系统和方法来进行用于顺序放置操作的可通达的目标接收器的动态选择。为了确定接收器106R是否可通达，可以以与放置操作类似的方式使用群体数据、构造数据或两者的组合。群体数据是指关于接收器106R中的哪些为空的数据，并且可以用于确定期望将样本容器102放置到其中的目标接收器106R。构造数据是指关于特定相邻样本容器102的信息，该信息包括最大样本容器直径、样本容器偏移距离或管类型(例如，加盖的管、未加盖的管、管顶样品杯等)。来自先前拾取操作的构造信息也可以被存储在图像捕获控制器224中，并且可以在随后的放置操作期间能够由机器人控制器216访问。这允许以允许相邻样本容器102之间的最大间隙的方式构造放置策略。例如，放置策略可以被构造为避免将具有相对较大直径的两个样本容器102彼此相邻地放置接收器106R中。同样地，包括管顶样本容器的样本容器102可以被放置成远离大样本容器102L。类似地，可以在每隔一行或每隔一列中进行动态放置以最初增加放置间隙。

[0068] 考虑图3B中的样品架106，其具有多行接收器106R(示出了行6至9)，所述行中的一些容纳有样本容器102、102L。例如，预先确定的次序可以包括从第6行中的第一接收器106R(A6)处开始。群体数据指示被标记为A6和E6的接收器106R是空的，并且被标记为B6、C6、D6和E6的接收器106R容纳有样本容器102、102L。因此，根据群体数据和构造数据，可以确定的是，被标记为A6和E6的接收器106R两者都是可通达的。可以通过确保沿可由夹持器212实施的特定作用线的两侧都满足最小间隙来确定可通达性。因此，可以基于接收器106R是否可通达来确定放置次序。在一些实施例中，如果接收器106R不可通达，则基于成像数据，放置操作可以跳过该接收器106R并被放置在下一可通达的接收器106R中。下一拾取移动可以试图将被发现为不可通达的接收器106R解除阻挡。

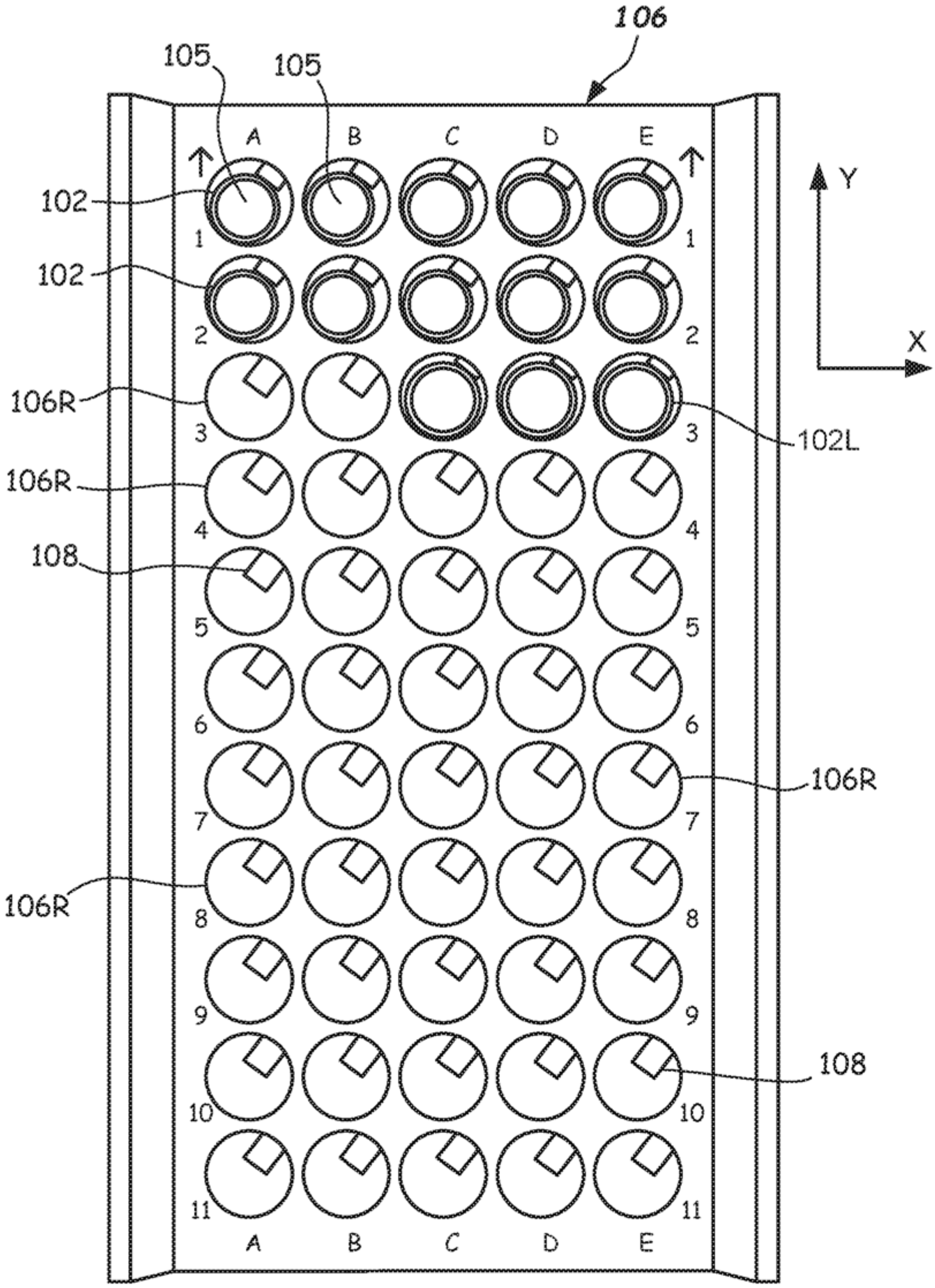
[0069] 图5示出了样本容器运输系统500，其中可以实施动态选择方法。样本容器运输系统500包括设置在夹持器212(以虚线示出)的通达范围内的样品架106。夹持器212可以被安装到机架机器人510的横向滑动件510C，该滑动件可以在横梁510B上来回移动以通达样品架106的任何列。同样地，横梁510B可以沿着左右滑动轨道510L、510R向前和向后移动，以允许通达样品架106的任何行。夹持器可以竖直地移动(进出纸张)以升高和降低样本容器102。因此，夹持器212可以能够在X，Y，Z坐标系中移动。可以根据上文描述的方法进行动态拾取操作，以基于从架图像捕获装置222和图像捕获控制器224获得的成像数据从样品架106拾取样本容器102，并将样本容器102运输到驻留在轨道540上并且绕轨道540移动的样本容器载体532(例如，定位盘)。同样地，样本容器102可以在从测试和/或处理返回时使用动态放置操作被放置回到样品架106中。拾取和放置顺序的选择可以如上文所描述，并且可以基于群体数据、构造数据或群体数据与构造数据两者。轨道540可以将样本容器102运输到各个设备或仪器以执行测试或以其他方式处理被容纳在样本容器102中的样本。轨道540

可以包括从主要通道540B到所有装载和的卸载的一个或多个分支540A。在一些实施例中，动态放置可以包括以指定次序返回特定样本容器载体532的策略，以使得提供增加样品架中的放置间隙的放置策略。

[0070] 根据本公开的另一实施例，提供了操作夹持器(例如，夹持器212)的方法600。在602中，方法600包括提供包括夹持器(例如，夹持器212)的机器人(例如，机器人210、510)，夹持器可由机器人在坐标系中(例如，在X、Y和Z中)移动并且包括夹持器指状物(例如，夹持器指状物212A、212B)，并且在604中，方法600包括提供包括可由夹持器通达的接收器(例如，106R、106T)的样品架(例如，样品架106)，接收器中的至少一些适于容纳样本容器(例如，102、102L、102T)。

[0071] 此外，在606中，方法600包括提供通过成像获得的关于样品架(例如，样品架106)和样本容器(例如，样本容器102、102L)的数据，并且最后，在608中，方法600包括基于该数据来确定用于拾取操作或放置操作中的一者的可通达的目标接收器(例如，106T)。通过成像获得的数据可以是群体数据和/或构造数据。确定可通达的目标接收器(例如，106T)可以包括在拾取操作的情况下测试在目标样本容器102T与周围的样本容器102、102L之间的间隙，以确保提供了最小阈值间隙。在放置操作的情况下，可通达性涉及确定目标接收器(例如，106T)周围的间隙并且基于所放置的样本容器102的类型并且可能基于围绕目标接收器106T的样本容器的类型，来将该间隙与目标阈值的值进行比较。

[0072] 虽然已经通过本文的示例实施例示出了特定的装置、系统和方法，但是应当理解的是，其他和不同的实施例也是可能的。本公开旨在覆盖落入所附权利要求范围内的所有修改、等同物和替代物。


106
105
105
A
B
C
D
E
102
102
106R
106R
108
106R
106R
102L
108
1
2
3
4
5
6
7
8
9
10
11
Y
X

现有技术

图 1

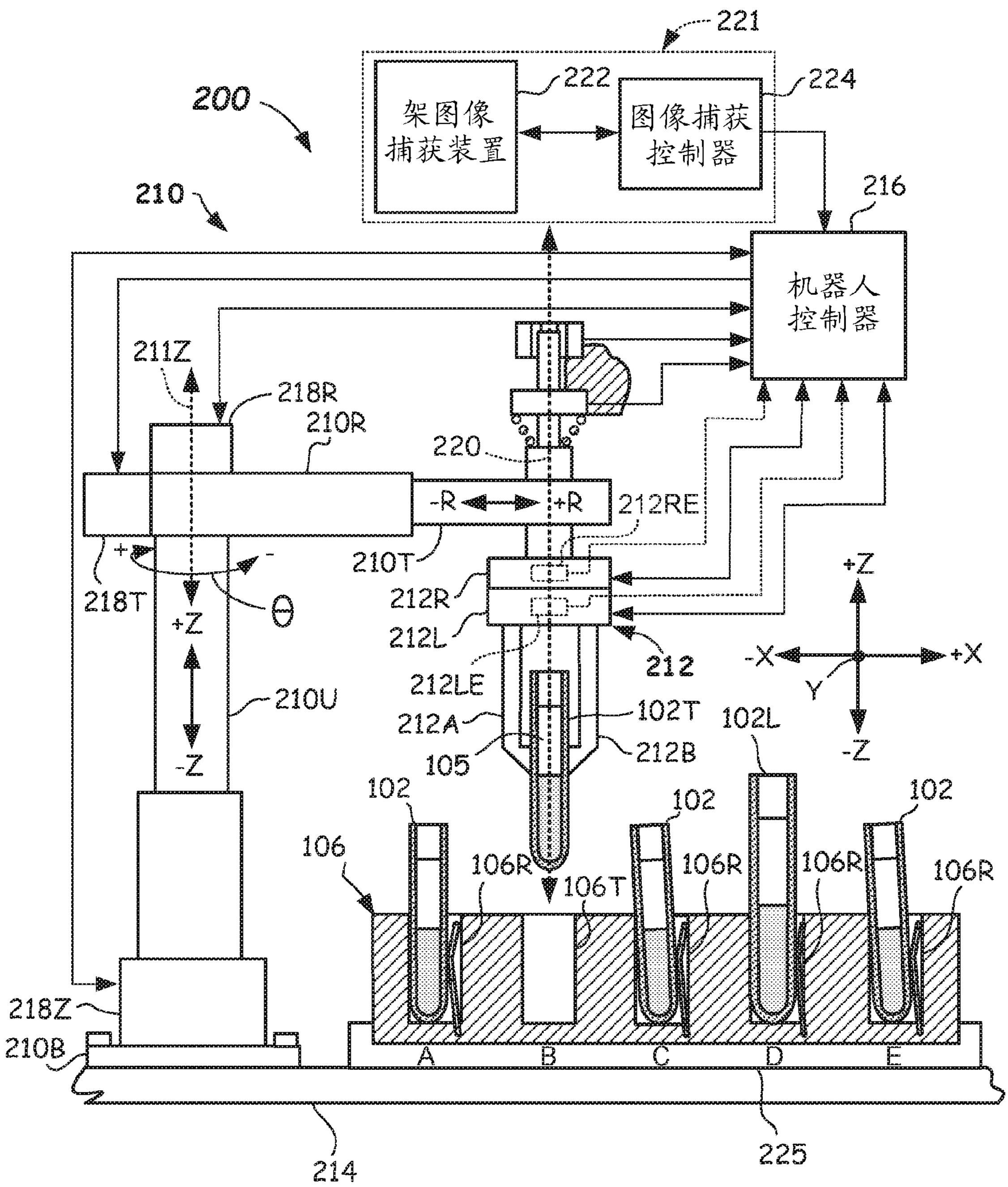

221
222
224
200
架图像捕获装置
图像捕获控制器
210
216
机器人控制器
211Z
218R
210R
220
-R
+R
212RE
210T
218T
θ
212R
212L
212
+Z
-X
+X
Y
-Z
212LE
210U
212A
102T
102L
105
212B
102
106
106R
106T
218Z
210B
A
B
C
D
E
214
225

图 2

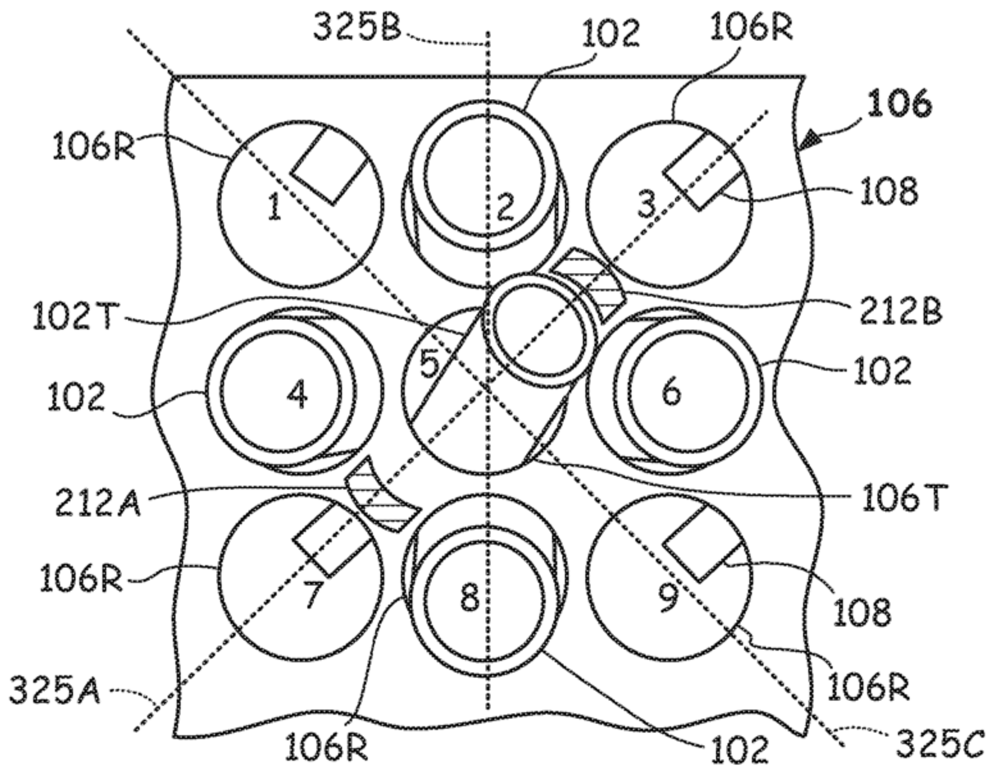

325B
102
106R
106
106R
1
2
3
108
212B
102T
5
4
6
102
102
212A
106T
106R
7
8
9
108
106R
325A
106R
102
325C

图 3A

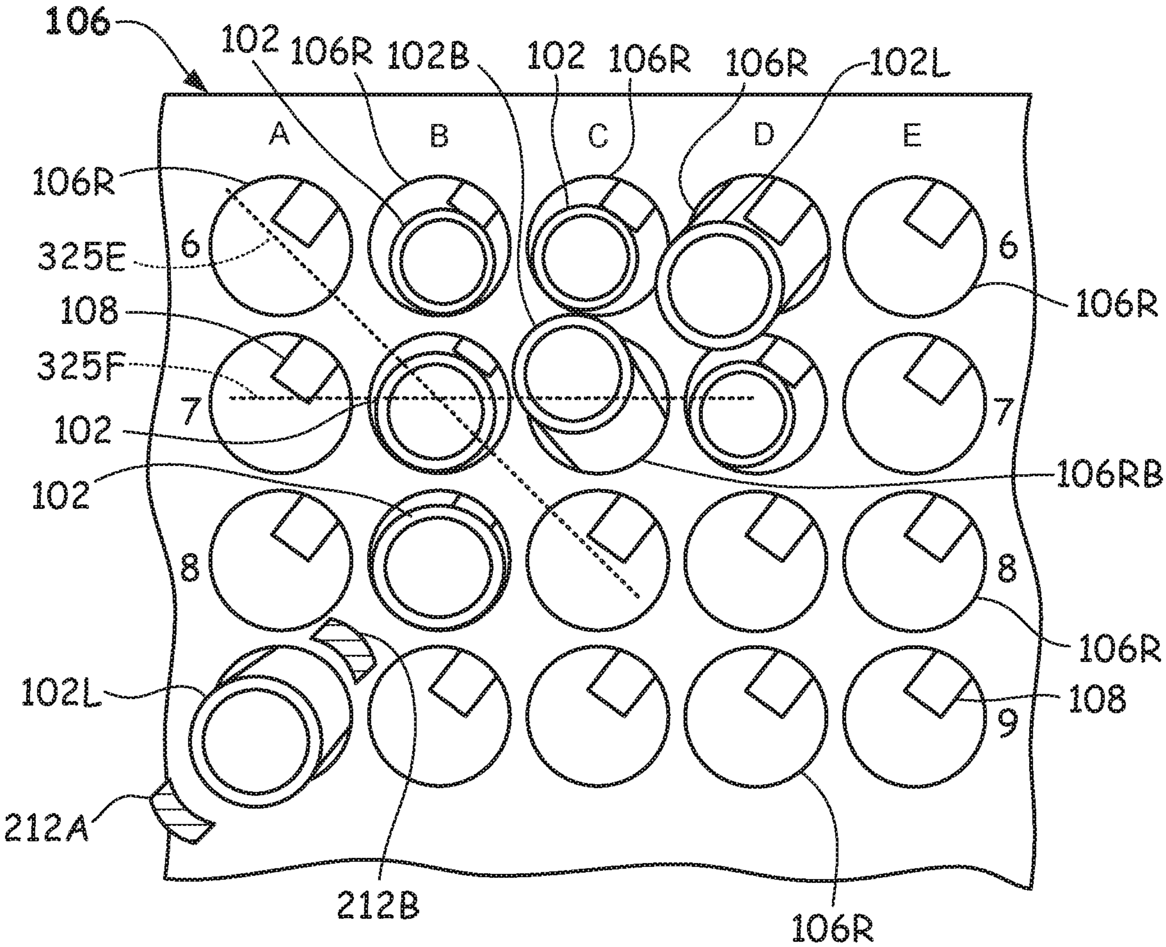

106
102
106R
102B
102
106R
106R
102L
A
B
C
D
E
106R
325E
6
6
106R
108
325F
7
7
102
106RB
102
8
8
106R
102L
108
9
212A
212B
106R

图 3B


X
T
X

图 4A

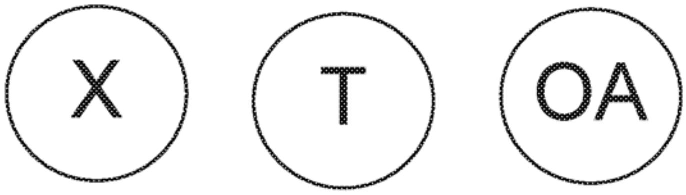

X
T
OA

图 4B

图 4C

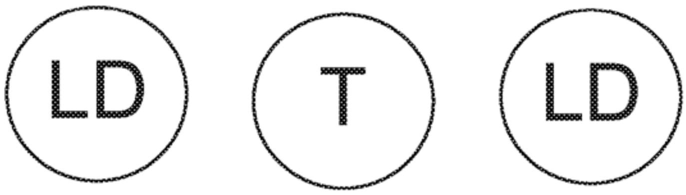


图 4D

图 4E

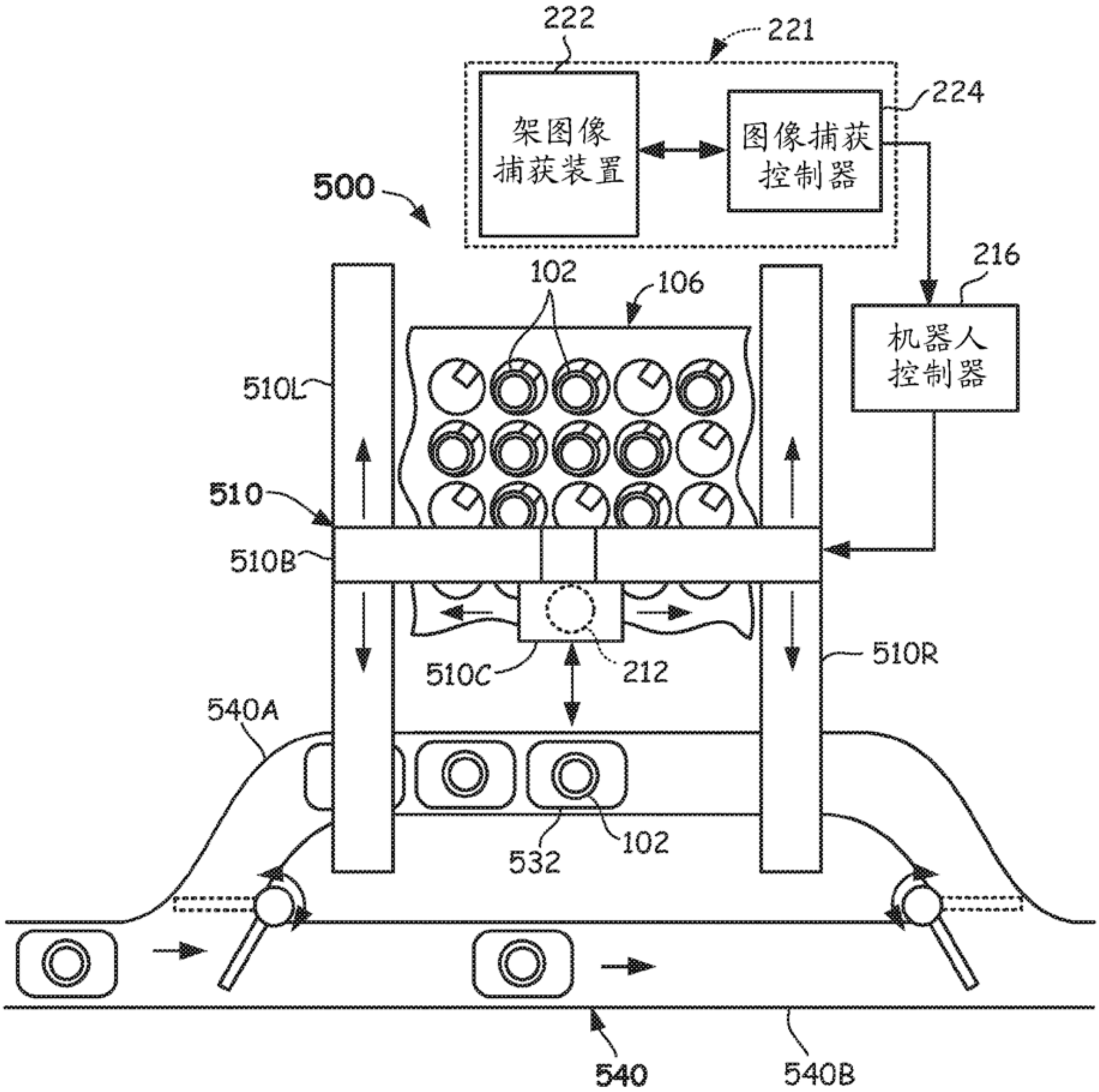

222
221
224
架图像
捕获装置
图像捕获
控制器
500
216
机器人
控制器
102
106
510L
510
510B
510C
212
510R
540A
532
102
540
540B

图 5

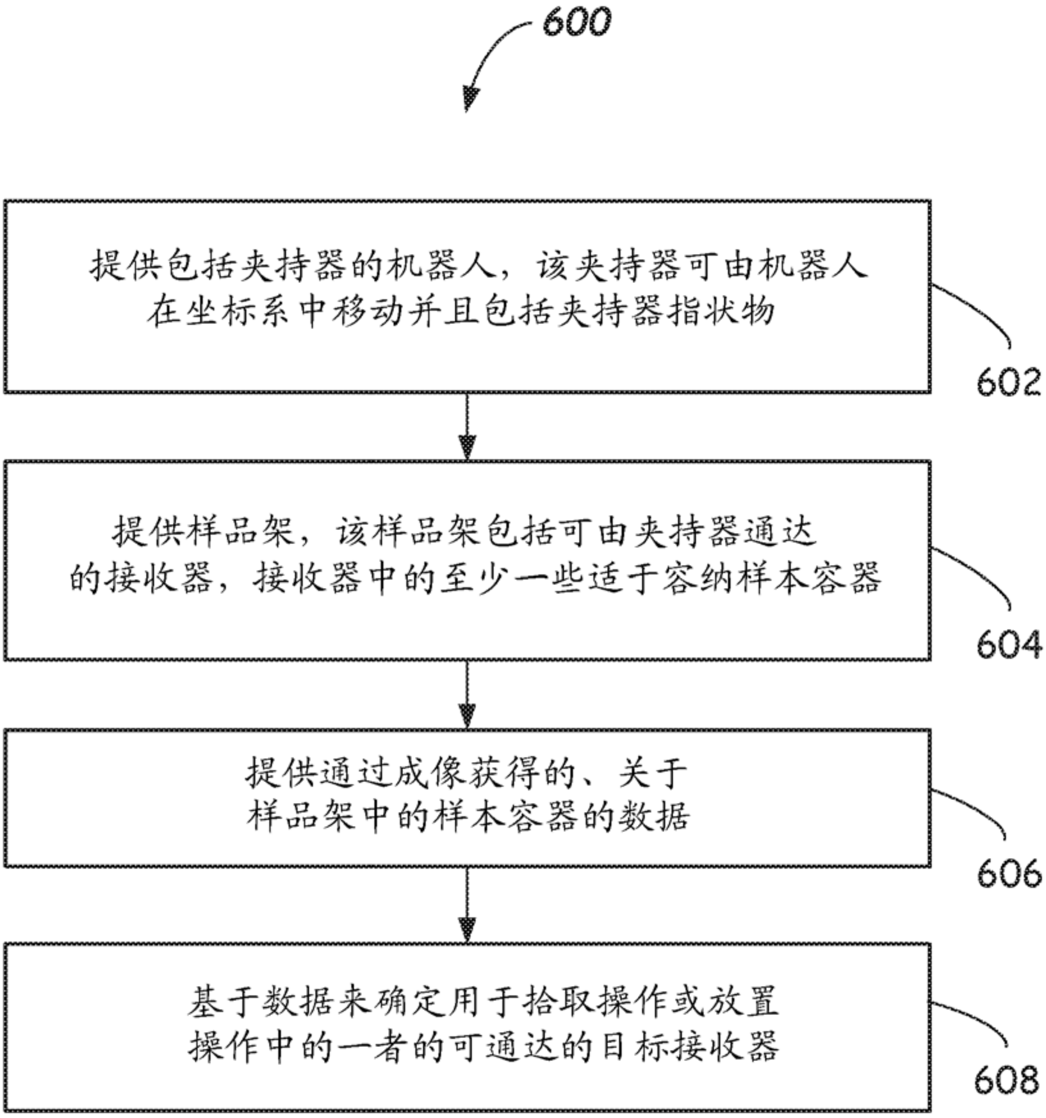

600
提供包括夹持器的机器人，该夹持器可由机器人在坐标系中移动并且包括夹持器指状物
602
提供样品架，该样品架包括可由夹持器通达的接收器，接收器中的至少一些适于容纳样本容器
604
提供通过成像获得的、关于样品架中的样本容器的数据
606
基于数据来确定用于拾取操作或放置操作中的一者的可通达的目标接收器
608

图 6