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(54) Title: METHODS AND APPARATUS FOR DYNAMIC POSITION ADJUSTMENTS OF A ROBOT GRIPPER BASED ON SAMPLE RACK IMAGING DATA

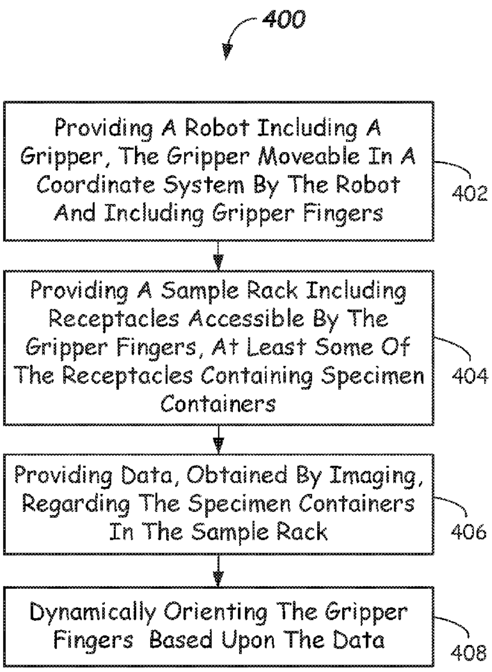

FIG. 4

(57) Abstract: Methods of positioning a gripper to pick or place a specimen container from a sample rack. One 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 containing specimen containers, providing data, obtained by imaging, regarding the specimen containers in the sample rack, and dynamically orienting the gripper based upon the data. The data may include population and/or configuration data and the dynamic orientation may include gripper finger opening distance, gripper finger rotational position, and/or gripper offset distance. Gripper positioning apparatus for carrying out the method are disclosed, as are other aspects.

[Continued on next page]

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METHODS AND APPARATUS FOR DYNAMIC POSITION ADJUSTMENTS OF A ROBOT GRIPPER BASED ON SAMPLE RACK IMAGING DATA

CROSS-REFERENCE TO RELATED APPLICATIONS

[001] This application claims priority to U.S. provisional application Serial No. 62/362,532 filed on July 14, 2016, the contents of which is incorporated herein by reference in its entirety.

FIELD

[002] The present disclosure relates to methods and apparatus adapted to pick and/or place a specimen container from and/or 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, vials, and the like) may be transported to and from sample racks (sometimes referred to as "cassettes") and to and from 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. The specimens may be of varying size (e.g., height and/or diameter). 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 the sample rack, and with grippers 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, lowered towards the receptacle to a controlled 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 to and from numerous receptacles of a sample rack. However, to maximize machine footprint usage, the receptacles in the sample racks are very tightly spaced.

[006] Accordingly, methods and apparatus that may improve accuracy of positioning of a gripper relative to a sample rack in testing and processing systems are sought.

SUMMARY

[007] In a first embodiment, a method of operating a gripper to pick or place a specimen container 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 fingers, at least some of the receptacles containing specimen containers, providing data, obtained by imaging, regarding the specimen containers in the sample rack, and dynamically orienting the gripper fingers based upon the data.

[008] In another embodiment, a gripper positioning apparatus is provided. The gripper positioning apparatus includes a robot including a 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 including data, obtained by imaging, regarding the specimen containers in the sample rack, and operatively configured to cause the gripper fingers to be dynamically oriented based upon the data.

[009] In a system aspect, a gripper positioning apparatus is provided. The gripper positioning apparatus includes a robot including a gripper, the gripper moveable in a coordinate system by the robot and including gripper fingers that open a variable distance, a sample rack including receptacles accessible by the gripper fingers, at least some of the receptacles containing specimen containers, and a robot controller configured to receive data, obtained by imaging, regarding the specimen containers in the sample rack, and operatively configured to cause the gripper fingers to be dynamically oriented to: open to an opening distance as determined based on the data, rotate to a rotational orientation as determined based on the data, or move to a x-y position to provide a condition of least interference between the gripper fingers and neighboring specimen containers contained in the sample rack as determined based on the data.

[0010] Still other aspects, features, and advantages of the present disclosure may be readily apparent from the following detailed description by 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. 2A illustrates a schematic side view of a gripper positioning apparatus configured for performing dynamic gripper finger positioning according to one or more embodiments.

[0013] FIG. 2B illustrates a schematic side view of a gripper positioning apparatus configured for performing dynamic gripper finger positioning and illustrating components of the system according to one or more embodiments.

[0014] FIG. 3A illustrates a partial top plan view of a sample rack including a target specimen container, wherein gripper fingers are shown in an opened configuration with the gripper fingers fully open (separated by a maximum opening distance) according to one or more embodiments.

[0015] FIG. 3B illustrates a top plan view of a portion 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.

[0016] FIG. 3C illustrates a partial top plan view of a sample rack including a target specimen container offset in a receptacle, and including some surrounding specimen containers that are leaning, and with gripper fingers opened to an intermediate distance, but also with the gripper fingers offset in X-Y according to one or more embodiments.

[0017] FIG. 3D illustrates a partial top plan view of a sample rack including a target specimen container offset and leaning in a receptacle, and including some receptacles with specimen containers that are leaning, and with gripper fingers in a configuration opened to an intermediate amount according to one or more embodiments.

[0018] FIG. 4 is a flowchart illustrating a method of positioning gripper fingers to a specimen container according to embodiments.

DETAILED DESCRIPTION

[0019] In robots, such as those used to accomplish robotic pick and place operations in clinical analyzers or other testing or processing systems (e.g., automated loading and unloading systems, centrifuges, cold storage areas), jams, collisions, and/or jarring of specimen containers can occur under certain conditions.

[0020] In particular, as is shown in FIG. 1, specimen containers 102 (e.g., blood collection tubes) used in automated in vitro diagnostics (IVD) equipment may be provided in an open-topped (de-capped) condition and filled with a bio-hazardous liquid (e.g., blood, blood serum or plasma, urine, interstitial fluid, cerebral fluid, or other bodily fluids). The specimen containers 102 are stored in an approximately vertical orientation in receptacles 106R (a few labeled) within the sample rack 106 (the first two and a half rows populated with specimen containers 102).

[0021] To maximize the use of the equipment footprint, the receptacles 106R of the sample rack 106 may be very closely/tightly 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 side wall of the receptacle 106R (as shown), all while largely maintaining the specimen container's vertical orientation.

[0022] However, due to mechanical tolerances and placement variations of the specimen containers 102, each specimen container 102 may lean away from a true vertical orientation in the receptacles 106R to some extent in one or more directions (e.g., X and/or Y as shown), thus causing a reduction in a theoretically perfect tube-to-tube clearance. Furthermore, because varying-diameter specimen containers 102 may be often processed on a given piece of equipment at the same time (e.g., Row 3 shown containing some relatively larger diameter specimen containers 102L), 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, tube leaning, and/or improper positioning in the receptacle 106R. Similarly, some receptacles 106R may be empty for some or all of the loading and unloading process.

[0023] The close-spacing of the receptacles 106R, combined with a goal of high throughput of the IVD equipment, may result in occasional unwanted contact (e.g., jams, collisions, and/or jarring) between gripper fingers 212A, 212B and a specimen container 102, or between a specimen container 102 being placed and another specimen container 102 as discussed above. 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 resulting in possibly downtime for remediation/cleanup.

[0024] An unrelated additional problem is that when a target specimen container 102 is placed in the receptacle

106R, in contact with the spring 108, and the gripper fingers are opened, the specimen container 102 may be jostled and the force exerted by the spring 108 may push the specimen container 102 sideways into contact with a wall of the receptacle 106R, possibly causing splashing of the specimen therein.

[0025] In the prior art, opening of the gripper fingers has been set to a constant value for all specimen containers 102 and receptacles 106R, with the constant value being selected taking into account the gripper finger width, all the expected tube sizes, possible placement variations, and receptacle 106R spacing. For pick and place operations, the gripper may be positioned above the center of the receptacle 106R and lowered to pick or place the specimen container 102 with the gripper opened to its maximum setting. Jams may be detected in the prior art by a crush sensor that detects vertical jams based upon exceeding a monitored threshold value, such as motor current. Similarly, a crash sensor may be provided to sense horizontal contact above a threshold value.

[0026] In view of the foregoing, one or more embodiments of the disclosure provides methods and apparatus to set a controlled extent of opening (gripper finger opening distance) of the gripper fingers based on sample rack 106 imaging data. The imaging data may include population data and/or configuration data. Population data is data about the presence or absence of neighboring specimen containers 102 around a particular target receptacle 106R. "Target receptacle" as used herein refers to a receptacle 106R that has been selected to undergo an operation thereat, such as a target specimen container 102 pick or place operation. "Target specimen container" as used herein is a specimen container 102 that has been selected to undergo a pick or place. Configuration data is data concerning the orientation and/or size of specimen containers 102 surrounding the target receptacle 106R, as well as the orientation and/or size of the target specimen container 102.

[0027] According to one or more embodiments, the extent of gripper finger opening may be dynamically varied for each pick or place operation. The variation may be dynamically selected responsive the population and/or configuration data for the particular target specimen container. In another embodiment, the X and/or Y positioning of the gripper and thus gripper fingers may be dynamically varied and offset from nominal centered position for each pick or place operation based upon population data and/or configuration data. In this way gripper positioning may be offset to account for offset of the specimen container in a receptacle. In yet another embodiment, the rotational positioning/orientation of the gripper fingers may be dynamically varied for each pick or place operation based upon population data and/or configuration data. The phrase "dynamically varied" as used herein means that for each particular specimen container pick or place operation, one or more of the parameters of the gripper (gripper finger opening distance, gripper offset, and/or gripper finger rotational orientation) are adjusted to facilitate suitable clearances between the gripper fingers and the surrounding specimen containers or the specimen container being picked.

[0028] Methods and apparatus in accordance within one or more embodiments may dynamically determine a controlled opening distance, X and Y gripper position, and/or rotational orientation of the gripper fingers. The dynamic determination takes into account the population data of specimen containers 102 in the sample rack 106 and/or configuration of specimen containers in the sample rack 106.

[0029] For example, methods and apparatus may take into account population data such as whether surrounding receptacles 106R contain specimen containers 102 or not. 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 102, offset in X and Y of one or more of the surrounding specimen containers 102, or, in the case of a target specimen container 102 to be picked, its size (e.g., diameter and height) and/or whether the target specimen container 102 is leaning, i.e., offset in X and/or Y.

[0030] This ability to dynamically adjust an extent of the gripper finger opening and/or the nominal gripper position in X and Y, and/or gripper finger rotational orientation, may dramatically reduce the propensity for contact (e.g., jams, collisions, and/or jarring) and thus reduce damage and/or spillage. This may reduce IVD instrument downtime.

[0031] These and other aspects and features of embodiments of the disclosure will be described with reference to FIGs. 2A-6 herein.

[0032] In accordance with one or more first apparatus embodiments, as best shown in FIGs. 2A and 2B, a gripper positioning apparatus 200 is described. The gripper positioning apparatus 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 apparatus 200 may be used in any suitable transfer apparatus or system, or testing instrument or device, such as a laboratory automation system (LAS), an automated clinical analyzer, assaying instrument, or other processing device such as a centrifuge, where specimen containers 102 are moved to or from a sample rack 106. In one or more embodiments, the testing instrument or device may be used for determining a constituent component (e.g., an analyte concentration) in a biological fluid specimen 105 contained in the specimen container 102.

[0033] The robot 210 includes a gripper 212 coupled to a moveable part of the robot 210. For example, the robot 210 may be an R, theta, Z robot and may include a base 210B that may be coupled to a frame 214 of the testing instrument or other device, an upright portion 210U configured to move vertically (in the +Z and -Z directions), a telescoping portion 210T configured to move radially (in the +R and -R directions), and a rotary portion 210R configured to move rotationally about a vertical axis 211Z (in the +Θ and -Θ directions). "Gripper" as used herein means any member coupled to a robot component (e.g., coupled to a robot arm or the like) that is used in robotic operations to grasp and move an article (e.g., a specimen container 102) from one location to another, such as in a pick and place operation.

[0034] The gripper 212 may include two gripper fingers 212A, 212B that are relatively moveable to one another, and may be opposed to one another. Gripper fingers 212A, 212B are adapted to grasp articles, such as specimen containers 102 (e.g., blood collection tubes). The gripper fingers 212A, 212B may be driven to open and close to a defined opening distance by an actuation mechanism 212L coupled to each of the gripper fingers 212A, 212B. In particular, 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), as in some embodiments a rotary actuator 212R may be provided that is configured to rotate the gripper fingers 212A, 212B to any 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 have more space envelope or clearance based upon population and/or configuration data obtained by imaging. The Y direction is into and out of the paper, as shown.

[0035] The opening and closing of the gripper fingers 212A, 212B may be accomplished by the actuation mechanism 212L, which may be an electric, pneumatic, or hydraulic servo motor, or the like that is coupled to the gripper fingers 212A, 212B. Other suitable mechanisms for causing gripping action of the fingers 212A, 212B may be used. Likewise, in some embodiments, where rotational capability is provided, a rotary actuator 212R may be configured to rotate the gripper fingers 212A, 212B about gripper axis 220. The rotary actuator 212R may be an electric, pneumatic, or hydraulic servo motor, or the like.

[0036] The actuation mechanism 212L and rotary actuator 212R may be driven responsive to drive signals from a robot controller 216. One or more linear 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 relative to a calibrated reference or zeroed position. 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. Other gripper types may be used, as well. The robot 210 may be any suitable robot components capable of moving the gripper 212 in space (e.g., three-dimensional space) in order to move specimen containers 102.

[0037] In one or more embodiments, the robot 210 may, for example, have a rotational motor 218R adapted to rotate the rotary portion 210R to a controlled 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 that may be adapted to move the gripper 212 in a vertical direction (e.g., along the vertical axis 211Z in the +/- Z direction, shown dotted). In one or more embodiments, the robot 210 may include a translational motor 218T adapted to impart translational motion of 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 position and/or rotation encoders. Gantry robots may be used wherein a gantry cross beam is moveable in X, and the gripper 212 is moveable in Y and Z (and possibly about Z) relative to the gantry cross beam.

[0038] In one or more embodiments, the robot 210 may be used to accomplish three-dimensional coordinate motion (X, Y, and Z) of the gripper 212 so that specimen containers 102 may be placed in, or removed from, a receptacle 106R of the sample rack 106 or placed in or removed from other positions in testing or processing equipment. In particular, the X and Y position of the gripper 212 may be adjusted to provide a condition of least interference between the gripper fingers 212A, 212B and neighboring specimen containers 102 contained in 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 the robot motions and to control position of the gripper 212 in the X,Y,Z coordinate system, as well as the extent of gripper finger 212A, 212B opening and/or rotational orientation. Moreover, the robot controller 216 may include suitable communication capability to receive or access data from a sample rack image capture system 221. Functionally, the robot controller 216 may be configured to receive data, obtained by imaging, from the sample rack image capture system 221 regarding the specimen containers 102 contained in the sample rack 106. Further, as will be apparent from the following, the robot controller 216 may be operatively configured to cause the gripper fingers 212A, 212B to be dynamically oriented. The dynamic orientation may be to: open to an opening distance 230 (FIG. 2B) as determined based on the data; rotate to a rotational orientation as determined based on the data; or move to an x-y position to provide a condition of least interference between the gripper fingers 212A, 212B and neighboring specimen containers 102 contained in the sample rack 106 as determined based on the data.

[0040] Again referring to FIGs. 2A and 2B, the sample rack image capture system 221 may be provided in the gripper positioning apparatus 200. The sample rack image capture system 221 may include a rack image capture apparatus 222, and an image capture controller 224. In particular, the rack image capture apparatus 222 may be a suitable digital camera and may be placed at any suitable location where multiple images of the sample rack 106 can be obtained illustrating the sample rack 106 from multiple perspectives. For example, the rack image capture apparatus 222 may be placed above a moveable sample rack loading drawer 223. The sample rack 106 may be supported by the moveable sample rack loading drawer 223 and moved (as indicated by directional arrows 225) into the testing or processing equipment relative to the frame 214 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 from various perspectives. For example, three or more images may be obtained at three or more different perspectives.

[0041] From these multiple digital images, image processing software stored in the image capture controller 224 may receive and process the image data and produce data based on the imaging. The data may comprise population data and/or configuration data on the amount, size, and orientation of the specimen containers 102 resident in the sample rack 106. The population data and/or configuration data may be accessed by the robot controller 216 via electronic communication and the data based on imaging may be used to determine and set one or more of the following: 1) opening distances of gripper finger 212A, 212B, 2) rotational orientation of gripper fingers 212A, 212B, and/or 3) placement of the gripper 212 in X, Y and/or Z when carrying out specimen container pick or place operations.

[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 control the operation of the robot 210, including control of the X and Y position of the gripper 212, the opening distance of the gripper fingers 212A, 212B, and/or the rotational orientation of the gripper fingers 212A, 212B.

[0043] 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"; US Pat. Pub. No. US2015/0355208 to German et al. entitled "Automation Tube Positioning Methodology"; 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."

[0044] In more detail, the image capture controller 224 may receive the images from multiple perspectives and process them. The image processing may be carried out by taking each image and identifying geometrical features therein, such as tops of specimen containers and receptacle locations and conditions and then determine the offset of the specimen container top and size by way of counting pixels. From the processing, details on the population of the sample rack 106 may also be obtained. For example, each receptacle 106R may be assigned a distinct slot code, such as A1, A2, A3, etc., based upon its column and row location (see FIG. 1) on the sample rack 106. The image processing software may, based upon the image, determine population data on which receptacles 106R are empty, and which receptacles 106R contain a specimen container 102. This population data may be stored in a database in memory of the image capture controller 224 and may be accessed by the robot controller 216 or otherwise be communicated thereto.

[0045] Likewise, the processing software in the image capture controller 224 may process the images and therefrom extract various configuration data. Configuration data may include, for example, height, maximum outer diameter of the top of the specimen container 102, and an X and Y center location of the top of the specimen container 102 relative to the receptacle 106R that it is inserted into, wherein such configuration data can be correlated in a database to the distinct slot code, and may be used later in positioning the gripper 212 for minimum interference.

[0046] In accordance with another embodiment of the disclosure, and as shown in FIG. 4, a method 400 of operating a gripper (e.g., gripper 212) to pick or place a specimen container (e.g., specimen container 102, 102T, 102L) is provided. The method includes, in 402, providing a robot (e.g., robot 210) including the gripper (e.g., gripper 212), the gripper moveable in a coordinate system (e.g., the X, Y, Z coordinate system) by the robot and including gripper fingers (e.g., gripper fingers 212A, 212B) that can selectively open and close an may be set to an opening distance 230 (FIG. 2B) that is variable. The opening distance 230 may range from a minimum distance to a maximum distance of opening measured between the specimen container inner contact surfaces of the gripper fingers 212A, 212B adapted to contact and grip the specimen containers 102. The opening distance 230 may include one or more intermediate opening distance values in some embodiments. Opening distances 230 may range from between about 8 mm to about 20 mm, for example. Other opening distances may be used. The opening distance between the gripper fingers 212A, 212B may be controlled by signals to the actuation mechanism 212L from the robot controller 216. For example, in one embodiment, the opening distance may be set to a small, a medium (intermediate), or a large opening distance 230 that are preselected, or set to a custom opening distance 230 based on the conditions and available space along a particular line of action 325.

[0047] The method 400 includes, in 404, providing a sample rack (e.g., sample rack 106) including receptacles (e.g., receptacles 106R) accessible by the gripper fingers (e.g., gripper fingers 212A, 212B), wherein at least some of the receptacles contain specimen containers (e.g., specimen containers 102, 102T, 102L). Accessible means that the gripper 212 can be moved a sufficient distance by the robot 210 to reach the receptacles 106R to pick the target specimen container 102T from or place the target specimen container 102T therein.

[0048] The method 400 further includes, in 406 providing data, obtained by imaging, regarding the specimen containers that are contained in the sample rack (e.g., sample rack 106). In particular, in one or more embodiments, the data may include population data regarding which of the receptacles 106R in the sample rack 106 contain specimen containers 102, and more specifically, which of the receptacles 106R surrounding the target receptacle 106T contain specimen containers 102. The data based on imaging may also contain data on which of the receptacles 106R are empty, and in particular, the population data comprises data on which of the receptacles 106R, surrounding a target receptacle 106T, are empty.

[0049] In one example, if two receptacles 106R on opposite sides of the target receptacle 106T are determined to be empty, as shown in FIG. 3A, then the gripper fingers 212A, 212B are opened to a maximum amount along a chosen line of action (e.g., line of action 325A) connecting the two receptacles 106R. In some embodiments one line of action is available (e.g., line of action 325A) such as when the gripper 212 is not rotatable. In other embodiments, the robot controller 216 may select another line of action if another line of action includes a higher available clearance as determined by any processing method. However, in some embodiments, as soon as one line of action is found that meets a minimum clearance value on each side of the target specimen container 102T, then the pick operation will simply commence.

[0050] In FIG. 3A, one method may order rank the available lines of action (e.g., 325A-325D) according to a ranking scheme. The highest ranked line of action may be chosen as the one that theoretically has the highest clearance for the gripper fingers 212A, 212B. For example, if a line of action includes two empty receptacles on opposite sides of the target receptacle, then that line of action is given a high ranking. Even among lines of action (e.g., 325A, 325D) that include two empty receptacles 106R on opposite side of the target receptacle 106T, ranking may take place whether the line of action is diagonal to a row of the sample rack 206, or along or perpendicular to a row, with the diagonal to the row receiving a relatively higher ranking, simply because there is more available spacing. Similarly, as shown in FIG. 3B, all else being equal, lines of action with one specimen container 102 on one side of the target receptacle (e.g., 325D) versus two (e.g., 325B) may be given a higher rank.

[0051] In one or more embodiments, the data may include configuration data. Configuration data is data on configuration of specimen containers 102 surrounding a target receptacle 106T, including data on the target specimen container 102T in the target receptacle 106T in the case of a pick operation. Configuration data may include a maximum diameter of each of the specimen containers 102 surrounding the target specimen container 102T, and may include a maximum diameter of the target specimen container 102T in the case of a pick operation. Configuration data may also include locations of the receptacles 106R, including the target receptacle 106T.

[0052] Specimen containers may be identified as small, medium and/or large, for example. Small may include a diameter of about 10 mm, medium may include a diameter of about 13 mm, and large may include a diameter of about 16 mm or 17 mm, for example. Other known sizes may be used and determined, such as by identifying the circular tops of the specimen containers and then counting pixels to obtain a diameter estimate. US Pat. App. No. 2016/0025757 to Pollack, et al. describes a "Tube Tray Vision System" operable to obtain information about the population and configuration by imaging. US Pat. Pub.

2105/0355208 to German et al. describes an "Automation Tube Positioning Methodology" and particularly methods of determining tube offset. Further information of visioning systems may be found in 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."

[0053] Configuration data may include a height of the specimen containers 102 surrounding the target specimen container 102T (for place operations) or the height of the target specimen container 102T in the target receptacle 106T (for pick operations). Offset may be measured along a possible line of action through the target specimen container 102T or target receptacle 106T.

[0054] Configuration data obtained by imaging may include whether the specimen containers 102 are offset in a direction(s) in a particular one of the receptacles 106R. For example, configuration data may include whether the specimen containers 102 are offset due to leaning away or due to leaning towards the target receptacle 106T (for place operations) relative to their respective receptacles 106R. Configuration data may also include, for pick operations, offset of the target specimen container 102T within the target receptacle 106T, and in some embodiments, an offset distance between corresponding top portions of the target specimen container 102T and the surrounding specimen containers 102 may be determined and provided. In place operations in the target receptacle 106T, the clearance distances between respective specimen containers along each line of action may be determined.

[0055] As shown in FIG. 2B, in the case of a pick operation, the configuration data may include data on the configuration of the target specimen containers 102T and any surrounding specimen containers 102 (e.g., specimen container 102L) and in particular a clearance value C1 from the target specimen container 102T along one or more of the possible lines of action applicable to the particular type of gripper 212. For example, some types of grippers 212 may include a single line of action that may be along a 45 degree angle to the rows of the sample rack 106.

[0056] In other embodiments, the gripper fingers 212A, 212B may include multiple lines of action by rotating the gripper fingers 212A, 212B to another line of action with the rotary actuator 212R. In some embodiments, the clearance value C1, as shown in FIG. 2B, is a distance between the location of the target specimen container 102T and a surrounding one of the specimen containers 102 (e.g., large specimen container 102L). In the case where the operation is a place operation, then the clearance C2 is a distance between respective specimen containers 102 on opposite sides of the target receptacle 106T along one or more lines of action.

[0057] Referring again to FIG. 4, to carry out the pick operation, the method 400 may include moving the gripper (e.g., gripper 212) to a position above a target receptacle (e.g., target receptacle 106T). The position may be above the previously-calibrated location of the target receptacle 106T containing the target specimen container 102T. Optionally, the position in X and Y of the gripper 212 may be centered over the offset center of the top of the target specimen container 102T based upon the configuration data obtained by imagery. In

408, the gripper fingers (e.g., gripper fingers 212A, 212B) may be dynamically opened to the controlled opening distance 230 (FIG. 2B) selected based upon the data obtained by imaging. The gripper fingers 212A, 212B may be opened to the controlled opening distance 230 along a line of action and then the gripper 212 may be moved to above the target receptacle 106T, or the gripper 212 may be moved and the gripper fingers 212A, 212B may be opened to the controlled opening distance 230 along a line of action. If the gripper 212 has a single line of action (i.e., is non-rotatable) then it may be opened dynamically along that single line of action by actuation mechanism 212L.

[0058] If the gripper 212 is of the type that has rotational capability, the gripper 212 may be rotated using the rotary actuator 212R to one of the lines of action through the target specimen container 102T and dynamically opened either before or after such rotation. The selection of the sought after line of action may be by any suitable scheme, such as start and test, or by surveying and ranking the various possibilities. Start and test may include selecting a first line of action and testing it to see if minimum clearance is available for each gripper finger 212A, 212B. Surveying and rank ordering may be by surveying all the possible lines of action and the clearance available, and then rank ordering them in terms of which one has the highest clearance. The line of action with the highest clearance may be selected.

[0059] The term “dynamically” as used herein means that the opening distance 230 of the gripper fingers 212A, 212B is determined and set for each target receptacle 106T based on the data obtained by imaging, wherein the target receptacle 106T is the specific receptacle from or to which a target specimen container 102T is being picked or placed.

[0060] The data is obtained by imaging the sample rack 106 including a plurality of specimen containers 102, 102T, 102L contained in receptacles 106R therein. The imaging may take place at any convenient time, such as when initially loading the sample rack 106 into the equipment via one or more rack image capture apparatus 222 (e.g., digital camera(s)) mounted above the loading area. However, the imaging may take place in some embodiments when the sample rack 106 has come to rest in its final location. One, or more than one, rack image capture apparatus 222 (e.g., one or more digital cameras or the like) may be used to capture multiple images from different perspectives or poses.

[0061] The data may be retrieved from a database stored in memory of the image capture controller 224, or from a database stored in memory of the robot controller 216, that has received the data from the image capture controller 224. In some cases, a single processor may carry out both of the robot control functions as well as the digital imaging and image processing. The data obtained by imaging may include the population data, the configuration data, or both, as described above.

[0062] As shown in FIGs. 3A and 3B, the method 400 may, for each target receptacle 106T, survey one or more possible lines of action (e.g., line of action 325A, 325B, 325C, 325D) to determine if a minimum clearance is present along that surveyed line of action. The minimum clearance may be along the line of action (e.g., along line of action 325A, 325B, 325C, 325D) and measured between closest portions of the target specimen container 102T and any surrounding specimen containers 102, such as those positioned on either side of the target specimen container 102T along a line of action. The clearance distance on either side of the target specimen container 102T may be different. Starting with a diagonal line of action (e.g., line of action 325A), if the minimum clearance is present, then the gripper fingers 212A, 212B may carry out the pick operation by dynamically opening to the determined opening distance.

[0063] However, if more than the minimum clearance is available on both sides of the target specimen container 102T, then the gripper fingers 212A, 212B may open a relatively larger distance, thus minimizing possible contact with the target specimen container 102T. FIG. 3A illustrates a population in the sample rack 106 where receptacles 106R labeled 2, 3, 6, 7 and 9 are empty, and receptacles 106R labeled 1, 4, 5 and 8 are full and with the target specimen container 102T being in the target receptacle 106T labeled 5. Software application may survey the available lines of action and determine that the diagonal line of action 325A is optimal and allows a maximum opening distance 230 of the gripper fingers 212A, 212B. The other lines of action (e.g., 325B, 325C, 325D) may be considered suboptimal by the software because they contain one specimen container 102 in addition to the target specimen container 102T.

[0064] In cases like shown in FIG. 3B, all lines of action (e.g., 325A-325D) include one or two additional specimen containers 102 along the line of action in addition to the target specimen container 102T. In this case, diagonal lines of action (e.g., 325A, 325C) may be selected over non-diagonal lines of action (e.g., 325B, 325D) in some embodiments. Those lines of action including two specimen containers 102 (e.g., line of action 325B) may be given a low rank order. If between two acceptable lines of action, the one with a specimen container 102L with a configuration that is offset away (e.g., leaning away) from the target specimen container may be selected (e.g. line of action 325A). Once a line of action is selected from the available lines of action, the gripper fingers may be opened to a controlled opening distance 230 based upon the clearance available as determined based on the imaging data.

[0065] In cases where the target specimen container 102T is offset from a determined location of the center of the target receptacle 106T based upon either calibration data or imaging, then the robot 210 may be positioned at an X and/or Y position so that the gripper 212 is centered over a top of the target specimen container 102T. However, in some instances, as shown in FIGs. 3C and 3D, the gripper 212 may be further offset in the X and/or Y directions by an offset distance D as measured along the line of action 325A. As shown in FIGs. 3C and 3D, the gripper axis 220 is positioned offset from a center location of the top of the target specimen container 102T. This may provide additional clearance between a leaning specimen container 102L, such as is shown in receptacle 106R and labeled 3, wherein the specimen container 102L leans toward the target specimen container 102T.

[0066] As shown in FIG. 3D, the offset distance D may be provided when the target specimen container 102T is leaning, so as to first contact the target specimen container 102T with an individual one of the gripper fingers 212A, 212B, which may bring the target specimen container 102T into an upright configuration. For example, the offset distance D may be away from a center of the top the target specimen container 102T along the selected line of action, but towards a center of the target receptacle 106T. Combinations of variable finger opening distance 230, finger rotational orientation, and offset distance D in x and/or y may be used for any particular pick of a target specimen container 102T or place of a target specimen container 102T into a target receptacle 106T.

[0067] In some embodiments, the configuration data includes tube height and/or tube type. For example, tube height data obtained by imaging may be used to determine how deeply the gripper 212, and thus gripper fingers 212A, 212B, should be moved in the minus Z direction in order to perform a pick operation. Tube height data may also be used to allow maneuvering of the gripper 212 when grasping a target specimen container 102T just picked from a target receptacle 106T to the next destination (e.g., to a specimen container carrier) without collision, but without having to raise the target specimen container 102T above the highest specimen container 102L. In some instances, potential contact by the gripper fingers 212A, 212B may be entirely avoided by grasping a large specimen container 102L identified based on the data obtained by imaging at a location that is vertically above a top of a neighboring smaller specimen container(s) 102.

[0068] In other cases, tube type may be discriminated based upon imaging data and/or gripper data. For example, a tube top specimen container may be provided in the specimen container 102 in some embodiments. The imaging data may indicate a large diameter specimen container 102, but the gripper feedback data from the linear encoder 212LE (FIG. 2A) may indicate a small diameter specimen container 102. However, these two pieces of data together may be indicative of a tube top specimen container being present in the target specimen container 102T.

[0069] The data obtained by imaging may also be used to help select a receptacle 106R for placement of the specimen container 102R after the specimen container returns from processing. Because the population data was originally known, the history of removal and reinsertion may be tracked to arrive at modified data on the population of the sample rack 106. As such, a position for reinsertion of the target specimen container 102T may be selected based upon the modified data.

[0070] While specific apparatus, systems, and methods have been shown by way of example embodiments described in detail 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 to pick or place a specimen container, 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 fingers, at least some of the receptacles containing specimen containers;

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

dynamically orienting the gripper fingers based upon the data.

2. The method of claim 1, wherein the dynamically orienting the gripper comprises opening the gripper fingers a variable distance selected based on the data.

3. The method of claim 1, wherein the dynamically orienting the gripper comprises selecting a gripper line of action by rotating the gripper fingers to a defined rotational position based upon the data.

4. The method of claim 1, wherein the dynamically orienting the gripper comprises adjusting an X and Y position of the gripper based upon the data.

5. The method of claim 1, wherein the data includes a population data on which receptacles in the sample rack contain a specimen container.

6. The method of claim 1, wherein the data includes a population data on which receptacles, surrounding a target receptacle, contain specimen containers.

7. The method of claim 1, wherein the data includes a configuration data on specimen containers surrounding a target receptacle.

8. The method of claim 7 wherein the configuration data comprises one or more of: tube diameter, tube offset, tube height, and tube type.

9. The method of claim 7 wherein the configuration data comprises an offset to a top of a target specimen container relative to a center of a target receptacle.

10. The method of claim 7 wherein the data comprises population data that is generated from a sample rack image capture system.

11. The method of claim 10, wherein the population data comprises data on which of the receptacles, surrounding the target receptacle, are empty.

12. The method of claim 11 wherein if two receptacles on opposite sides of the target receptacle are determined to be

empty, then the gripper is opened to a maximum amount along a line of action connecting the two receptacles.

13. The method of claim 1, wherein an X and Y position of the gripper is adjusted to provide a condition of least interference with neighboring specimen containers.

14. The method of claim 1, wherein an X and Y position of the gripper and extent of opening of the gripper is adjusted based upon the data.

15. The method of claim 1, wherein selection of a receptacle for reinsertion of a specimen container after processing is decided based upon modified data.

16. A gripper positioning apparatus, comprising:

a robot including a 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 including data, obtained by imaging, regarding the specimen containers in the sample rack, and operatively configured to cause the gripper fingers to be dynamically oriented based upon the data.

17. The gripper positioning apparatus of claim 16, wherein the data comprises population data on the receptacles of the sample rack and configuration data on the specimen containers.

18. The gripper positioning apparatus of claim 16, comprising an actuator coupled to the gripper fingers to cause opening of the gripper fingers to a dynamically-determined opening distance based on the data obtained my imaging.

19. The gripper positioning apparatus of claim 16, comprising a rotary actuator coupled to the gripper fingers to cause rotation the gripper fingers to a dynamically-determined rotational orientation based on the data obtained my imaging.

20. A gripper positioning apparatus, comprising:

a robot including a gripper, the gripper moveable in a coordinate system by the robot and including gripper fingers that open a variable distance;

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

a robot controller configured to receive data, obtained by imaging, regarding the specimen containers in the sample rack, and operatively configured to cause the gripper fingers to be dynamically oriented to:

open to an opening distance as determined based on the data,

rotate to a rotational orientation as determined based on the data, or

move to an x-y position to provide a condition of least interference between the gripper fingers and neighboring specimen containers contained in the sample rack as determined based on the data.

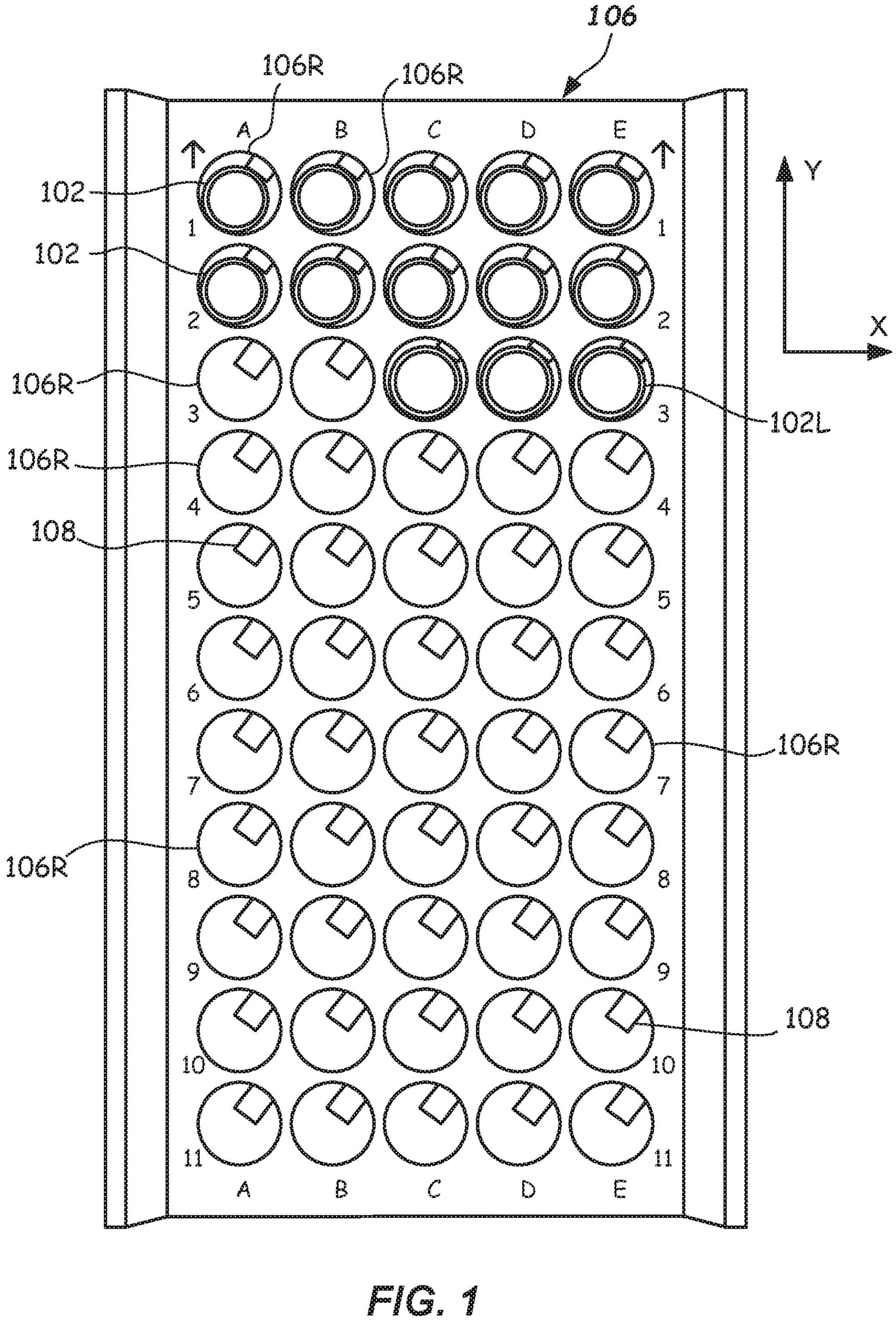
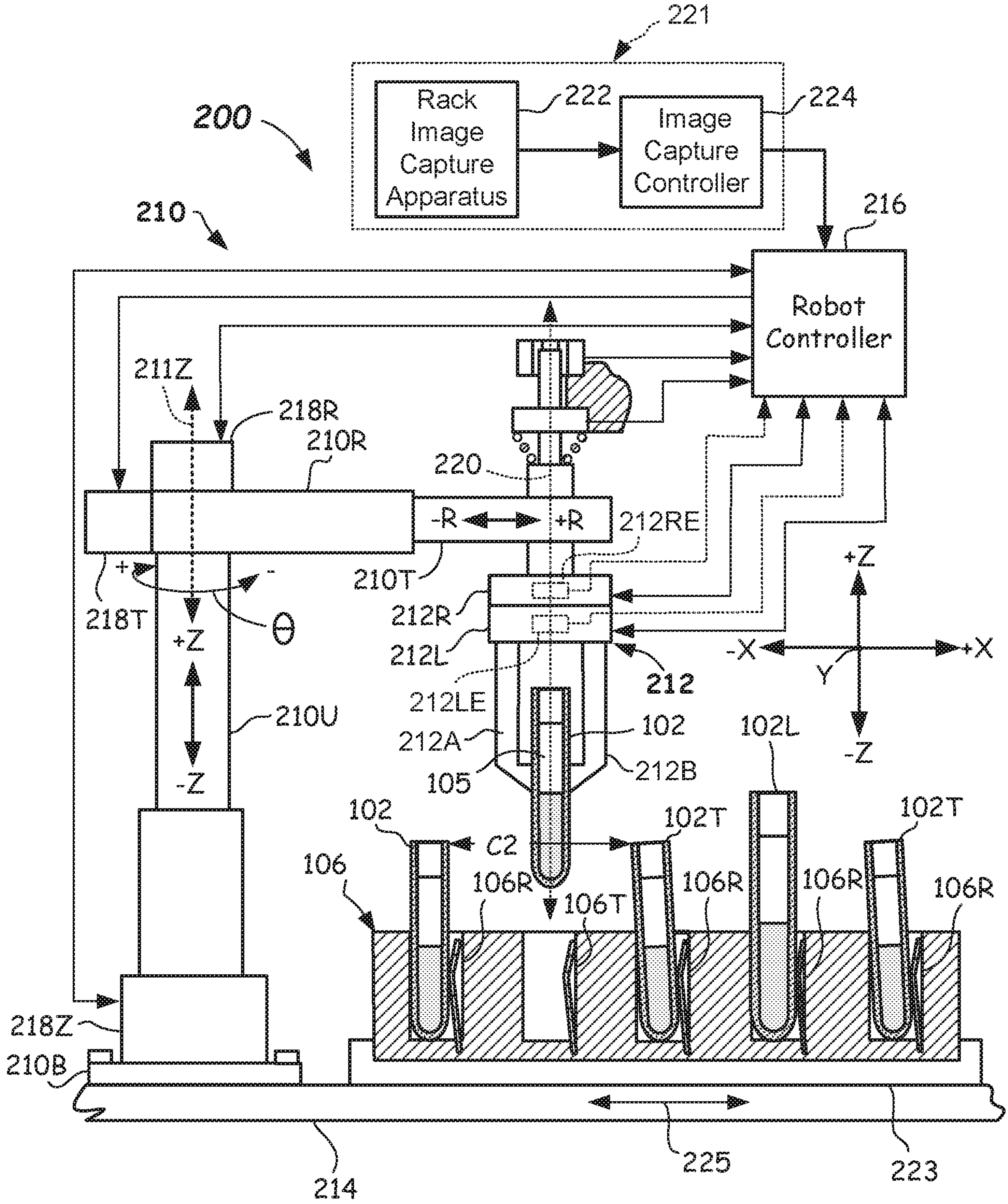


FIG. 1
Prior Art


221
200
Rack Image Capture Apparatus
222
Image Capture Controller
224
210
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Robot Controller
211Z
218R
210R
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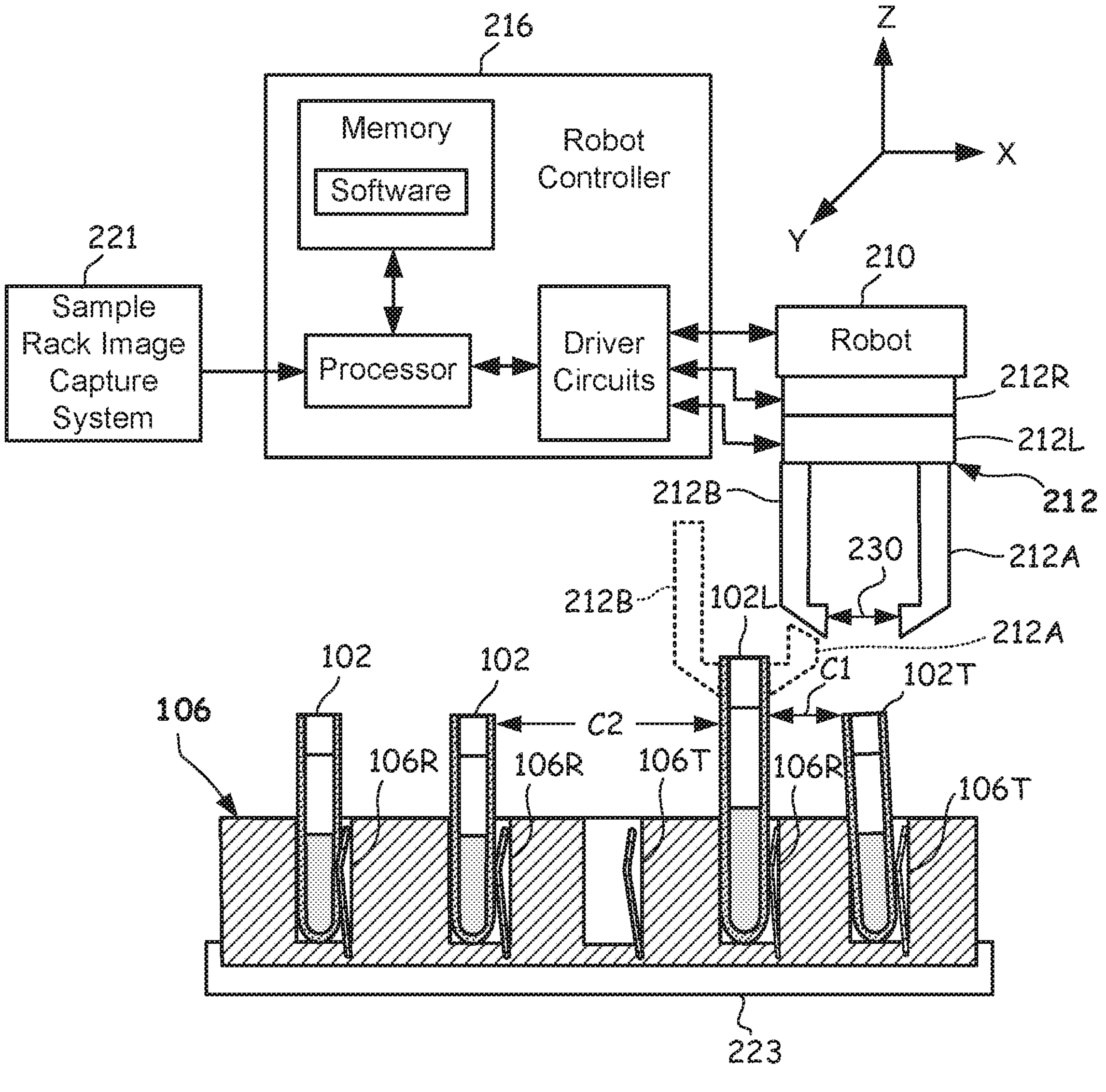
+R
212RE
+Z
218T
210T
θ
212R
-X
+X
Y
212L
212
-Z
212LE
210U
212A
102
102L
105
212B
C2
102T
106
106R
106T
218Z
210B
214
225
223

FIG. 2A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Memory
Software
Robot
Controller
Z
X
Y
221
Sample
Rack Image
Capture
System
Processor
Driver
Circuits
210
Robot
212R
212L
212
212B
230
212A
212B
102L
212A
C1
102T
102
102
C2
106
106R
106R
106T
106R
106T
223

FIG. 2B

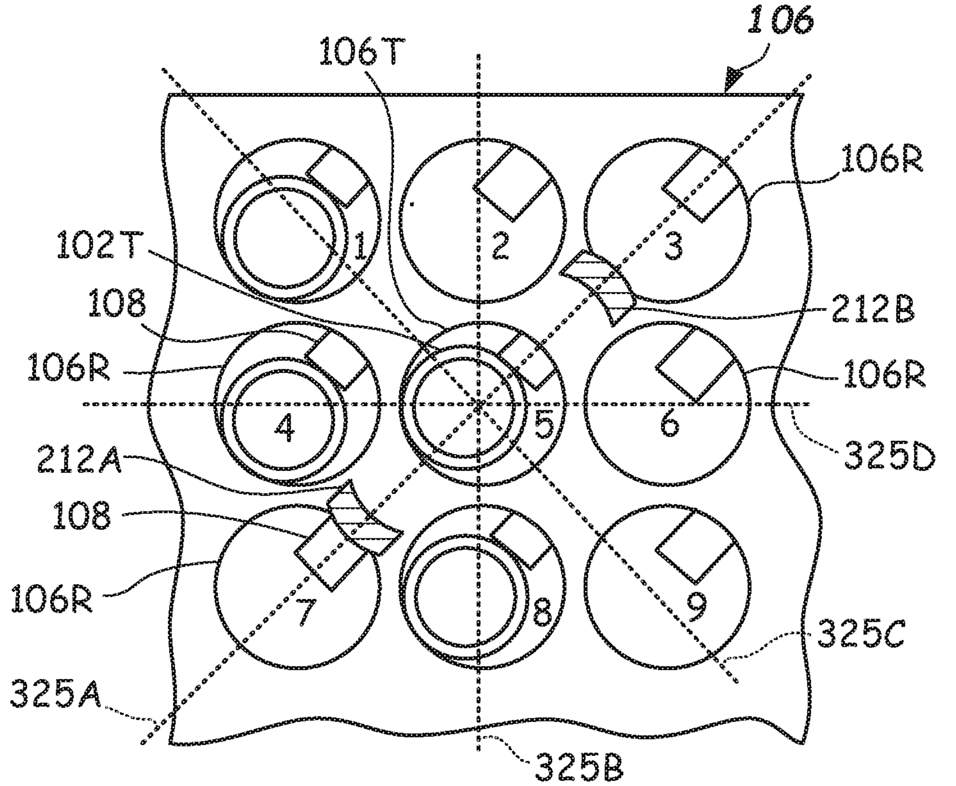
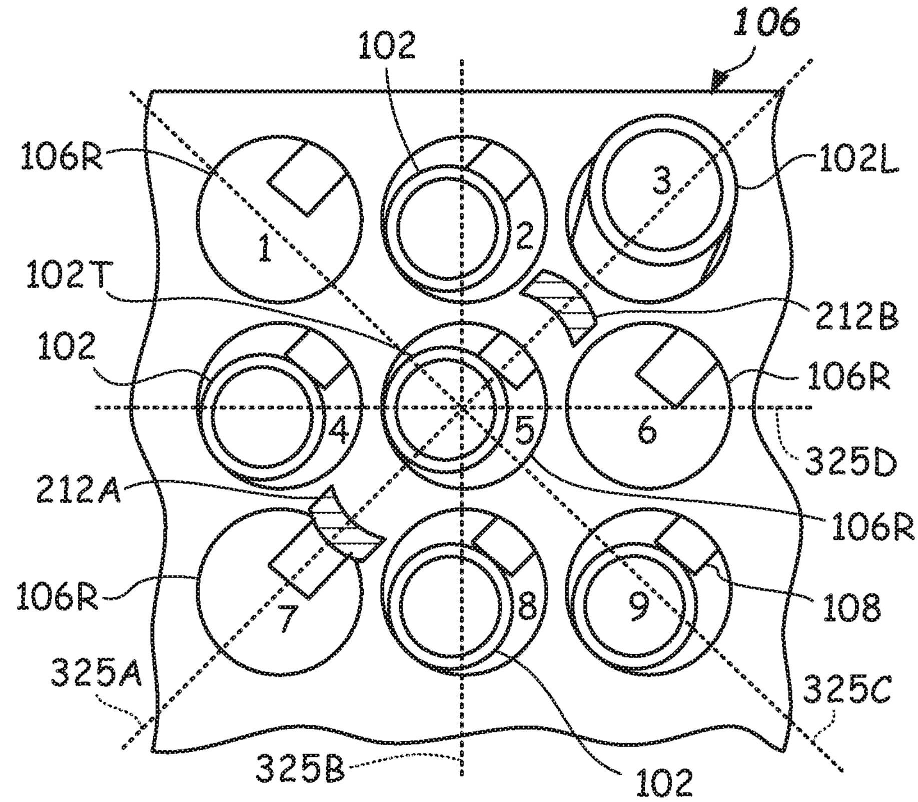

106
106T
106R
1
2
3
102T
212B
108
106R
4
5
6
106R
325D
212A
108
106R
7
8
9
325C
325A
325B

FIG. 3A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106R
102L
1
2
3
102T
212B
102
106R
4
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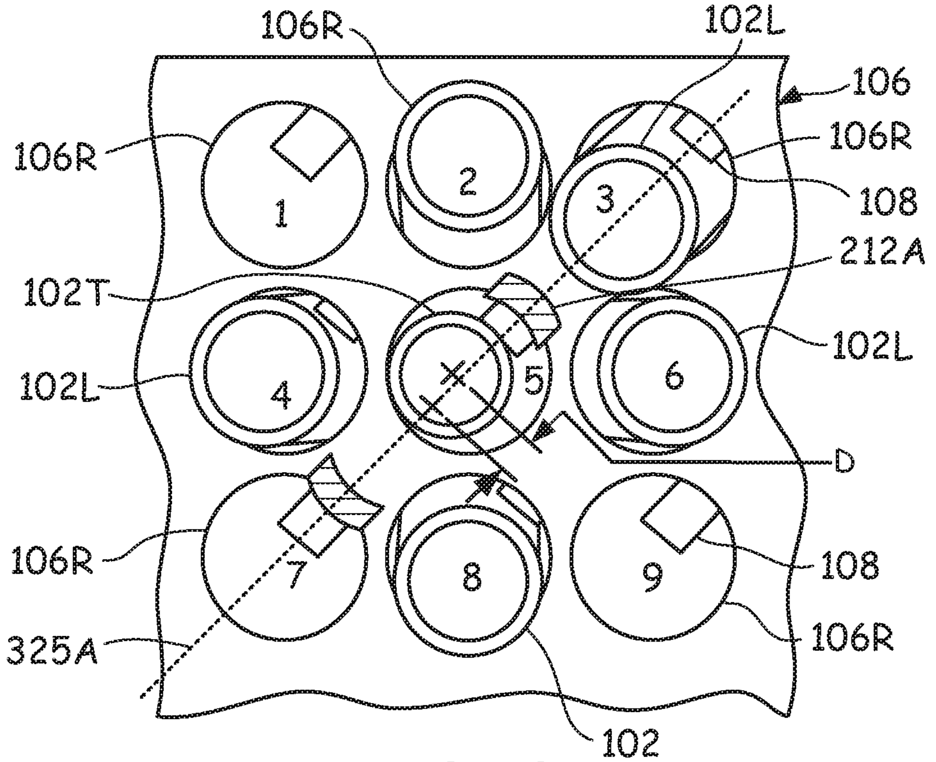
325D
212A
106R
106R
7
8
9
108
325A
325C
325B
102

FIG. 3B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102L
106
106R
108
212A
102T
102L
102L
D
106R
108
106R
325A
102
1
2
3
4
5
6
7
8
9

FIG. 3C

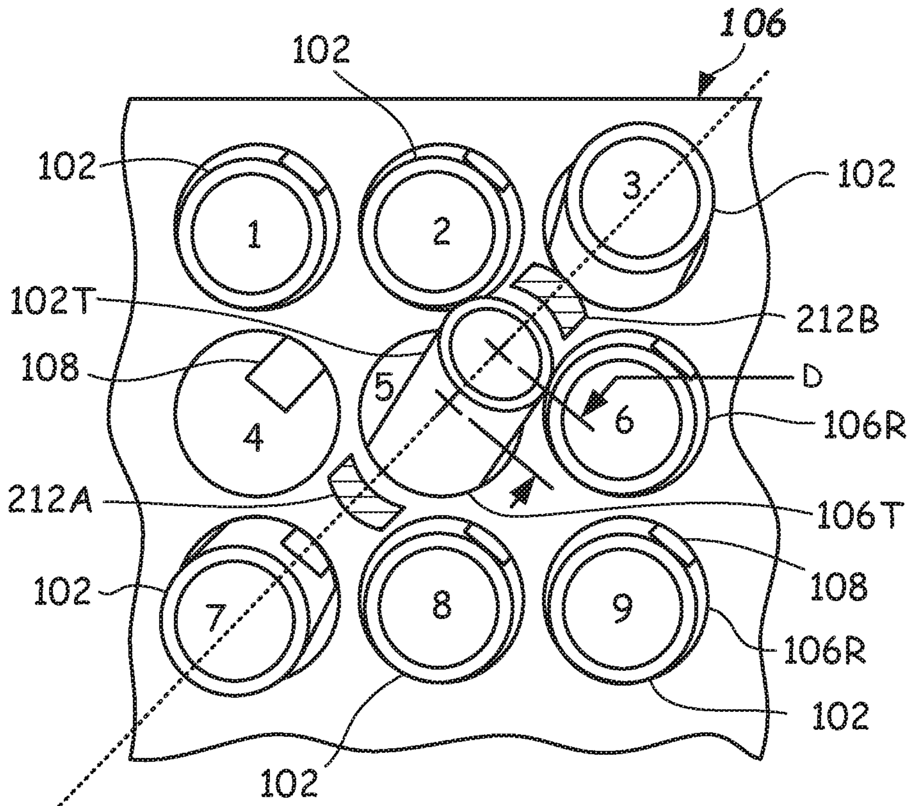
106
102
102
102
212B
102T
108
D
106R
212A
106T
108
102
106R
102
102
1
2
3
4
5
6
7
8
9

FIG. 3D

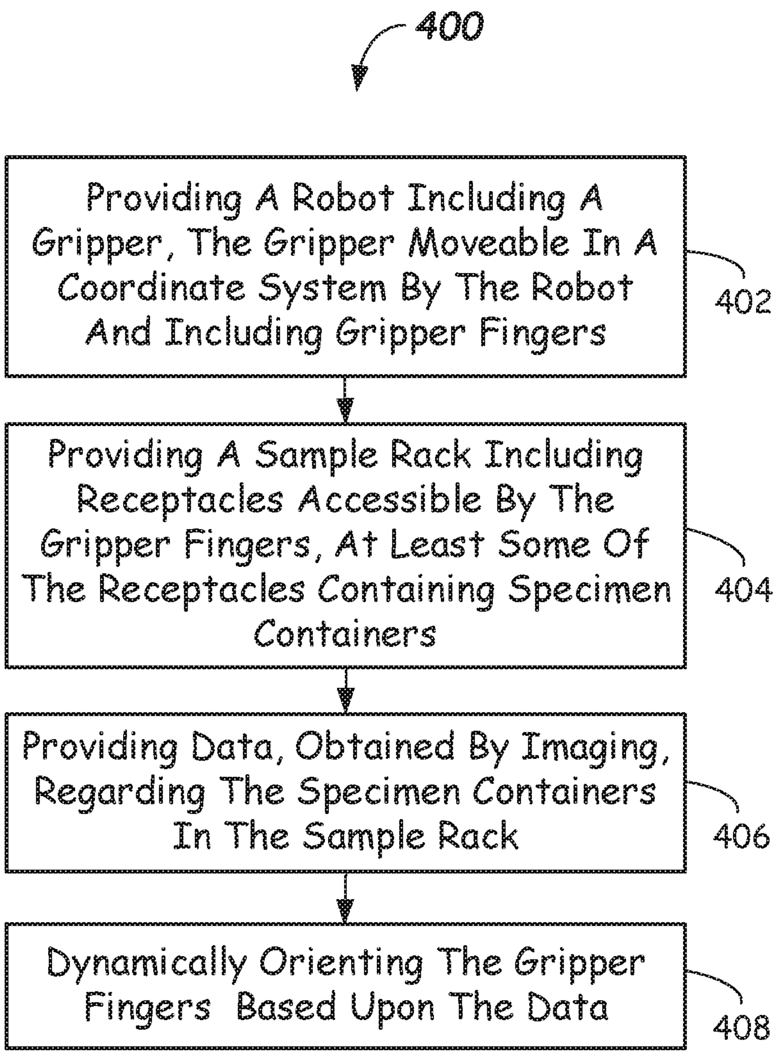
400
Providing A Robot Including A Gripper, The Gripper Moveable In A Coordinate System By The Robot And Including Gripper Fingers
402
Providing A Sample Rack Including Receptacles Accessible By The Gripper Fingers, At Least Some Of The Receptacles Containing Specimen Containers
404
Providing Data, Obtained By Imaging, Regarding The Specimen Containers In The Sample Rack
406
Dynamically Orienting The Gripper Fingers Based Upon The Data
408

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US17/39586

A. CLASSIFICATION OF SUBJECT MATTER
IPC - B25J 5/02, 9/16, 13/00, 15/08; G01N 35/00, 35/04 (2017.01)
CPC - B25J 9/1692; G01N 35/0099

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
See Search History document

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 -- Y -- A	US 2015/0142171 A1 (SIEMENS HEALTHCARE DIAGNOSTICS INC.) May 21, 2015; abstract; figure 1; paragraphs [0027]-[0042]	1-6, 14-16, 18-20 -------- 7-11, 13, 17 -------- 12
Y -- A	US 6293750 B1 (COHEN, B, et al.) September 25, 2001; column 16, line 55 – column 17, line 5; column 20, lines 7-40	7-8, 10-11, 17 -------- 12
Y -- A	WO 2000/038046 A1 (SMITHKLINE BEECHAM CORPORATION) June 29, 2000; page 18, lines 18-20	7-9 -------- 12
Y	US 2015/0003678 A1 (CANON KABUSHIKI KAISHA) January 1, 2015; abstract; paragraphs [0022], [0057]	13

☐ 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
31 August 2017 (31.08.2017)	29 SEP 2017

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

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G01N 35/04(2006.01)

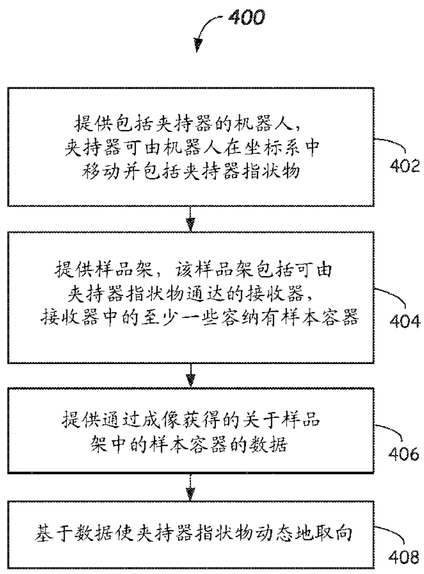
权利要求书2页 说明书11页 附图6页

(54)发明名称

基于样品架成像数据的用于机器人夹持器动态位置调整的方法和装置

(57)摘要

定位夹持器以从样品架拾取或放置样本容器的方法。一种方法包括:提供包括夹持器的机器人,该夹持器可由机器人在坐标系统中移动并且包括夹持器指状物;提供包括容纳有样本容器的接收器的样品架;提供通过成像获得的关于样品架中的样本容器的数据;以及根据该数据使夹持器动态地取向。数据可以包括群体数据和/或构造数据,并且动态取向可以包括夹持器指状物打开距离、夹持器指状物旋转位置和/或夹持器偏移距离。公开了用于执行该方法的夹持器定位装置以及其他方面。



CN 109414811 A

1.一种操作夹持器以拾取或放置样本容器的方法，所述方法包括：

提供机器人，所述机器人包括所述夹持器，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；

提供通过成像获得的关于所述样品架中的所述样本容器的数据；以及

基于所述数据使所述夹持器指状物动态地取向。

2.根据权利要求1所述的方法，其中，使所述夹持器动态地取向包括：使所述夹持器指状物打开基于所述数据所选择的可变距离。

3.根据权利要求1所述的方法，其中，使所述夹持器动态地取向包括：通过基于所述数据将所述夹持器指状物旋转到限定的旋转位置来选择夹持器作用线。

4.根据权利要求1所述的方法，其中，使所述夹持器动态地取向包括：基于所述数据来调整所述夹持器的X和Y位置。

5.根据权利要求1所述的方法，其中，所述数据包括关于所述样品架中的哪些接收器容纳有样本容器的群体数据。

6.根据权利要求1所述的方法，其中，所述数据包括关于目标接收器周围的哪些接收器容纳有样本容器的群体数据。

7.根据权利要求1所述的方法，其中，所述数据包括关于目标接收器周围的样本容器的构造数据。

8.根据权利要求7所述的方法，其中，所述构造数据包括以下中的一者或多者：管直径、管偏移、管高度和管类型。

9.根据权利要求7所述的方法，其中，所述构造数据包括目标样本容器的顶部相对于目标接收器的中心的偏移。

10.根据权利要求7所述的方法，其中，所述数据包括从样品架图像捕获系统生成的群体数据。

11.根据权利要求10所述的方法，其中，所述群体数据包括关于所述目标接收器周围的哪些接收器为空的数据。

12.根据权利要求11所述的方法，其中，如果确定了在所述目标接收器的相对两侧上的两个接收器是空的，则沿着连接所述两个接收器的作用线将所述夹持器打开至最大量。

13.根据权利要求1所述的方法，其中，调整所述夹持器的X和Y位置以提供与相邻样本容器的干涉最小的条件。

14.根据权利要求1所述的方法，其中，基于所述数据来调整所述夹持器的X和Y位置以及所述夹持器的打开程度。

15.根据权利要求1所述的方法，其中，基于修改的数据来决定在处理之后用于重新插入样本容器的接收器的选择。

16.一种夹持器定位装置，所述夹持器定位装置包括：

机器人，所述机器人包括夹持器，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,所述控制器包括通过成像获得的关于所述样品架中的所述样本容器的数据,并且被可操作地构造为致使所述夹持器指状物基于所述数据动态地取向。

17.根据权利要求16所述的夹持器定位装置,其中,所述数据包括关于所述样品架的接收器的群体数据、以及关于所述样本容器的构造数据。

18.根据权利要求16所述的夹持器定位装置,所述夹持器定位装置包括致动器,所述致动器联接到所述夹持器指状物,以致使所述夹持器指状物基于通过成像获得的数据打开到动态地确定的打开距离。

19.根据权利要求16所述的夹持器定位装置,所述夹持器定位装置包括旋转致动器,所述旋转致动器联接到所述夹持器指状物,以致使所述夹持器指状物基于通过成像获得的数据旋转到动态地确定的旋转取向。

20.一种夹持器定位装置,所述夹持器定位装置包括:

机器人,所述机器人包括夹持器,所述夹持器能够由所述机器人在坐标系中移动并且包括打开可变距离的夹持器指状物;

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

机器人控制器,所述机器人控制器被构造为接收通过成像获得的关于所述样品架中的样本容器的数据,并且被可操作地构造为使得所述夹持器指状物动态地取向以:

打开到如基于所述数据所确定的打开距离,

旋转到如基于所述数据所确定的旋转取向,或

移动到如基于所述数据所确定的x-y位置,以提供所述夹持器指状物与被容纳在所述样品架中的相邻样本容器之间干涉最小的条件。

基于样品架成像数据的用于机器人夹持器动态位置调整的方法和装置

[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62/362,532的优先权，所述文献的内容通过引用整体并入本文。

技术领域

[0002]　本公开涉及适于从用于处理生物液体的系统中的样品架拾取样本容器和/或将样本容器放置到用于处理生物液体的系统中的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(在本文中另外被称为“样本”)或与生物液体样品接触和/或可以显着提高生产率。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、瓶等)可以被运输到样品架(有时被称为“盒”)和从样品架被运输，以及被运输到测试或处理装置的测试或处理位置和从测试或处理装置的测试或处理位置被运输。

[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)。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)，并且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被降低到指定高度，并且然后闭合以抓取样本容器。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，朝向接收器被降低到控制的深度，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，样本容器可以被移动到样品架的多个接收器中和从样品架的多个接收器被移动。然而，为了最大化机器占用面积使用，样品架中的接收器间隔非常紧密。

[0006]　因此，寻求可以改进夹持器相对于测试和处理系统中的样品架的定位精度的方法和装置。

发明内容

[0007]　在第一实施例中，提供了操作夹持器以拾取或放置样本容器的方法。该方法包括：提供包括夹持器的机器人，夹持器可由机器人在坐标系中移动并包括夹持器指状物；提供样品架，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；提供通过成像获得的关于样品架中的样本容器的数据；以及基于数据使夹持器指状物动态地取向。

[0008] 在另一实施例中，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，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，该控制器包括通过成像获得的关于样品架中的样本容器的数据，并且被可操作地构造为使得夹持器指状物基于数据动态地取向。

[0009] 在系统方面，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，该夹持器可由机器人在坐标系中移动并且包括打开可变距离的夹持器指状物；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；以及机器人控制器，该机器人控制器被构造为接收通过成像获得的关于样品架中的样本容器的数据，并且被可操作地构造为致使夹持器指状物动态地取向以：打开到如基于数据所确定的打开距离，旋转到如基于数据所确定的旋转取向，或者移动到如基于数据所确定的x-y位置以提供夹持器指状物与被容纳在样品架中的相邻样本容器之间的干涉最小的条件。

[0010] 通过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，本公开的又其他方面、特征和优点将从下文的详细描述容易地显而易见。本公开还可以能够具有不同的实施例，并且可以在各个方面修改其多个细节，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2A示出了根据一个或多个实施例的被构造用于执行动态夹持器指状物定位的夹持器定位装置的示意性侧视图。

[0013] 图2B示出了根据一个或多个实施例的被构造用于执行动态夹持器指状物定位的夹持器定位装置的示意性侧视图，并且示出了系统的部件。

[0014] 图3A示出了根据一个或多个实施例的包括目标样本容器的样品架的局部俯视平面图，其中，夹持器指状物以夹持器指状物完全打开(分离达最大打开距离)的打开构造示出。

[0015] 图3B示出了根据一个或多个实施例的样品架的一部分的俯视平面图，其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。

[0016] 图3C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，其包括在接收器中偏移的目标样本容器，并且包括倾斜的一些周围的样本容器，并且其中夹持器指状物被打开到中间距离，但是其中夹持器指状物还在X-Y方向上偏移。

[0017] 图3D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，其包括在接收器中偏移并倾斜的目标样本容器，并且包括具有倾斜的样本容器的一些接收器，并且其中夹持器指状物处于被打开到中间量的构造。

[0018] 图4是示出根据实施例的将夹持器指状物定位到样本容器的方法的流程图。

具体实施方式

[0019] 在机器人中可能会在某些条件下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，自动化装载和卸载系统、离心机、冷藏区域)中实现机器人拾取和放置操作的机器人。

[0020] 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(例如，血液收集管)可以以敞顶(去盖)状态提供并且被填充有生物有害(bio-hazardous)液体(例如，血液、血清或血浆、尿液、间质流体、脑流体或其他身体流体)。样本容器102以近似竖直的取向被存储在样品架106内的接收器106R(一些被标记)中(样本容器102填充前两行半)。

[0021] 为了最大化设备占用面积的使用，样品架106的接收器106R可以非常接近地/紧密地间隔开。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的限定的侧壁(如所示出的)，所有这些同时在很大程度上维持样本容器的竖直取向。

[0022] 然而，由于样本容器102的机械公差和放置变化，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接收器106R中的真实竖直取向倾斜，因此导致理论上的完美管至管间隙的减小。此外，因为可能会经常在给定的设备上同时处理不同直径的样本容器102(例如，所示出的行3容纳有一些相对较大直径的样本容器102L)，所以在样品架106中的相邻的样本容器102、102L之间的间隙可以基于管尺寸、管倾斜和/或在接收器106R中的不适当定位而从接收器106R到接收器106R不同。类似地，对于装载和卸载过程的一些或全部，一些接收器106R可以是空的。

[0023] 接收器106R的紧密间隔与IVD设备的高吞吐量的目标相组合，可能会导致在夹持器指状物212A、212B与样本容器102之间的、或在被放置的样本容器102与另一样本容器102之间的偶然的不希望的接触(例如，堵塞、碰撞和/或震动)，如上文所讨论的。这种接触可能会减慢自动化处理，因为由接触造成的损坏可能必须通过操作员手动干预来校正。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。

[0024] 不相关的附加问题是，当目标样本容器102被放置在接收器106R中与弹簧108接触、并且夹持器指状物被打开时，样本容器102可能被推挤并且由弹簧108施加的力可能会将样本容器102向侧面推动成与接收器106R的壁接触，这可能会导致在样本容器中的样本飞溅。

[0025] 在现有技术中，对于所有样本容器102和接收器106R，夹持器指状物的打开已被设定为恒定值，其中，在考虑夹持器指状物宽度、所有预期管尺寸、可能的放置变化和接收器106R间隔的情况下选择恒定值。对于拾取和放置操作，夹持器可以被定位在接收器106R的中心上方并且在夹持器被打开至其最大设定的情况下被降低以拾取或放置样本容器102。在现有技术中可以通过挤压传感器来检测堵塞，该挤压传感器基于超过所监测的阈值的值(诸如，马达电流)来检测竖直堵塞。类似地，可以提供碰撞传感器以感测高于阈值的值的水平接触。

[0026] 鉴于前述内容，本公开的一个或多个实施例提供了用于基于样品架106成像数据

来设定夹持器指状物的控制的打开程度(夹持器指状物打开距离)的方法和装置。成像数据可以包括群体(填充,population)数据和/或构造数据。群体数据是关于特定目标接收器106R周围的相邻样本容器102的存在或不存在的数据。如本文所使用的“目标接收器”是指已经被选择成在其处经历操作的接收器106R,所述操作诸如是目标样本容器102拾取或放置操作。如本文所使用的“目标样本容器”是已经被选择成经历拾取或放置的样本容器102。构造数据是关于目标接收器106R周围的样本容器102的取向和/或尺寸以及目标样本容器102的取向和/或尺寸的数据。

[0027] 根据一个或多个实施例,可以针对每个拾取或放置操作动态地改变夹持器指状物打开的程度。可以响应于特定目标样本容器的群体和/或构造数据来动态地选择该变化。在另一实施例中,对于每个拾取或放置操作,基于群体数据和/或构造数据,夹持器以及因此夹持器指状物的X和/或Y定位可以动态地改变并且偏离于名义中心位置。以这种方式,夹持器定位可以被偏移以应对样本容器在接收器中的偏移。在又另一实施例中,可以基于群体数据和/或构造数据针对每个拾取或放置操作来动态地改变夹持器指状物的旋转定位/取向。如本文所使用的短语“动态地改变”意味着对于每个特定的样本容器拾取或放置操作,夹持器的参数中的一个或多个(夹持器指状物打开距离、夹持器偏移和/或夹持器指状物旋转取向)被调整以有利于在夹持器指状物与周围的样本容器或被拾取的样本容器之间的合适间隙。

[0028] 根据一个或多个实施例的方法和装置可以动态地确定控制的打开距离、X和Y夹持器位置和/或夹持器指状物的旋转取向。动态确定考虑样品架106中的样本容器102的群体数据和/或样品架106中的样本容器的构造。

[0029] 例如,方法和装置可以考虑群体数据,诸如,周围的接收器106R是否容纳有样本容器102。类似地,一个或多个实施例可以考虑构造数据,所述构造数据关于周围的样本容器102中的一个或多个的尺寸(例如,直径和/或高度)、周围的样本容器102中的一个或多个在X和Y上的偏移、或者在待拾取的目标样本容器102的情况下目标样本容器102的尺寸(例如,直径和高度)和/或目标样本容器102是否倾斜,即,在X和/或Y上偏移。

[0030] 这种动态地调整夹持器指状物打开程度和/或在X和Y上的名义夹持器位置和/或夹持器指状物旋转取向的能力可以显着降低接触(例如,堵塞、碰撞和/或震动)的倾向,并且因此减少损坏和/或溢出。这可以减少IVD仪器停机时间。

[0031] 本文将参考图2A-图6描述本公开的实施例的这些方面和其他方面和特征。

[0032] 根据一个或多个第一装置实施例,如图2A和图2B中最佳地示出的那样,描述了夹持器定位装置200。夹持器定位装置200包括机器人210,其可用于抓取目标样本容器102T(诸如,血液收集管,瓶等)并将目标样本容器102T从第一位置传送到第二位置。夹持器定位装置200可以在任何合适的传送装置或系统或测试仪器或设备中使用,诸如,实验室自动化系统(LAS)、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,样本容器102被移动到样品架106或从样品架106被移动。在一个或多个实施例中,测试仪器或设备可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)。

[0033] 机器人210包括联接到机器人210的可移动部分的夹持器212。例如,机器人210可以是R、θ、Z机器人并且可以包括:基座210B,基座210B可以联接到测试仪器或其他设备的框架214;直立部分210U,其被构造为竖直地移动(沿+Z和-Z方向);伸缩部分210T,其被构造为

径向地移动(沿+R和-R方向);以及旋转部分210R,其被构造为围绕竖直轴线211Z旋转地移动(沿+θ和-θ方向)。如本文所使用的"夹持器"意味着联接到机器人部件(例如,联接到机器人臂等)的任何部件,其在机器人操作中(诸如,在拾取和放置操作中)被使用以抓取物品(例如,样本容器102)并将物品从一个位置移动到另一位置。

[0034] 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,并且可彼此相对。夹持器指状物212A、212B适于抓取物品,诸如,样本容器102(例如,血液收集管)。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驱动以打开和闭合到限定的打开距离。特别地,夹持器指状物212A、212B可以沿X-Y平面中的任何合适方向(例如,沿X或Y方向或其组合)打开和闭合,如在一些实施例中,可以提供旋转致动器212R,该旋转致动器被构造为将夹持器指状物212A、212B旋转到任何旋转位置/取向。因此,夹持器指状物212A、212B的打开和闭合的作用线能够被旋转以与样品架106上的如下区域一致:基于通过成像获得的群体和/或构造数据,该区域具有更多空间包络(space envelope)或间隙。如所示出的,Y方向进出纸张。

[0035] 夹持器指状物212A、212B的打开和闭合可以通过致动机构212L来实现,致动机构212L可以是联接到夹持器指状物212A、212B的电动、气动或液压伺服马达等。可以使用用于引起指状物212A、212B的夹持动作的其他合适的机构。同样地,在提供了旋转能力的一些实施例中,旋转致动器212R可以被构造为使夹持器指状物212A、212B围绕夹持器轴线220旋转。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编码器212LE和/或旋转编码器212RE以提供关于相对于校准的参考或归零位置的夹持器指状物212A、212B的旋转取向和/或夹持器指状物212A、212B的打开程度的位置反馈。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的夹持器212。也可以使用其他夹持器类型。机器人210可以是能够在空间(例如,三维空间)中移动夹持器212以便移动样本容器102的任何合适的机器人部件。

[0037] 在一个或多个实施例中,机器人210可以例如具有旋转马达218R,旋转马达218R适于在旋转方向(例如,+/-θ)上将旋转部分210R旋转到控制的角度取向。机器人210还可以包括联接到直立部分210U的竖直马达218Z,其可以适于在竖直方向上移动夹持器212(例如,沿着在+/-Z方向上的竖直轴线211Z,以虚线示出)。在一个或多个实施例中,机器人210可以包括平移马达218T,其适于施加联接到旋转部分210R的夹持器212的平移运动(例如,沿+/-R方向)。然而,尽管示出了R、θ、Z机器人,但是可以提供用于施加X、Y、R、θ和/或Z运动或其他组合的其他合适的机器人类型、机器人马达和机构。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,从位置和/或旋转编码器。可以使用门架(gantry)机器人,其中,门架横梁可沿X移动,并且夹持器212可相对于门架横梁沿Y和Z(并且可能围绕Z)移动。

[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的三维坐标运动(X、Y和Z),使得样本容器102可以被放置在样品架106的接收器106R中或从样品架106的接收器106R被移除、或被放置在测试或处理设备中的其他位置中或从处理设备中的其他位置被移除。特别地,可以调整夹持器212的X和Y位置,以提供夹持器指状物212A、212B与被容纳在样品架106中的相邻样本容器102之间的干涉最小的条件。

[0039] 机器人控制器216可以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、以及夹持器指状物212A、212B的打开程度和/或旋转取向。此外,机器人控制器216可以包括合适的通信能力以接收或访问来自样品架图像捕获系统221的数据。在功能上,机器人控制器216可以被构造为从样品架图像捕获系统221接收通过成像获得的、关于被容纳在样品架106中的样本容器102的数据。此外,如将从下文显而易见的,机器人控制器216可以被可操作地构造为使得夹持器指状物212A、212B动态地取向。动态取向可以是:打开到如基于数据所确定的打开距离230(图2B);旋转到如基于数据所确定的旋转取向;或者移动到如基于数据所确定的x-y位置以提供夹持器指状物212A、212B与被容纳在样品架106中的相邻样本容器102之间干涉最小的条件。

[0040] 再次参考图2A和图2B,样品架图像捕获系统221可以被设置在夹持器定位装置200中。样品架图像捕获系统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可以是合适的数字相机,并且可以被放置在这样的任何合适的位置处:在该位置处,能够获得从多个视角示出样品架106的样品架106的多个图像。例如,架图像捕获装置222可以被放置在可移动样品架装载抽屉223上方。样品架106可以由可移动样品架装载抽屉223支撑并且相对于框架214被移动(如由方向箭头225所示出)到测试或处理设备中到达可由机器人210通达的位置。在该移动期间,架图像捕获装置222可以从各个视角采集样品架106的顶部的多个数字图像。例如,可以以三个或更多个不同的视角获得三个或更多个图像。

[0041] 从这些多个数字图像中,被存储在图像捕获控制器224中的图像处理软件可以接收并处理图像数据以及基于成像产生数据。数据可以包括关于驻留于样品架106中的样本容器102的量、尺寸和取向的构造数据和/或群体数据。机器人控制器216可以经由电子通信访问群体数据和/或构造数据,并且基于成像的数据可以用于确定和设定以下中的一者或多者:1)夹持器指状物212A、212B的打开距离,2)夹持器指状物212A、212B的旋转取向,和/或3)当执行样本容器拾取或放置操作时,夹持器212在X、Y和/或Z上的放置。

[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捕获的图像并控制机器人210的操作,包括控制夹持器212的X和Y位置、夹持指状物212A、212B的打开距离和/或夹持指状物212A、212B的旋转取向。

[0043] 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以下中发现:2014年3月14日提交的Pollack等的题为“Tube Tray Vision System”的美国专利公布US2016/0025757号;German等的题为“Automation Tube Positioning Methodology”的美国专利公布US2015 / 0355208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。

[0044] 更详细地,图像捕获控制器224可以接收来自多个视角的图像并处理所述图像。可以通过如下来执行图像处理:采集每个图像并识别其中的几何特征,诸如,样本容器的顶部以及接收器位置和状态,并且然后通过对像素计数来确定样本容器顶部的偏移和尺寸。从处理中,还可以获得关于样品架106的群体的细节。例如,每个接收器106R可以基于其在样品架106上的列和行位置(见图1)被分配独有的槽代码,诸如A1、A2、A3等。图像处理软件可以基于图像来确定群体数据,该群体数据关于哪些接收器106R为空的、以及哪些接收器106R容纳有样本容器102。该群体数据可以被存储在图像捕获控制器224的存储器中的数据库中,并且可以被机器人控制器216访问或以其他方式被传送到机器人控制器。

[0045] 同样地,图像捕获控制器224中的处理软件可以处理图像并从中提取各种构造数据。构造数据可以包括,例如,样本容器102的顶部的最大外直径、高度、以及相对于样本容器102被插入到其中的接收器106R的样本容器102的顶部X和Y中心位置,其中,这种构造数据可以在数据库中与独有的槽代码相关,并且可以在稍后用于定位夹持器212中以便实现最小干涉。

[0046] 根据本公开的另一实施例,并且如图4中所示出,提供了操作夹持器(例如,夹持器212)以拾取或放置样本容器(例如,样本容器102、102T、102L)的方法400。在402中,该方法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),该夹持器可由机器人在坐标系(例如,X、Y、Z坐标系)中移动并且包括夹持器指状物(例如,夹持器指状物212A、212B),该夹持器指状物可以选择性地打开和闭合并且可以被设定至可变的打开距离230(图2B)。打开距离230可以在于适于接触并夹持样本容器102的夹持器指状物212A、212B的样本容器内接触表面之间测量的从最小打开距离到最大打开距离的范围内。在一些实施例中,打开距离230可以包括一个或多个中间打开距离值。例如,打开距离230可以在约8 mm至约20 mm之间的范围内。可以使用其他打开距离。夹持器指状物212A、212B之间的打开距离可以由来自机器人控制器216的至致动机构212L的信号控制。例如,在一个实施例中,打开距离可以被设定成预先选择的小的、中等的(中间的)、或者大的打开距离230,或者基于沿着特定作用线325的条件和可用空间被设定成自定义打开距离230。

[0047] 在404中,方法400包括提供样品架(例如,样品架106),其包括可由夹持器指状物(例如,夹持器指状物212A、212B)通达的接收器(例如,接收器106R),其中,接收器中的至少一些容纳有样本容器(例如,样本容器102、102T、102L)。可通达意味着夹持器212能够被机器人210移动足够的距离以到达接收器106R以从接收器106R中拾取目标样本容器102T或将目标样本容器102T放置在接收器106R中。

[0048] 在406中,方法400还包括提供通过成像获得的关于被容纳在样品架(例如,样品架106)中的样本容器的数据。特别地,在一个或多个实施例中,该数据可以包括群体数据,该群体数据关于样品架106中的哪些接收器106R容纳有样本容器102,并且更具体地,目标接收器106T周围的哪些接收器106R容纳有样本容器102。基于成像的数据还可以包含关于哪些接收器106R为空的数据,并且特别地,群体数据包括关于目标接收器106T周围的哪些接收器106R为空的数据。

[0049] 在一个示例中,如果确定在目标接收器106T的相对两侧上的两个接收器106R是空的,如图3A中所示出,则夹持器指状物212A、212B沿着连接两个接收器106R的所选择的作用线(例如,作用线325A)被打开到最大量。在一些实施例中,诸如当夹持器212不可旋转时,一

个作用线(例如,作用线325A)是可用的。在其他实施例中,如果另一作用线包括如由任何处理方法所确定的较高可用间隙,则机器人控制器216可以选择另一作用线。然而,在一些实施例中,只要发现满足目标样本容器102T的每侧上的最小间隙值的一个作用线,则将简单地开始拾取操作。

[0050] 在图3A中,一种方法可以根据排序方案对可用的作用线(例如,325A-325D)进行排序。排序最高的作用线可以被选择为理论上具有夹持器指状物212A、212B的最高间隙的作用线。例如,如果作用线包括在目标接收器的相对两侧上的两个空接收器,那么该作用线被给定高排序。即使在包括在目标接收器106T的相对侧上的两个空接收器106R的作用线(例如,325A、325D)当中,也可以进行关于作用线是相对于样品架206的行的对角线还是沿着该行或垂直于该行的排序,其中,行的对角线接收相对较高的排序,这仅仅是因为存在更多的可用间隔。类似地,如图3B中所示出,在所有其他条件相同的情况下,相对于具有两个样本容器的作用线(例如,325B),具有在目标接收器的一侧上的一个样本容器102的作用线(例如,325D)可以被给定更高的排序。

[0051] 在一个或多个实施例中,数据可以包括构造数据。在拾取操作的情况下,构造数据是关于目标接收器106T周围的样本容器102的构造的数据,包括关于目标接收器106T中的目标样本容器102T的数据。在拾取操作的情况下,构造数据可以包括目标样本容器102T周围的样本容器102中的每个的最大直径,并且可以包括目标样本容器102T的最大直径。构造数据还可以包括接收器106R(包括目标接收器106T)的位置。

[0052] 例如,样本容器可以被识别为小的、中等和/或大的。例如,小的可以包括约10 mm的直径,中等可以包括约13 mm的直径,并且大的可以包括约16 mm或17 mm的直径。可以使用和确定其他已知尺寸,诸如,通过识别样本容器的圆形顶部并且然后对像素计数以获得直径估计来实现。Pollack等的美国专利申请2016/0025757号描述了“管托盘视觉系统(Tube Tray Vision System)”,其可操作以通过成像获得关于群体和构造的信息。German等的美国专利公布2105/0355208描述了“自动化管定位方法(Automation Tube Positioning Methodology)”,并且特别是确定管偏移的方法。视觉系统的进一步的信息可以在以下中发现: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。

[0053] 构造数据可包括目标样本容器102T周围的样本容器102的高度(对于放置操作)或目标接收器106T中的目标样本容器102T高度(对于拾取操作)。可以沿着通过目标样本容器102T或目标接收器106T可能的作用线测量偏移。

[0054] 通过成像获得的构造数据可以包括样本容器102是否在接收器106R中的特定接收器中在(一个或多个)方向上偏移。例如,构造数据可以包括样本容器102是由于相对于它们相应的接收器106R远离目标接收器106T(对于放置操作)倾斜而偏移还是由于相对于它们相应的接收器106R朝向目标接收器106T倾斜而偏移。对于拾取操作,构造数据还可以包括

目标样本容器102T在目标接收器106T内的偏移，并且在一些实施例中，可以确定并提供目标样本容器102T的对应顶部部分与周围的样本容器102之间的偏移距离。在目标接收器106T中的放置操作中，可以确定沿着每个作用线的相应样本容器之间的间隙距离。

[0055] 如图2B中所示出，在拾取操作的情况下，构造数据可以包括关于目标样本容器102T和任何周围的样本容器102(例如，样本容器102L)的构造的数据，并且特别是从目标样本容器102T沿着适用于特定类型的夹持器212的可能的作用线中的一个或多个的间隙值C1。例如，一些类型的夹持器212可以包括单个作用线，其可以相对于样品架的行沿着45度角度。

[0056] 在其他实施例中，通过利用旋转致动器212R将夹持器指状物212A、212B旋转到另一作用线，夹持器指状物212A、212B可以包括多个作用线。在一些实施例中，如图2B中所示出，间隙值C1是目标样本容器102T的位置与样本容器102(例如，大样本容器102L)中周围的一个之间的距离。在操作是放置操作的情况下，则间隙C2是沿着一个或多个作用线在目标接收器106T的相对两侧上的相应样本容器102之间的距离。

[0057] 再次参见图4，为了执行拾取操作，方法400可以包括将夹持器(例如，夹持器212)移动到目标接收器(例如，目标接收器106T)上方的位置。该位置可以在容纳有目标样本容器102T的目标接收器106T的先前校准的位置上方。可选地，可以基于通过影像获得的构造数据来使夹持器212在X和Y中的位置在目标样本容器102T的顶部的偏移中心上方居中。在408中，夹持器指状物(例如，夹持器指状物212A、212B)可以动态地打开到基于通过成像获得的数据选择的控制的打开距离230(图2B)。夹持器指状物212A、212B可以沿着作用线被打开到控制的打开距离230，并且然后夹持器212可以被移动到目标接收器106T上方，或者夹持器212可以被移动并且夹持器指状物212A、212B可以沿着作用线被打开到控制的打开距离230。如果夹持器212具有单个作用线(即，是不可旋转的)，则夹持器212可以通过致动机构212L沿着该单个作用线动态地打开。

[0058] 如果夹持器212是具有旋转能力的类型，则可以使用旋转致动器212R将夹持器212旋转到穿过目标样本容器102T的作用线之一，并且在这样的旋转之前抑或之后动态地打开。所寻求的作用线的选择可以通过任何合适的方案来实现，诸如开始和测试，或通过调查和排序各种可能性来实现。开始和测试可以包括选择第一作用线并对其进行测试以查看对于每个夹持器指状物212A、212B是否可获得最小间隙。调查和排序可以通过如下来实现：调查所有可能的作用线和可获得的间隙、并且然后根据哪个作用线具有最高间隙来对它们进行排序。可以选择具有最高间隙的作用线。

[0059] 如本文使用的术语“动态地”意味着基于通过成像获得的数据来针对每个目标接收器106T确定并设定夹持器指状物212A、212B的打开距离230，其中，目标接收器106T是这样的特定接收器：从目标接收器106T中拾取目标样本容器102T或将目标样本容器102T放置到目标接收器106T。

[0060] 通过对包括被容纳在其中的接收器106R中的多个样本容器102、102T、102L的样品架106进行成像来获得数据。成像可以在任何有利的时间进行，诸如，当最初将样品架106装载到设备中时，经由被安装在装载区域上方的一个或多个架图像捕获装置222(例如，数字相机)来进行。然而，在一些实施例中可以在样品架106已经停留在其最终位置中时进行成像。一个或多于一个的架图像捕获装置222(例如，一个或多个数字相机等)可以用于从不同

的视角或姿态捕获多个图像。

[0061] 可以从存储在图像捕获控制器224的存储器中的数据库或者从存储在机器人控制器216的存储器中的数据库检索数据，该机器人控制器已经从图像捕获控制器224接收数据。在一些情况下，单个处理器可以执行机器人控制功能以及数字成像和图像处理两者。如上文所描述，通过成像获得的数据可以包括群体数据、构造数据或群体数据和构造数据两者。

[0062] 如图3A和图3B中所示出，针对每个目标接收器106T，方法400可以调查一个或多个可能的作用线（例如，作用线325A、325B、325C、325D）以确定沿着该所调查的作用线是否存在最小间隙。最小间隙可以沿着作用线（例如，沿着作用线325A、325B、325C、325D）并且在目标样本容器102T的最接近部分与任何周围的样本容器102之间测量，所述周围的样本容器诸如沿着作用线被定位在目标样本容器102T的任一侧上的那些周围的样本容器102。在目标样本容器102T的任一侧上的间隙距离可以不同。从对角线作用线（例如，作用线325A）开始，如果存在最小间隙，则夹持器指状物212A、212B可以通过动态地打开到确定的打开距离来执行拾取操作。

[0063] 然而，如果在目标样本容器102T的两侧上可获得超过最小间隙，则夹持器指状物212A、212B可以打开相对较大的距离，因此最小化与目标样本容器102T的可能接触。图3A示出了样品架106中的群体，其中被标记为2、3、6、7和9的接收器106R是空的，并且标记为1、4、5和8的接收器106R是满的，并且其中目标样本容器102T在目标接收器106T中且被标记为5。软件应用程序可以调查可用的作用线并确定对角线作用线325A是最佳的并且允许夹持器指状物212A、212B的最大打开距离230。其他作用线（例如，325B、325C、325D）可以被软件认为是次优的，因为除了目标样本容器102T之外，它们还容纳一个样本容器102。

[0064] 在类似图3B中所示出的情况下，除了目标样本容器102T之外，所有作用线（例如，325A-325D）沿着作用线包括一个或两个另外的样本容器102。在这种情况下，在一些实施例中，可以选择对角线作用线（例如，325A、325C）而不是非对角线作用线（例如，325B、325D）。包括两个样本容器102的那些作用线（例如，作用线325B）可以被给予低排序次序。如果在两个可接受的作用线之间，则可以选择带有具有从目标样本容器偏移远离（例如，倾斜远离）的构造的样本容器102L的那个作用线（例如，作用线325A）。一旦从可用的作用线中选择了作用线，就可以基于如基于成像数据所确定的可用间隙来将夹持器指状物打开到控制的打开距离230。

[0065] 在基于校准数据抑或成像，目标样本容器102T从目标接收器106T的确定的中心位置偏移的情况下，则机器人210可以被定位在一X和/或Y位置处使得夹持器212在目标样本容器102T的顶部上方居中。然而，在一些情况下，如图3C和图3D中所示出，夹持器212可以在X和/或Y方向上进一步偏移如沿着作用线325A所测量的偏移距离D。如图3C和图3D中所示出，夹持器轴线220被定位成偏离于目标样本容器102T的顶部的中心位置。这可以在倾斜的样本容器102L（诸如，被示出为在接收器106R中并且被标记为3的）之间提供额外的间隙，其中，样本容器102L朝向目标样本容器102T倾斜。

[0066] 如图3D中所示出，可以在目标样本容器102T倾斜时提供偏移距离D，以便首先使目标样本容器102T与夹持器指状物212A、212B中的单独的夹持器指状物接触，这可以将目标样本容器102T带入直立构造。例如，偏移距离D可以沿着所选择的作用线远离目标样本容器

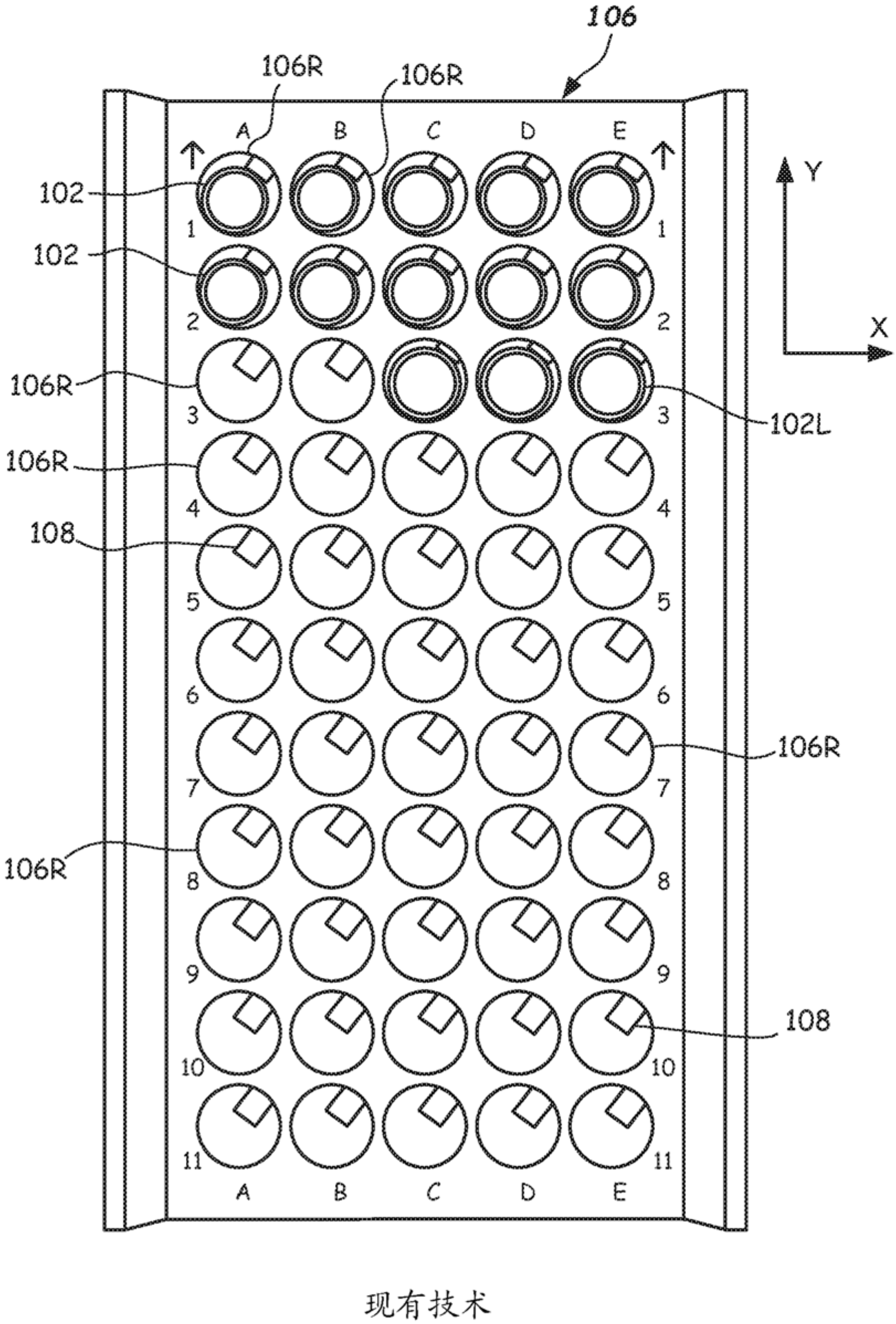
102T的顶部的中心，但是朝向目标接收器106T的中心。可变指状物打开距离230、指状物旋转取向和在x和/或y上的偏移距离D的组合可以用于目标样本容器102T的任何特定拾取或目标样本容器102T到目标接收器106T中的放置。

[0067] 在一些实施例中，构造数据包括管高度和/或管类型。例如，通过成像获得的管高度数据可以用于确定夹持器212并且因此夹持器指状物212A、212B应当在负Z方向上被移动多深以便执行拾取操作。管高度数据还可以用于允许在抓取刚刚从目标接收器106T拾取的目标样本容器102T到下一目的地(例如，到样本容器载体)时在没有碰撞但是不必将目标样本容器102T升高到最高的样本容器102L上方的情况下操纵夹持器212。在一些情况下，可以通过抓取大样本容器102L来完全避免由夹持器指状物212A、212B导致的潜在接触，基于通过在相邻的较小样本容器102的顶部竖直上方的位置处成像而获得的数据来识别该大样本容器。

[0068] 在其他情况下，可以基于成像数据和/或夹持器数据来辨别管类型。例如，在一些实施例中，可以在样本容器102中提供管顶样本容器。成像数据可能指示大直径样本容器102，但是来自线性编码器212LE(图2A)的夹持器反馈数据可能指示小直径样本容器102。然而，这两个数据一起可以指示管顶样本容器存在于目标样本容器102T中。

[0069] 通过成像获得的数据还可以用于帮助选择用于在样本容器从处理返回之后放置样本容器102R的接收器106R。因为群体数据是最初已知的，所以可以追踪移除和重新插入的历史以得出关于样品架106的群体的修改的数据。如此，可以基于修改的数据来选择用于目标样本容器102T的重新插入的位置。

[0070] 虽然已经通过本文详细描述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
106R
106R
A
B
C
D
E
102
102
106R
106R
108
106R
106R
102L
106R
108
Y
X
1
2
3
4
5
6
7
8
9
10
11

现有技术

图 1

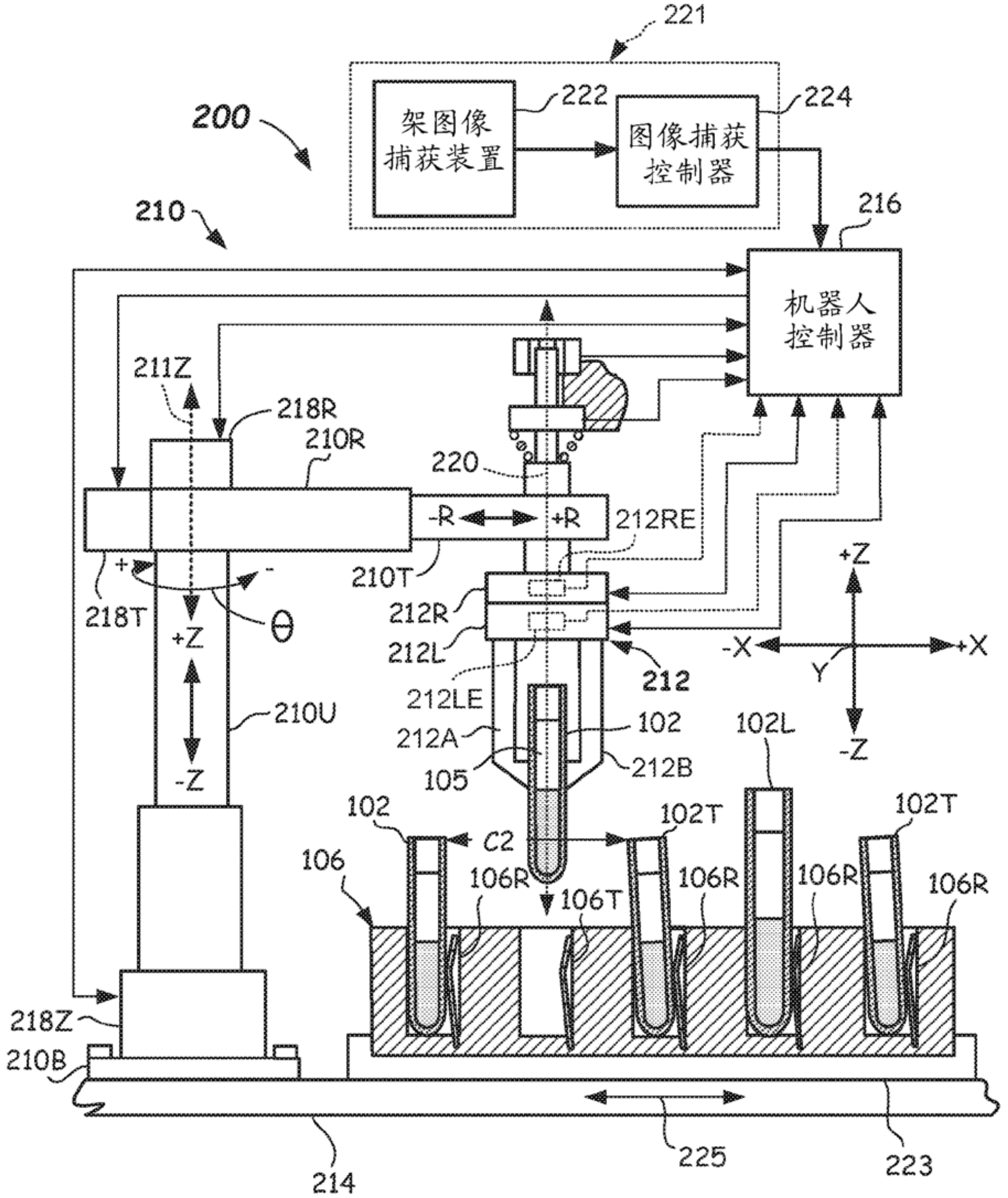

221
架图像捕获装置
222
图像捕获控制器
224
200
210
216
机器人控制器
211Z
218R
210R
220
-R
+R
212RE
+Z
+
-
210T
218T
θ
212R
212L
-X
+X
Y
212
+Z
212LE
210U
102
102L
212A
-Z
-Z
105
212B
102
C2
102T
102T
106
106R
106T
106R
106R
106R
218Z
210B
225
223
214

图 2A

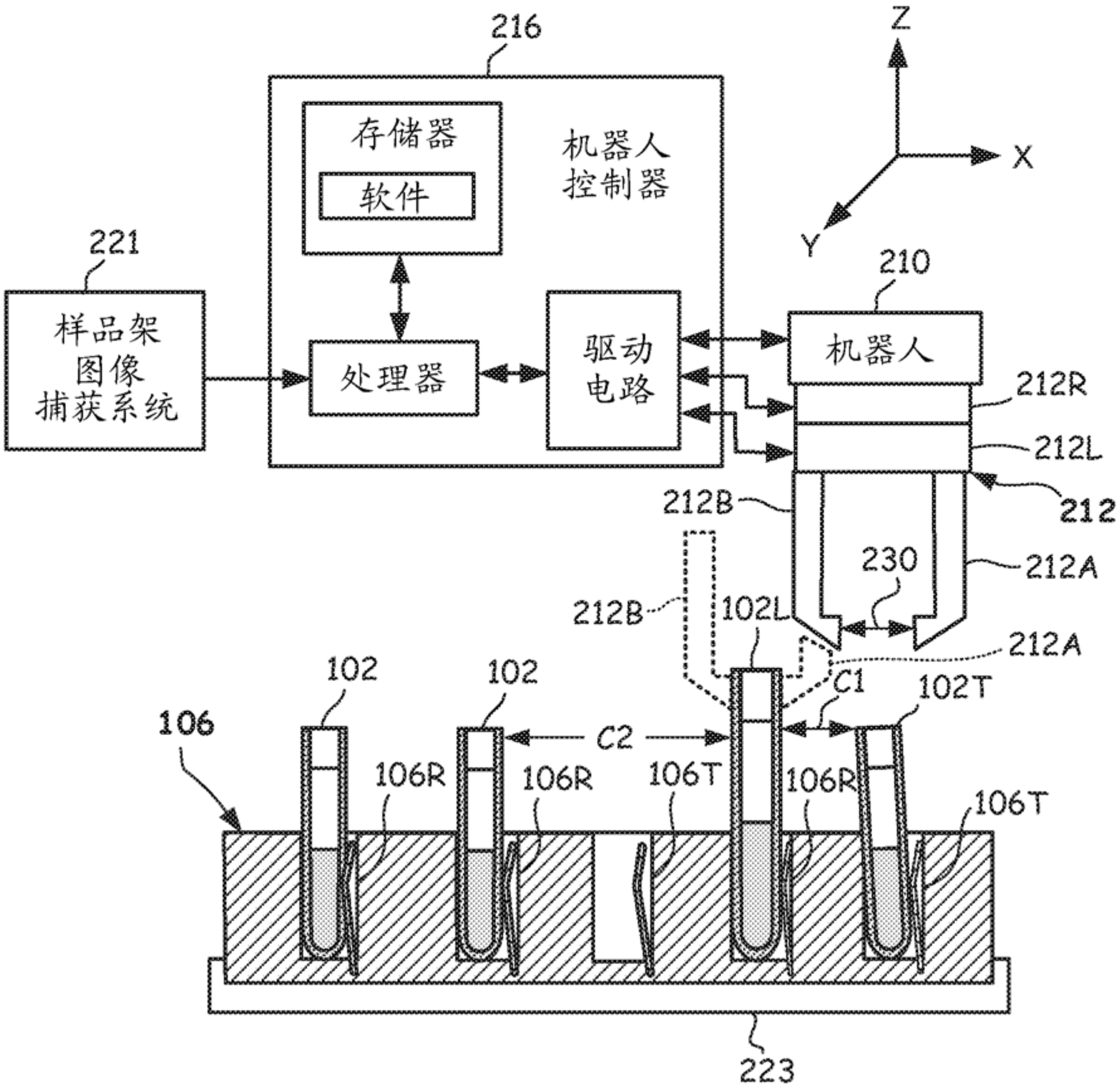

216
存储器
软件
机器人
控制器
处理器
驱动
电路
221
样品架
图像
捕获系统
Z
X
Y
210
机器人
212R
212L
212
212B
230
212A
212B
102L
212A
C1
102T
102
102
C2
106
106R
106R
106T
106R
106T
223

图 2B

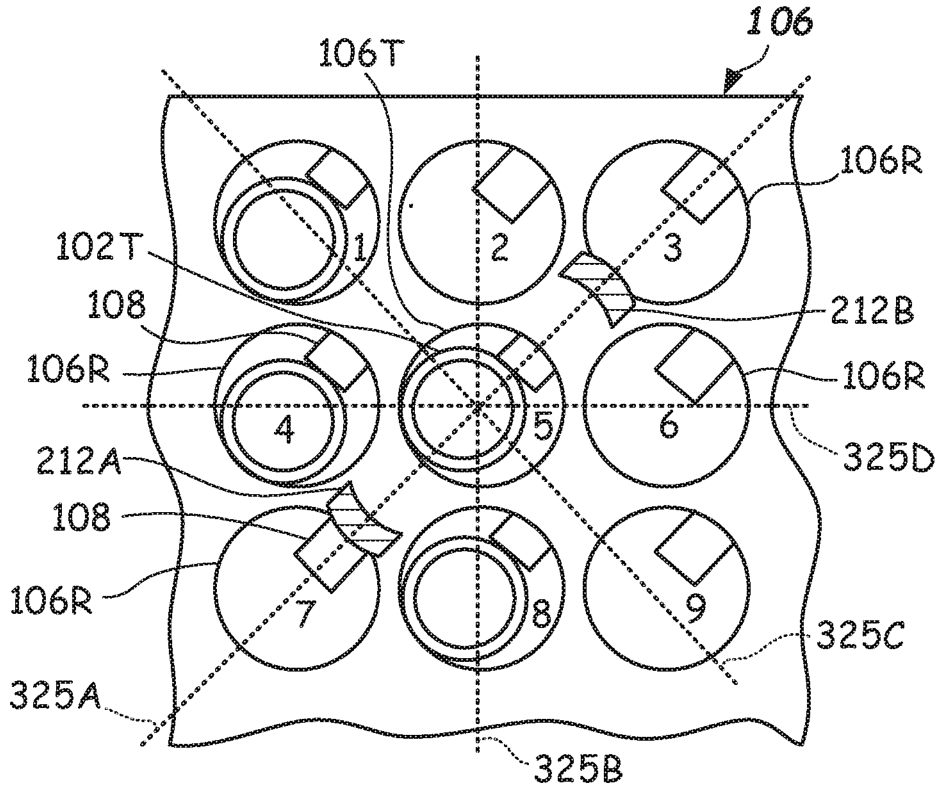

106
106T
106R
102T
1
2
3
212B
108
106R
4
5
6
106R
325D
212A
108
106R
7
8
9
325C
325A
325B

图 3A

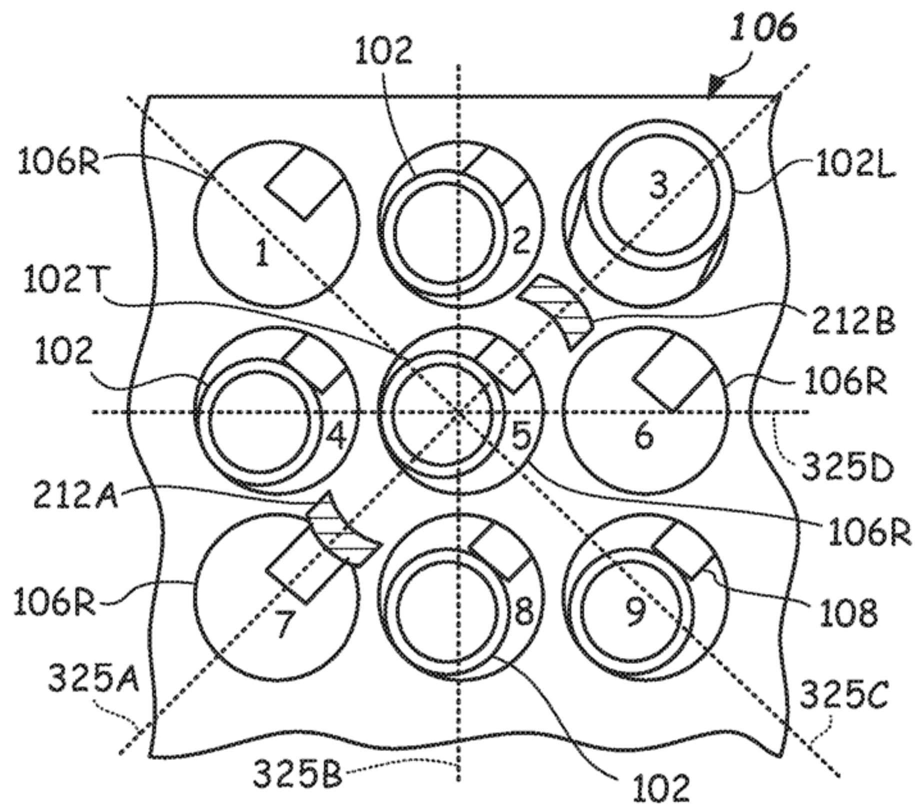

106
102
106R
1
2
3
102L
102T
212B
102
4
5
6
106R
325D
212A
106R
106R
7
8
9
108
325A
325C
325B
102

图 3B

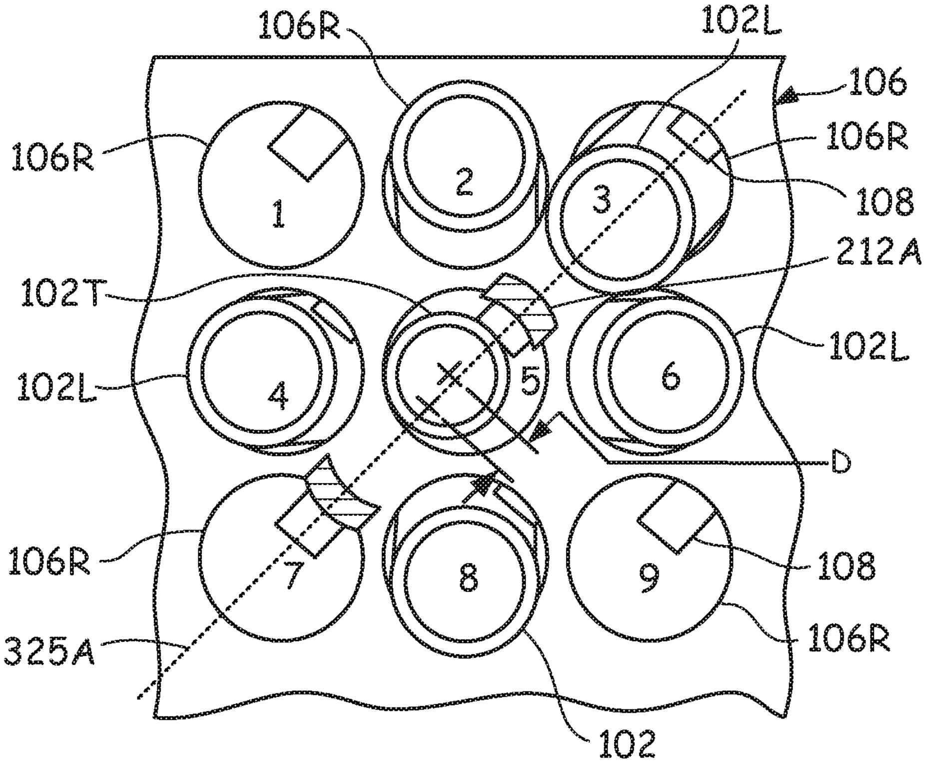

106R
102L
106
106R
106R
108
1
2
3
212A
102T
102L
102L
4
5
6
D
106R
7
8
9
108
325A
106R
102

图 3C

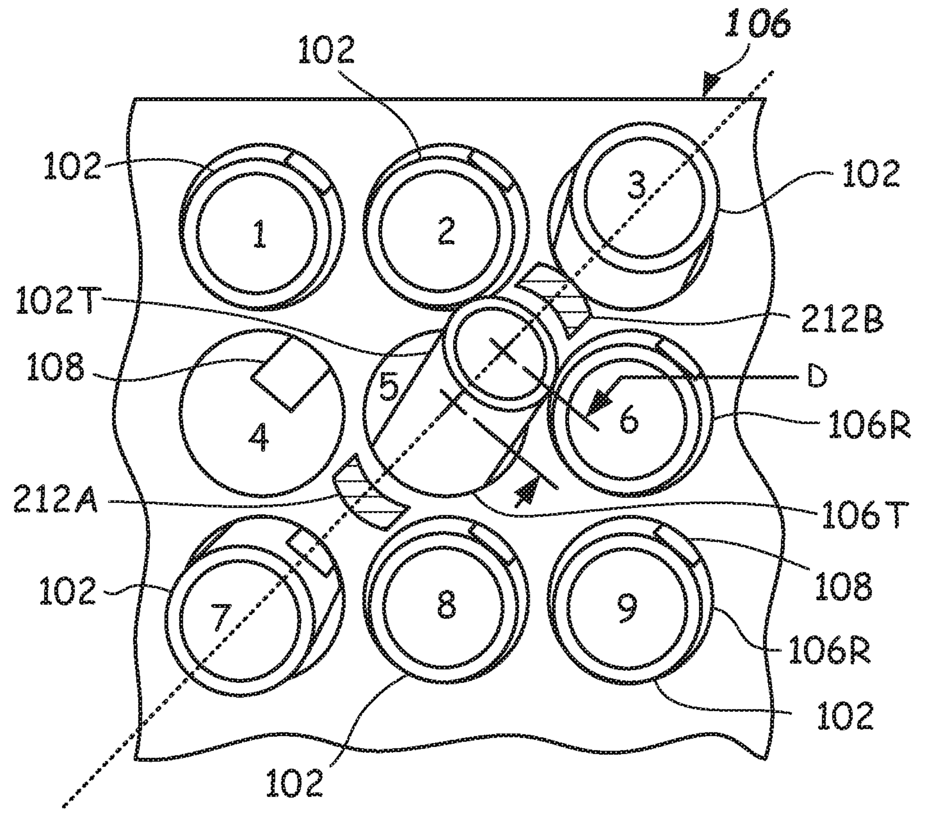

106
102
102
1
2
3
102
102T
212B
108
5
D
4
6
106R
212A
106T
108
102
7
8
9
106R
102
102

图 3D

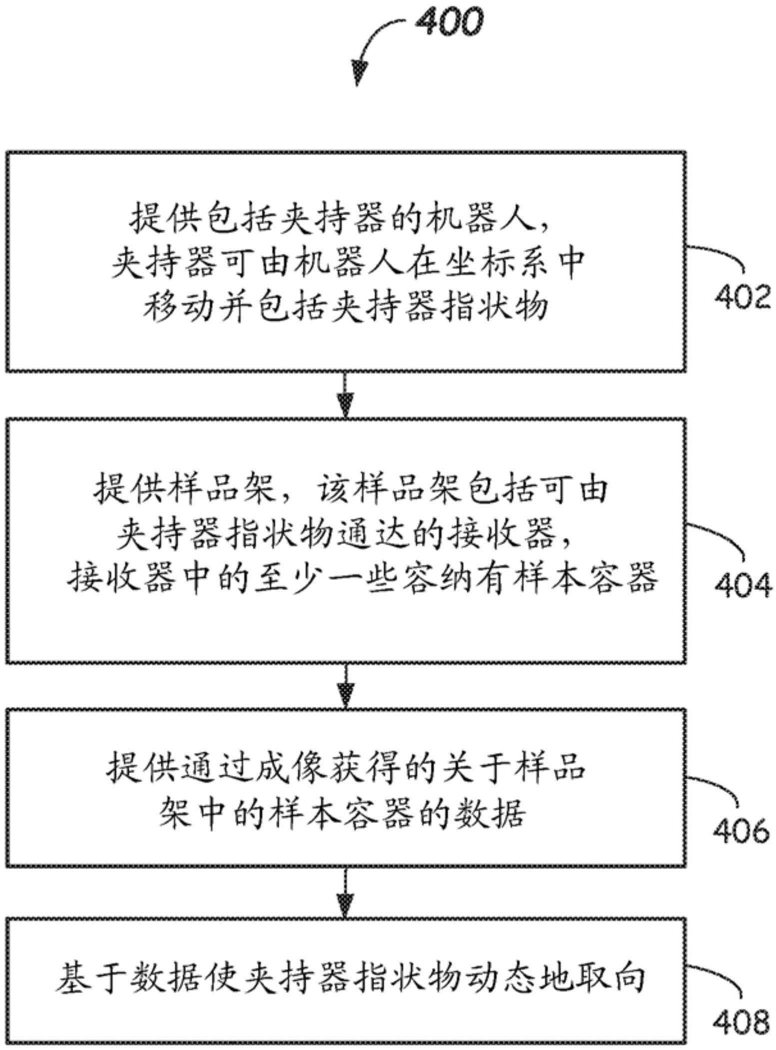

400
提供包括夹持器的机器人，
夹持器可由机器人在坐标系中
移动并包括夹持器指状物
402
提供样品架，该样品架包括可由
夹持器指状物通达的接收器，
接收器中的至少一些容纳有样本容器
404
提供通过成像获得的关于样品
架中的样本容器的数据
406
基于数据使夹持器指状物动态地取向
408

图 4