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(54) **Title:** WASTE SORTING GANTRY ROBOT

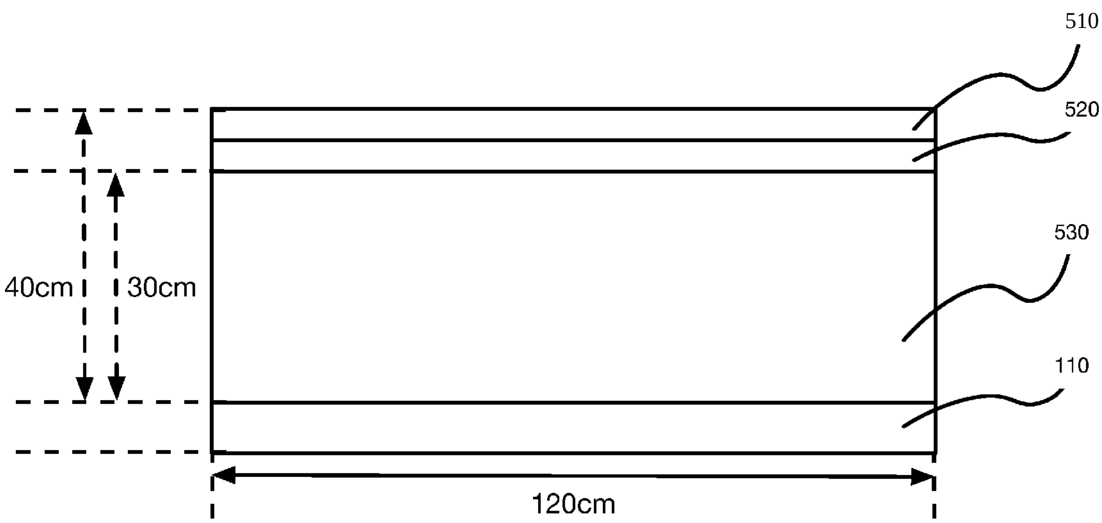

Figure 5

(57) Abstract: A waste sorting gantry robot is provided comprising a gantry frame, a manipulator for interacting with one or more waste objects to be sorted within a working area, and wherein the manipulator is moveably mounted on the gantry frame and the manipulator is moveable within the working area. A conveyor is used for moving one or more waste objects within the working area and at least one chute having a chute opening at least partially within the working area is provided for placing picked objects. The working area has a first axis in a direction of the conveyor and a second axis in a direction perpendicular to the direction of the conveyor, and wherein a ratio of the size of the working area in the first axis to the size of the working area in the second axis is smaller than 0.5.

WO 2019/207200 A1

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Waste Sorting Gantry Robot

The present invention relates to a waste sorting robot for sorting waste objects.

In the waste management industry, industrial and domestic waste is increasingly being sorted in order to recover and recycle useful components. Each type of waste, or “fraction” of waste can have a different use and value. If waste is not sorted, then it often ends up in landfill or incineration which has an undesirable environmental and economic impact.

Industrial waste may be passed to waste management centres because handling and disposing of waste is time consuming and requires specialist equipment. Accordingly, a waste management centre may sort waste to collect the most valuable and useful fractions. For example, industrial waste may include mixed wood and metal fractions (as well as other fractions) and sorted wood and metal fractions can be reused and sold to recyclers. Waste which is sorted into a substantially homogeneous fraction is more desirable and economical for recyclers. This is because less processing of the material is required before being recycled into new products and materials.

It is known to sort domestic and industrial waste in different ways. For many years waste has been manually sorted by hand on a conveyor belt. However, hand sorting waste can be arduous and dangerous to the human sorter depending on the type of industrial or domestic waste being sorted. Furthermore, some waste sorting plants which use human sorters require multiple shifts in order to increase the output of sorted waste.

One approach for improving the safety and the output of waste sorting is to automate one or more aspects of the waste sorting. The automation can comprise a controller sending control and movement instructions to a manipulator for interacting with the physical objects. The combination of a controller sending control instructions to a manipulator can also be referred to as a “robot”.

One such robotic waste sorting system is a “delta” robot suspended over a conveyor belt which moves objects to be sorted. The conveyor belt passes under the delta robot and within a working area of the delta robot. A working area of a robot is an area on a surface within which the robot is able to reach and manipulate an object. A working volume is the physical space within which the robot is able to move and manipulate an object. The working volume is determined by the height above the working area where the robot can manipulate an object.

The working volume / area can also include chutes which are not part of the surface of a conveyor belt.

A delta robot comprises a servo housing and a plurality of arms which are connected to one or more servos for moving the arms. The arms extend down from the servo housing to a base which is coupled to a manipulator. The arms are connected via universal joints at the base.

Whilst a delta robot can be relatively effective at picking small light objects, the delta robot is not suitable for lifting heavy objects. Furthermore, since the manipulator is suspended from the servo housing, the servos must have sufficient power to move the manipulator and the object. This means that the manipulators coupled to delta robots must be as light as possible to increase the maximum lift capacity of the delta robot.

Disadvantageously, the dimensions of the working volume for a delta robot varies across the width of the working space. In particular, the working volume is an inverted cone and becomes narrower as the manipulator moves away from the servo housing. In practice, this may mean that a delta robot cannot manipulate objects at the same height across the width of a conveyor belt and that delta robots are only suitable for working with narrow conveyor belts. This can be problematic because objects can be piled on each other making identifying and picking objects harder. This can limit the design choices and use applications when using a delta robot for waste sorting.

A delta robot is not particularly robust and the universal joints of a delta robot are particularly susceptible to wear and malfunction. Another consideration of a delta robot is that the movement of one or more arms causes movement in the other arms. Accordingly, whenever a delta robot moves, control instructions must be sent to each servo because each arm must move when the manipulator of the delta robot is moved. The non-linear control instructions to move the arms of the delta robot means that increased computational processing is required to control and move the delta robot within the working area / working volume.

Another known robot for automatic sorting of waste is a “gantry” robot. A gantry robot comprises a frame or gantry which engages the floor and bridges over a working area such as a conveyor belt. The gantry supports the weight of the manipulator and an object that the manipulator grips. The gantry robot comprises one or more axes of control which move in a straight line (e.g. linear). Normally the axes of control of a gantry robot are arranged at right angles to each other.

A gantry robot may pick objects from the conveyor belt and drop the picked objects into a chute. A chute comprises an opening which is in communication with a bin or another conveyor belt for receiving a particular fraction of waste. The picked objects placed in the bin or on the conveyor belt can then be moved to another location or step in waste processing. This means a picked object of a certain waste fraction is dropped into the corresponding chute. Known gantry robots have a four or more chutes located at the four corners of the rectangular working space for receiving the different fractions. A problem with this arrangement is that the manipulator is required to travel a large distance if subsequent picks are from differing fractions. This means that a manipulator may be able to successfully pick and drop fewer objects into the correct bin due to the required travel time of the manipulator.

Embodiments of the present invention aim to address the aforementioned problems.

According to an aspect of the present invention there is a waste sorting gantry robot comprising: a gantry frame, a manipulator for interacting with one or more waste objects to be sorted within a working area, and wherein the manipulator is moveably mounted on the gantry frame and the manipulator is moveable within the working area; a conveyor for moving one or more waste objects to be sorted within the working area; at least one chute having a chute opening at least partially within the working area, an exterior casing having a size in the first axis of between 20 cm and 100 cm, and at least one sensor positioned to determine characteristics of the objects before the objects enter the working area, wherein the working area having a first axis in a direction of the conveyor and a second axis in a direction perpendicular to the direction of the conveyor, and wherein a ratio of the size of the working area in the first axis to the size of the working area in the second axis is smaller than 0.5.

Advantageously, the dimensions of the working area are long and thin, and the gantry robot takes up less space along the conveyor belt. This makes the gantry robot easily retrofittable in existing sorting plants. Furthermore, this means that a manipulator may be able to successfully pick and drop fewer objects into the correct bin due to the decreased required travel time of the manipulator.

Optionally, a central axis of the chute opening may be aligned with the second axis of the working area. This means that the manipulator can reduce the required travel to drop an object in the chute and decrease the picking time.

Optionally two chutes are used, the chutes positioned at each side of the conveyor and each chute being aligned with the second axis of the working area. By providing a ratio of two chutes to one manipulator, where the chutes are aligned along the central axis of the working area, the manipulator can efficiently sort at least two different types of objects.

Optionally, at least one chute opening may be entirely within the working area. Optionally, the working area may have a size in the second axis of between 80 cm and 200 cm and a size in the first axis of between 0 cm and 80 cm. Optionally, the waste sorting gantry robot may comprise an exterior casing having a size in the second axis of between 200 cm and 280 cm and a size in the first axis of between 20 cm and 100 cm. By providing a gantry robot with these dimensions, the gantry robot is retrofittable in existing sorting lines whilst improving its efficiency.

Optionally, the manipulator may include a suction gripper. Optionally, the suction gripper may be rotationally symmetrical. By making the suction gripper rotationally symmetric, the suction gripper does not need to be rotated before making a pick. Accordingly, the gripper is lighter and the pick can be made quicker because no rotation of the gripper needs to be calculated by the controller.

Optionally, the suction gripper may be configured to establish a fix with a waste object in less than 0.5 seconds. The faster the manipulator can secure the object, the less time needs to be spent with the manipulator positioned over the moving object and tracking it. This allows the working area to be narrower.

Optionally, the size of the working area in the second axis may be a function of a speed at which the manipulator can move in a direction parallel to the second axis and a speed of the conveyor. Where the conveyor moves at a slower speed, the working area can be narrower. Similarly, the faster the manipulator can move reach the object, the narrower the working area can be without increasing the risk of the object leaving the working area before being reachable.

Optionally, the suction gripper may be moveable from between 0 and 50 cm of a surface of the conveyor in a direction normal to the surface of the conveyor.

Optionally, the manipulator may include a parallel gripper and / or a suction gripper.

Optionally, a plurality of waste sorting gantry robots of the type described above may be arranged along a conveyor, wherein the plurality of waste sorting gantry robots are arranged such that a space of between 60 cm - 120 cm exists between respective working areas. This allows a set of waste sorting robots to be retrofitted into a waste sorting plant previously employing human sorters. As the narrow robots are considerably more compact, they can allow a set of one or more sensors to be interspaced with the waste sorting gantry robots. Having sensors spaced regularly between the robots can allow a working knowledge of the objects positioned on the conveyor belt to be refreshed after each working area.

According to an aspect of the present invention there is a waste sorting gantry robot comprising: a gantry frame, a manipulator for interacting with one or more waste objects to be sorted within a working area, and wherein the manipulator is moveably mounted on the gantry frame and the manipulator is moveable within the working area; a conveyor for moving one or more waste objects to be sorted within the working area; at least one chute having a chute opening at least partially within the working area, wherein the working area having a first axis in a direction of the conveyor and a second axis in a direction perpendicular to the direction of the conveyor, and wherein a ratio of the size of the working area in the first axis to the size of the working area in the second axis is smaller than 0.5.

Various other aspects and further embodiments are also described in the following detailed description and in the attached claims with reference to the accompanying drawings, in which:

Figure 1 shows a perspective schematic view of the waste sorting gantry robot;
Figure 2 shows another perspective schematic view of the waste sorting gantry robot;
Figure 3 shows a schematic plan view of a working area of the waste sorting gantry robot;
Figure 4 shows a schematic cross-sectional view of the waste sorting gantry robot;
Figure 5 shows a cross section of a working area; and
Figure 6 shows a plurality of waste sorting gantry robots.

Figure 1 shows a schematic perspective view of a waste sorting robot 100. In some embodiments, the waste sorting robot 100 can be a waste sorting gantry robot 100. In other embodiments other types of waste sorting robots can be used. For the purposes of brevity, the embodiments will be described in reference to waste sorting gantry robots, but can also be other types of robot such as robot arms or delta robots.

In some embodiments, the waste sorting robot 100 is a Selective Compliance Assembly Robot Arm (SCARA). The waste sorting SCARA 100 may move in the X, Y, and Z planes like the waste sorting gantry robot, but incorporate movement in a theta axis at the end of the Z plane to rotate the end-of-arm tooling e.g. the gripper assembly 132. In some embodiments, the waste sorting robot 100 is a four axis SCARA robot 100 that consists of an inner link arm (not shown) that rotates about the Z-axis. The inner link arm is connected to an outer link arm (not shown) that rotates about a Z elbow joint (not shown). The Z elbow joint is connected to a wrist axis (not shown) that moves up and down and also rotates about Z. In some embodiments the waste sorting SCARA 100 comprises an alternative configuration which has the linear Z motion as the second axis.

For the purposes of brevity, the embodiments will be described in reference to waste sorting gantry robots 100, but any of the other aforementioned robot types can be used instead or in addition to the water sorting gantry robot 100.

The waste sorting gantry robot comprises a controller 102 for sending control and movement instructions to a manipulator 104 for interacting with the physical objects 106a, 106b, 106c. The combination of a controller sending control instructions to a manipulator can also be referred to as a “robot”. The controller 102 is located remote from the manipulator 104 and is housed in a cabinet (not shown). In other embodiments, the controller 102 can be integral with the manipulator and / or a gantry frame 120.

The manipulator 104 physically engages and moves the objects 106a, 106b, 106c that enters the working area 108. The working area 108 of a manipulator 104 is an area within which the manipulator 104 is able to reach and interact with the object 106a 106b, 106c. The working area 108 as shown in Figure 1 is projected onto the conveyor belt 110 for the purposes of clarity. The manipulator 104 is configured to move at variable heights above the working area 108. In this way, the manipulator 104 is configured to move within a working volume defined by the height above the working area 108 where the robot can manipulate an object. The manipulator 104 comprises one or more components for effecting relative movement with respect to the objects 106a, 106b, 106c. The manipulator 104 will be described in further detail below.

The physical objects 106a, 106b, 106c are moved into the working area 108 by a conveyor belt 110. The path of travel of the conveyor belt 110 intersects with the working area 108. This means that every object 106a, 106b, 106c that is moving on the conveyor belt 110 will pass through the working area 108. The conveyor belt 110 can be a continuous belt, or a conveyor belt formed from overlapping portions. The conveyor belt 110 can be a single belt or alternatively a plurality of adjacent moving belts.

In other embodiments, the physical objects 106a, 106b, 106c can be conveyed into the working area 108 via other conveying means. The conveyor can be any suitable means for moving the objects 106a, 106b, 106c into the working area 108. For example, the objects 106a, 106b, 106c are fed under gravity via slide (not shown) to the working area 108. In other embodiments, the objects can be entrained in a fluid flow, such as air or water, which passes through the working area 108.

The direction of the conveyor belt 110 is shown in Figure 1 by two arrows. The objects 106a, and 106b are representative of different types of objects to be sorted having not yet been physically engaged by the manipulator 104. In contrast, the object 106c is an object that has been sorted into a particular type of object. In some embodiments, the manipulator 104 interacts with only some of the objects 106c. For example, the waste sorting gantry robot 100 is only removing a particular type of objects. In other scenarios, the manipulator 104 will interact and sort every object 106a, 106b, 106c which is on the conveyor belt 110.

In some embodiments, the objects to be sorted are waste products. The waste products can be any type of industrial, commercial, domestic or any other waste which requires sorting and processing. Unsorted waste material comprises a plurality of fractions of different types of waste. Industrial waste can comprise fractions of, for example, metal, wood, plastic, hardcore and one or more other types of waste. In other embodiments, the waste can comprise any number of different fractions of waste formed from any type or parameter of waste. The fractions can be further subdivided into more refined categories. For example, metal can be separated into steel, iron, aluminium etc. Domestic waste also comprises different fractions of waste such as plastic, paper, cardboard, metal, glass and / or organic waste.

A fraction is a category of waste that the waste can be sorted into by the waste sorting gantry robot 100. A fraction can be a standard or homogenous composition of material, such as aluminium, but alternatively a fraction can be category of waste defined by a customer or user.

In some embodiments, the waste can be sorted according to any parameter. A non-limiting list of parameters for dividing unsorted waste into fractions is as follows: material, previous purpose, size, weight, colour, opacity, economic value, purity, combustibility, whether the objects are ferrous or any other variable associated with waste objects. In a further embodiment, a fraction can comprise one or more other fractions. For example, one fraction can comprise a paper fraction, a cardboard fraction, and a wood fraction to be combinable to be a combustible fraction. In other embodiments, a fraction can be defined based on the previous purpose of the waste object, for example plastic tubes used for silicone sealant. It may be desirable to separate out some waste objects because they are contaminated and cannot be recycled.

The objects are fed from a hopper or other stored source of objects onto the conveyor belt 110. Alternatively, the waste objects are fed from another conveyor belt (not shown) and there is no source of stored waste objects. In this case, the additional conveyor belt can be fed manually from e.g. an excavator. Optionally, the objects 106a, 106b, 106c can be pre-processed before being placed on the conveyor belt. For example, the objects can be washed, screened, crushed, ripped, shaken, vibrated to prepare the material before sorting. Alternatively, the waste objects 106a, 106b, 106c can be sorted with another robot or mechanical device. The objects 106a, 106b, 106c can be optionally pre-sorted before being placed on the conveyor belt 110. For example, ferrous material can be removed from the unsorted waste by passing a magnet in proximity to the conveyor belt 110. Large objects can be broken down into pieces of material which are of a suitable size and weight to be gripped by the manipulator 104.

The manipulator 104 is configured to move within the working volume. The manipulator 104 comprises one or more servos for moving the manipulator 104 in one or more axes. In some embodiments, the manipulator 104 is moveable along a plurality of axes. In some embodiments, the manipulator is moveable along three axes which are substantially at right angles to each other. In this way, the manipulator 104 is movable in an X-axis which is parallel with the longitudinal axis of the conveyor belt 110 ("beltwise"). Additionally, the manipulator 104 is movable across the conveyor belt 110 in a Y-axis which is perpendicular to the longitudinal axis of the conveyor belt 110 ("widthwise"). The manipulator 104 is movable in a Z-axis which is in a direction normal to the working area 108 and the conveyor belt 110 ("heightwise"). Optionally, the manipulator 104 can rotate about one or more axes. In some embodiments a gripper assembly 132 coupled to the manipulator 104 can rotate about a W-axis. The gripper assembly 132 is discussed in further detail below.

The directions of movement of the manipulator 104 within the working space along the X-axis, Y-axis and the Z-axis are shown by the two headed arrows with dotted lines. The manipulator 104 is moved with respect to the conveyor belt 110 by an X-axis servo 112, a Y-axis servo 114 and a Z-axis servo 116 respectively along the X-axis, the Y-axis and the Z-axis. The servos 112, 114, 116 are connectively connected to the controller 102 and controller 102 is configured to issue instructions for actuating one or more servos 112, 114, 116 to move the manipulator 104 within the working space. The connections between the servos 112, 114, 116 and the controller 102 are represented by dotted lines. Each connection between the servo

112, 114, 116 and the controller 102 can comprises one or more data and / or power connections.

Since the directions of movement of the manipulator 104 are substantially perpendicular to each other, movement of the manipulator in one of the axes is independent of the other axes. This means that the manipulator 104 movement can be defined in a cartesian coordinate frame of reference which makes processing movement instructions by the controller 102 simpler.

As mentioned previously, the manipulator 104 is mounted on a frame 120. In some embodiments, the frame 120 can be a gantry frame 120. In other embodiments, the frame 120 can be other structures suitable for supporting the manipulator 104 above the working area 108. For example, the frame 120 can be a structure for suspending the manipulator 104 above the working area with rods and / or cables. Hereinafter, the frame 120 will be referred to a gantry frame 120 but can be applicable to other frames for supporting a manipulator 104.

The gantry frame 120 comprises vertical struts 122 which engage with the floor or another substantially horizontal surface. In some embodiments, the vertical struts 122 can be tilted upright struts. In this way, the tilted upright struts are angled to the vertical. The tilted upright struts may be required to mount the gantry frame 120 to the floor in a non-standard installation. Figure 1 shows the gantry frame 120 comprising four vertical struts 122 coupled together by horizontal beams 124. In other embodiments, the horizontal beams 124 can be tilted lateral beams 124. This may be required if the waste sorting gantry robot 100 is being installed in a small or unusual space. In other embodiments, there can be any suitable number of vertical struts 122. The beams 124 and struts 122 are fixed together with welds, bolts or other suitable fasteners. Whilst the horizontal beams 124 are shown in Figure 1 to be located above the conveyor belt 110, one or more horizontal beams 124 can be positioned at different heights. For example, one or more horizontal beams 124 can be positioned underneath the conveyor belt. This can lower the centre of mass of the gantry frame 120 and make the entire waste sorting gantry robot 100 more stable if the vertical struts 122 are not secured to the floor.

The beams 124 and the struts 122 are load bearing and support the weight of the manipulator 104 and an object 106a, 106b, 106c that the manipulator 104 grasps. In some embodiments, the beams 124 and struts 122 are made from steel but other stiff, lightweight materials such as aluminium can be used. The vertical struts 122 can each comprise feet 126 comprising a plate through which bolts (not shown) can be threaded for securing the struts 122 to the floor. For the purposes of clarity, only one foot 126 is shown in Figure 1, but each strut 122 can comprise a foot 126. In other embodiments, there are no feet 126 or fasteners for securing the gantry frame 120 to the floor. In this case, the gantry frame rests on the floor and the frictional forces between the gantry frame and the floor are sufficient to prevent the waste sorting gantry robot from moving with respect to the floor.

The manipulator 104 comprises at least one movable horizontal beam 128 which is movably mounted on the gantry frame 120. The moveable beam 128 can be mounted in a beam carriage (not shown). The moveable horizontal beam 128 is movably mounted on one or more of the other fixed horizontal beams 124 of the gantry frame 120. The moveable horizontal beam 128 is movable in the X-axis such that the manipulator 104 moves in the X-axis when the movable horizontal beam moves in the X-axis. The moveable horizontal beam 128 is mounted to the fixed horizontal beams 124 via an X-axis servo mechanism 112. In some embodiments, the servo 112 is coupled to the moveable horizontal beam 128 via a belt drive. In other embodiments, the servo is coupled to the moveable horizontal beam via a rack and pinion mechanism. In some embodiments, other mechanisms can be used to actuate movement of the moveable horizontal beam along the X-axis. For example, a hydraulic or pneumatic system can be used for moving the movable horizontal beam 128.

The X-axis servo 112 can be mounted on the moveable beam 128 or on the fixed horizontal beams 124. It is preferable for the X-axis servo to be mounted on the fixed horizontal beams 124 such that the X-axis servo does not have to exert force moving its own weight.

A manipulator carriage 130 is movably mounted on the moveable horizontal beam 128. The manipulator shuttle 130 is moveable along the longitudinal axis of the movable horizontal beam 128. In this way, the manipulator carriage 130 is movable in the Y-axis relative to the moveable beam 128. In some embodiments, the manipulator carriage 130 comprises a Y-axis servo mechanism 114 for moving the manipulator carriage 130 along the Y-axis. In other embodiments, the Y-axis servo 114 is not mounted in the manipulator carriage 130 and manipulator carriage 130 moves with respect to the Y-axis servo. In some embodiments, the servo 114 is coupled to the moveable horizontal beam 128 via a belt drive. In other embodiments, the servo 114 is coupled to the moveable horizontal beam 128 via a rack and pinion mechanism. In some embodiments, other mechanisms can be used to actuate movement of the moveable horizontal beam along the Y-axis. For example, a hydraulic or pneumatic system can be used for moving the manipulator carriage 130.

When the manipulator carriage 104 moves along the Y-axis, a gripper assembly 132 also moves in the Y-axis. The gripper assembly 132 is movably mounted to the manipulator carriage 130. The gripper assembly 132 is movable in the Z-axis in order to move the manipulator 104 heightwise in the Z-axis direction.

In some embodiments, the gripper assembly 132 comprises a Z-axis servo mechanism 116 for moving the gripper assembly 132 along the Z-axis. In other embodiments, the Z-axis servo 114 is not mounted in the gripper assembly 132 but is mounted in the manipulator carriage 130. In this way, the gripper assembly 132 moves with respect to the Z-axis servo 116. In some embodiments, the servo 116 is coupled to the gripper assembly 132 via a belt drive. In other embodiments, the servo 116 is coupled to the gripper assembly 132 via a rack and pinion mechanism. In some embodiments, other mechanisms can be used to actuate movement of the moveable horizontal beam along the Z-axis. For example, a hydraulic or pneumatic system can be used for moving the gripper assembly 132.

As mentioned, the manipulator 104 as shown in Figure 1 comprises a gripper assembly 132. In one embodiment, the gripper assembly 132 comprises a pair of jaws 118 configured to grip objects 106a, 106b, 106c. A gripper assembly 132 comprising a pair of jaws 118 is also known as a “finger gripper.” The gripper jaws 118 are actuated with a servo (not shown) for opening and closing the jaws 118. The servo for the gripper jaws 118 is connectively coupled to the controller 102 so that the controller 102 can actuate the opening and closing of the jaws 118. In some embodiments, the gripper assembly 132 further comprises a rotation servo (not shown) to rotate the gripper assembly 132 and / or the gripper jaw 118 about the W-axis. In some embodiments the W-axis and the Z-axis are coaxial, but in other embodiments the W-axis and the Z-axis are offset This means that the gripper jaws 118 can be rotated to better grasp long thin objects across their narrow dimensions.

Additionally, or alternatively in a more preferable embodiment, the gripper assembly (132) can be a suction gripper (as shown in Figure 2) for gripping the objects using negative pressure. The suction gripper can have a suction cup which is substantially symmetric about the Z-axis. This means that the suction gripper does not need to be rotated about the Z-axis to achieve an optimal orientation with respect to the objects 106a, 106b, 106c. This means that the gripper assembly rotation servo is not required with a suction gripper. In the case with an asymmetrical suction gripper 132, the gripper assembly 132 comprises a rotation servo to rotate the gripper assembly 132 about the W-axis as previously discussed above.

In other embodiments, the gripper assembly 132 of the manipulator 104 can be any suitable means for physically engaging and moving the objects 106a, 106b, 106c. Indeed, the manipulator 104 can be one or more tools for grasping, securing, gripping, cutting or skewering objects. In further embodiments the manipulator 104 can be a tool configured for interacting with and moving an object at distance such as an electromagnet or a nozzle for blowing compressed air.

As mentioned, the controller 102 is configured to send instructions to the servos 112, 114, 116 of the manipulator 104 to control and interact with objects 106a, 106b, 106c on the conveyor belt 110. The controller 102 is connectively coupled to at least one sensor 134 for detecting the objects 106a, 106b, 106c on the conveyor belt 110. The at least one sensor 134 is positioned in front of the manipulator 104 so that detected measurements of the objects 106a, 106b, 106c are sent to the controller 104 before the objects 106a, 106b, 106c enter the working area 108. In some embodiments, the at least one sensor 134 can be one or more of an RGB camera, an infrared camera, a metal detector, a hall sensor, a temperature sensor, visual and / or infrared spectroscopic detector, 3D imaging sensor, terahertz imaging system, radioactivity sensor, and / or a laser. The at least one sensor 134 can be any sensor suitable for determining a parameter of the object 106a, 106b, 106c.

Figure 1 shows that the at least one sensor 134 is positioned in one position. The at least one sensor 134 is mounted in a sensor housing 136 to protect the sensor 134. In other embodiments, a plurality of sensors are positions along and around the conveyor belt 110 to receive parameter data of the objects 106a, 106b, 106c.

The controller 102 receives information from the at least one sensor 134 corresponding to one or more objects 106a, 106b, 106c on the conveyor belt 110. The controller 102 determines instructions for moving the manipulator 104 based on the received information according to one or more criteria. Various information processing techniques can be adopted by the controller 102 for controlling the manipulator 104. Such information processing techniques are described in WO2012/089928, WO2012/052615, WO2011/161304, W02008/102052 which are incorporated herein by reference.

Once the manipulator 104 has received instructions from the controller 102, the manipulator 104 executes the commands and moves the gripper assembly 132 to pick an object 106c from the conveyor belt 110. The process of selecting and manipulating an object on the conveyor belt 110 is known as a “pick”.

Once a pick has been completed, the manipulator 104 drops or throws the object 106c into a chute 138. An object 106c dropped into the chute 138 is considered to be a successful pick.

A successful pick is one where an object 106c was selected and moved to the chute 138 associated with the same fraction of waste as the object 106c.

The chute 138 comprises a chute opening 142 in the working area 108 for dropping picked objects 106c. The chute opening 142 of the chute 138 is adjacent to the conveyor belt 110 so that the manipulator 104 does not have to travel far when conveying a picked object 106c from the conveyor belt 110 to the chute opening 142. By positioning the chute opening 142 of the chute adjacent to the conveyor belt 110, the manipulator 104 can throw, drop, pull and / or push the object 106c into the chute 138.

The chute 138 comprises walls 140 defining a conduit for guiding picked objects 106c into a fraction receptacle (not shown) for receiving a sorted fraction of waste. In some embodiments, a fraction receptacle is not required at the sorted fractions of waste are piled up beneath the chute 138. Figure 1 only shows one chute 138 associated with the manipulator 104. In other embodiments, there can be a plurality of chutes 138 and associated openings 142 located around the conveyor belt 110. Each opening 142 of the different chutes 138 is located within the working area 108 of the manipulator 104. The walls 140 of the conduit can be any shape, size or orientation to guide picked objects 106c to the fraction receptacle. In some embodiments, the successfully picked objects 106c move under the force of gravity from the chute opening 142 of the chute 138 to the fraction receptacle. In other embodiments, the chute 138 may guide the successfully picked objects 106c to another conveyor belt (not shown) or other means for moving the successfully picked objects 106c to the fraction receptacle.

Figure 2 shows a typical sorting line raster in waste plants. Figure 2a shows human sorters 210 sitting or standing on one side of a conveyor belt 110, picking a particular fraction of waste from the conveyor belt. The typical distance between pickers is 80 cm, with a total of 160 cm space for each sorter. In this arrangement, the conveyor belt is 60 cm wide and the sorter has 60 - 80 cm room from the conveyor belt. Consequently, the operating space 222 for each sorter is typically 160 cm by 120 cm. Figure 2b shows a second configuration in which sorters are positioned either side of the conveyor. In this arrangement, the distance between sorters along the edge of the conveyor is typically the same as with the single sided arrangement. E.g. A distance between pickers is 80 cm, with a total of 160 cm space for each sorter. Where sorters are working either side of the conveyor belt, the belt can be wider, e.g. 120cm. In this arrangement, the conveyor belt is 120 cm wide and the sorter has 60 - 80 cm room from the conveyor belt. Consequently, the operating space 224 for each pair of sorters is typically 160 cm by 240 cm.

Figure 3 shows a schematic plan view of an embodiment of the waste sorting robot configured to be retro-fitted into the waste plant of figure 2. The embodiment and following embodiments describe a smaller, modular robot than those described by the prior art capable of fitting the limited space available in a typical waste sorting plant. The waste sorting robot of figure 3 has a working area 108, a sensor region of interest 250, an exterior casing 240. As shown in figure 3, the waste robot can fit within the operating space 224 provided in a typical waste sorting plant.

Figure 4 shows a schematic plan view of the working area 108 of the robot in figure 3. The manipulator 104 can move anywhere within the working area 108. The path of the conveyor belt 110 intersects with the working area 108. The chute opening 142 is located within the working area 108. In this way, the gantry frame 120 comprises a chute 138 for receiving picked objects 106c.

As shown in figure 4, the working area having a first central axis C in a beltwise direction (and parallel with the X-axis) and a second central axis D in a widthwise direction perpendicular to the direction of the conveyor (and parallel with the Y-axis). The one or more chutes are preferably parallel and within working area of the gantry crane. In embodiments, the working area has a width A along axis D of between 120 cm and 200 cm and a width B along axis C of between 40 cm and 80 cm. In a preferred embodiment, the working area has a width A along axis D of 160 cm and a width B along axis C of 60 cm. The ratio of the size B of the working area in the first central axis C to the size A of the working area in the second central axis D is smaller than 0.5. This ratio is possible as robot is designed such that the manipulator is configured to travel along the Y-axis within the working area to reach from one side of the conveyor belt to the other whilst only moving a relatively small amount in the X-axis. This relatively small movement in the X-axis is due to the positioning of chutes along the D-axis, ensuring that, in order to delivery waste objects to a respective chute, the manipulator need only travel substantially along the D-axis. However, in order to facilitate the securing of waste objects to the gripper, it is preferable for the manipulator to match the speed of the waste object in the X-axis, even if only momentarily. A suction gripper should not slide over the object, resulting in a failed pick.

Preferably, a central axis of the one or more chute openings is aligned with the D-axis of the working area. This enables the rate of successful drop into a bin to be better, as it ensures that the path of object during and immediately after being manipulated by the manipulator (i.e. when being thrown by the manipulator) to be substantially along the D-axis. As well as improving the rate of successful drops, the movement substantially along a single axis makes computation of the thrown object easier. Furthermore, the above configuration is especially useful where there is not a requirement to successfully pick all waste objects in a workspace, as the shape configuration allows the robots to be chained together (described further below).

In one embodiment, the waste sorting gantry robot comprises two chutes, the chutes positioned at each side of the conveyor and each chute being aligned with the second axis of the working area. Since the chutes are aligned at each end of the manipulator, the ratio of chutes to manipulator is 2:1 . This is compared to the known robots where the ratio of chutes to manipulator is at least 4:1 or more. Given that a manipulator only throws objects in one of two bins / chutes, the manipulator moves a smaller distance and the picking speed for a particular fraction can be improved.

In embodiments, the waste sorting gantry robot having the above working area dimensions may comprises an exterior casing having a size in along the D axis of between 200 cm and 280 cm and a size along the C-axis of between 60 cm and 100 cm.

In one embodiment, the size of the working area in the X-axis is a function of the time taken for the gripper to establish a secure fix to a waste object. Preferably, the suction gripper can establish a secure fix to the waste object in less than 0.5 seconds. In some embodiments where the suction gripper can establish a secure fix to the waste object in less than 0.1 seconds and wherein the manipulator can move in the Y-Axis sufficiently quickly, the working area is effectively a one-dimensional line, with the manipulator having no substantial range in the X-axis. In one example, the manipulator can move 1m/s in the Y-Axis and secure a fix to the waste object in between 0.05 and 0.5 seconds.

In one embodiment, the size B of the working area is a function of a speed at which the manipulator can move in the Y-axis and a speed of the conveyor. The faster the manipulator can move in the Y-axis, the less the manipulator needs to move in the X-axis to ‘catch-up’ with any objects that have crossed the D axis.

Figure 5 shows a cross section of working area 110 of figure 4 along axis D. The suction gripper is moveable from between 0 and 50 cm of a surface of the conveyor belt 110 in a direction normal to the surface of the conveyor. The maximum picked object height 530 defines the maximum height of any object that can be picked by the manipulator. Z-axis compression 520 defines the amount of give the gripper has in the Z-axis relative. I.e. how much the manipulator can be compressed in the Z-axis. This compression has the advantage of allowing the gripper to be pressed against the waste object with some force, but with a degree of give that prevents the gripper from being damaged if applied too forcefully to the waste object. Additional clearance 510 describes an extra buffer space to allow for oversized objects.

Figure 6 shows a plurality of waste sorting gantry robots of any preceding claim arranged along a conveyor 110. Multiple robot pickers can be chained together making a more efficient waste sorting system. Chained robots are advantageous because each workspace can be dedicated to a specific fraction of waste. Subsequent gantry robots along the conveyor belt can pick objects which have not been picked by the earlier robots. Since the exterior dimensions of the casing 240 of waste robots described above are thinner in the X-axis than previously known robots, more robots can be aligned along the x-axis of the conveyor belt. Optionally, wherein the plurality of waste sorting gantry robots are arranged such that a space of between 60 cm - 120 cm exists between respective working areas. In some embodiments where the waste robots are arranged in an even denser formation, the space between the respective working areas may be as small as 20 cm to 60 cm.

In some embodiments, a set of one or more sensors 134 are interspaced with the waste sorting gantry robots. Each sensor 134 may be positioned so that its ‘region of interest’ 250, the region of the conveyor belt for which the sensor is configured to provide detect waste objects, is between the respective working area of the waste robots either side of the region of interest 250. In some embodiments, the region of interest 250 of a sensor may partially or fully overlap a neighbouring working area 110.

The embodiments described in reference to the Figures can be used in conjunction with other types of waste sorting robots such as delta robots or robot arms. In other embodiments, the sorting robots can also be used with other types of sorting robot which are not waste sorting robots. For example, the embodiments herein described can be used with industrial robots in the automotive industry, food industry, agriculture (fruit, vegetables), manufacturing (parts, shoes etc), mining (coal sorting, purification), logistics (parcels, bags at airports) etc.

In other embodiments the robots described with respect to the Figures can be used with solid waste. This includes but is not limited to Industrial, Commercial, and Municipal Solid Waste (MSW), Dry-Mixed-Recyclables (DRM), Construction and Demolition (C&D), Commercial and Industrial (C&I), medical, hazardous, and nuclear.

In another embodiment two or more embodiments are combined. Features of one embodiment can be combined with features of other embodiments.

Embodiments of the present invention have been discussed with particular reference to the examples illustrated. However, it will be appreciated that variations and modifications may be made to the examples described within the scope of the invention.

Claims

1. A waste sorting gantry robot comprising:

a gantry frame,

a manipulator for interacting with one or more waste objects to be sorted within a working area, and wherein the manipulator is moveably mounted on the gantry frame and the manipulator is moveable within the working area;

a conveyor for moving one or more waste objects to be sorted within the working area,

at least one chute having a chute opening at least partially within the working area,

an exterior casing having a size in the first axis of between 20 cm and 100 cm, and

at least one sensor positioned to determine characteristics of the objects before the objects enter the working area,

wherein the working area having a first axis in a direction of the conveyor and a second axis in a direction perpendicular to the direction of the conveyor, and wherein a ratio of the size of the working area in the first axis to the size of the working area in the second axis is smaller than 0.5.

2. The waste sorting gantry robot of claim 1, wherein a central axis of the chute opening is aligned with the second axis of the working area.

3. The waste sorting gantry robot of any preceding claim, further comprising two chutes, the chutes positioned at each side of the conveyor and each chute being aligned with the second axis of the working area.

4. The waste sorting gantry robot of any preceding claim, wherein at least one chute opening is entirely within the working area.

5. The waste sorting gantry robot of any preceding claim, wherein the working area having a size in the second axis of between 80 cm and 200 cm and a size in the first axis of between 0 cm and 80 cm.

6. The waste sorting gantry robot of claim 5, wherein the working area having a size in the second axis of 120 cm and a size in the first axis of 60 cm.

7. The waste sorting gantry robot of any preceding claim, wherein the exterior casing having a size in the second axis of between 200 cm and 280 cm.

8. The waste sorting gantry robot of any preceding claim, wherein the manipulator includes a suction gripper.

9. The waste sorting gantry robot of any preceding claim, wherein the suction gripper is rotationally symmetrical.

10. The waste sorting gantry robot of any preceding claim, wherein the suction gripper can establish a fix with a waste object in less than 0.5 seconds

11. The waste sorting gantry robot of any preceding claim, wherein the size of the working area in the second axis is a function of a speed at which the manipulator can move in a direction parallel to the second axis and a speed of the conveyor.

12. The waste sorting gantry robot of any preceding claim, wherein the suction gripper is moveable from between 0 and 50 cm of a surface of the conveyor in a direction normal to the surface of the conveyor.

13 The waste sorting gantry robot of any of claims 1 to 6, wherein the manipulator includes a parallel gripper.

14. The waste sorting gantry robot of any preceding claim, wherein the manipulator includes a parallel gripper and a suction gripper.

15. A waste sorting arrangement, comprising a plurality of waste sorting gantry robots of any preceding claim arranged along a conveyor, wherein the plurality of waste sorting gantry robots are arranged such that a space of between 60 cm - 120 cm exists between respective working areas.

16. The waste sorting arrangement of claim 13, wherein a set of one or more sensors are interspaced with the waste sorting gantry robots.

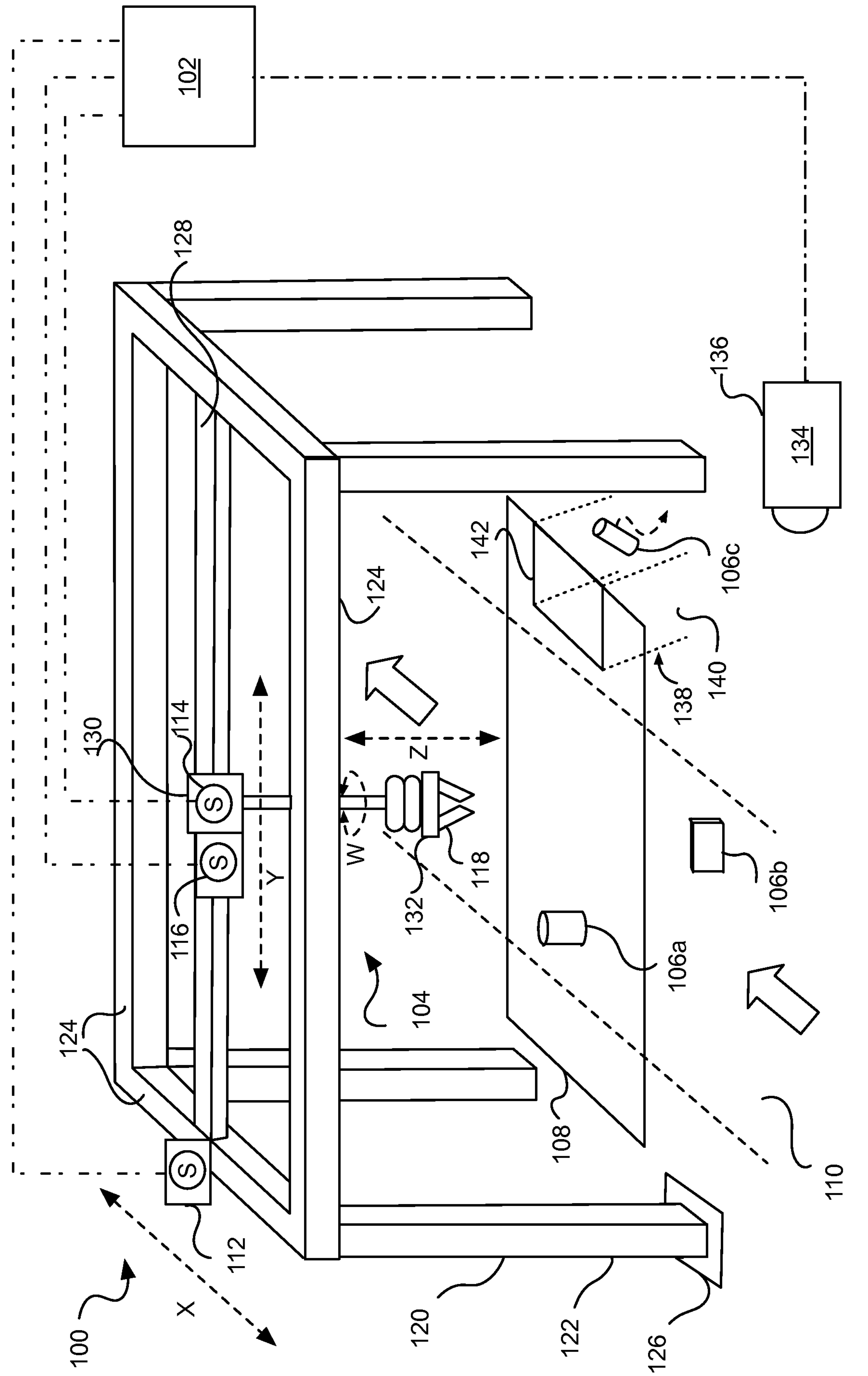
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Figure 1

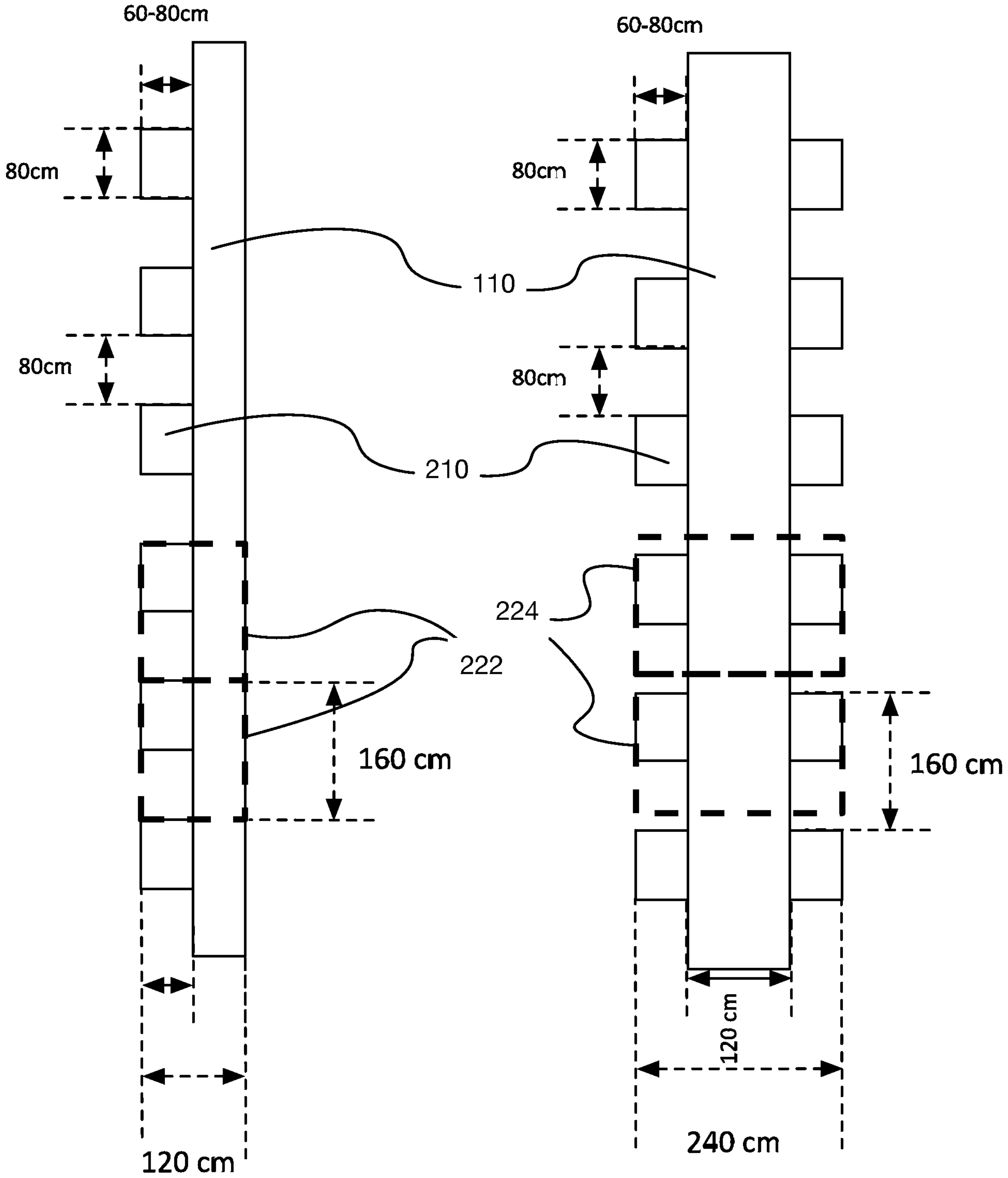

Figure 2a Figure 2b

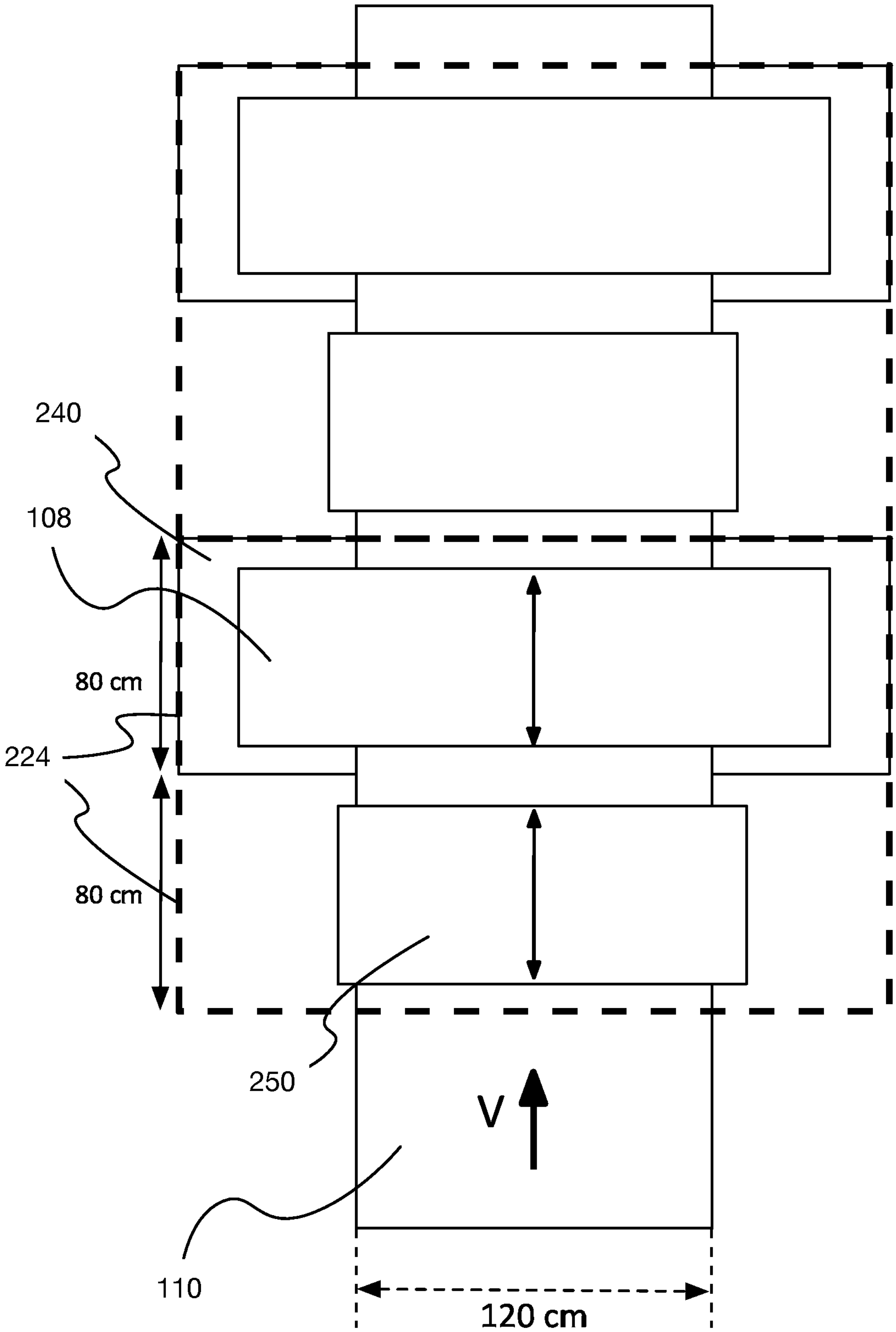

Figure 3

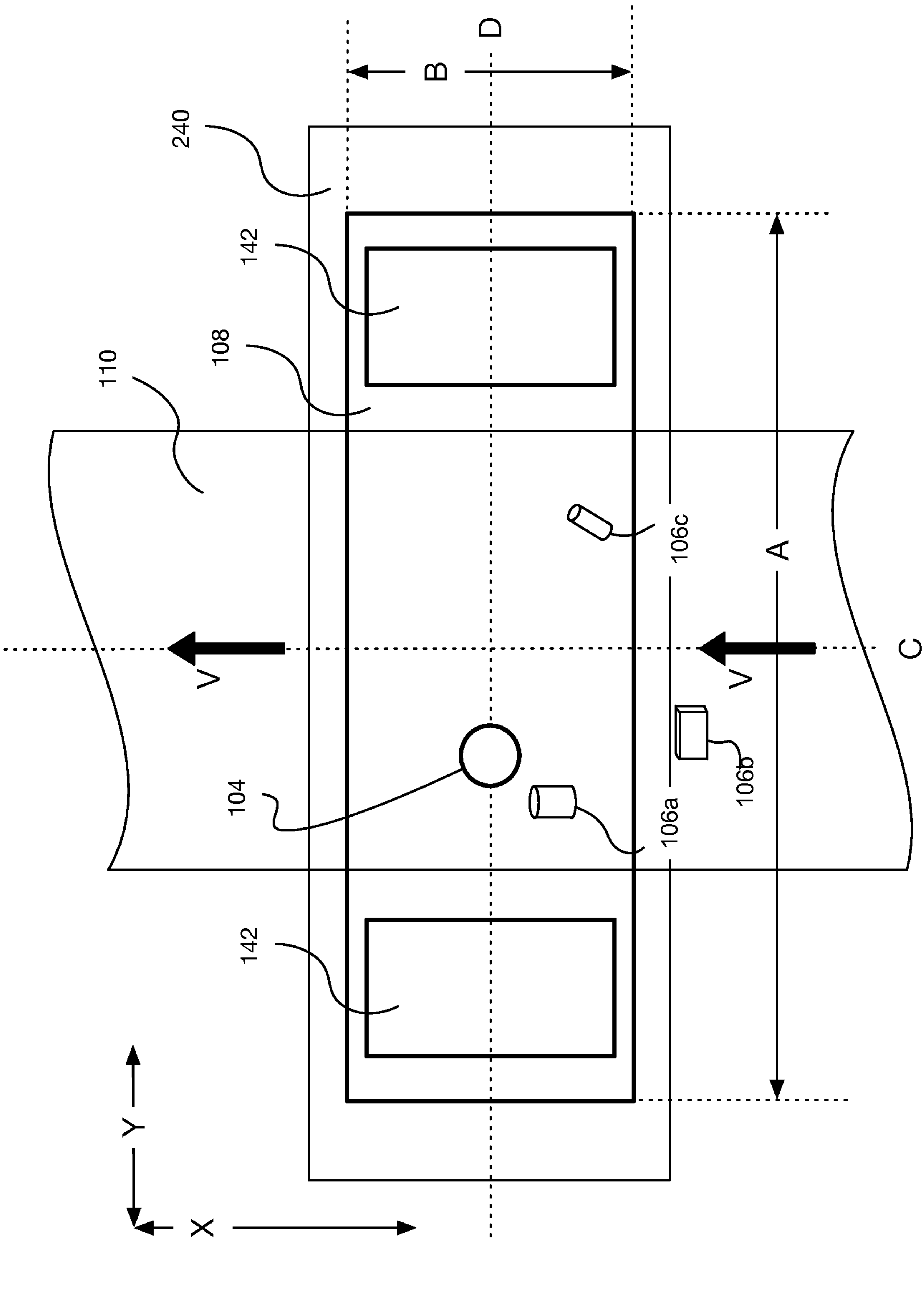

Figure 4

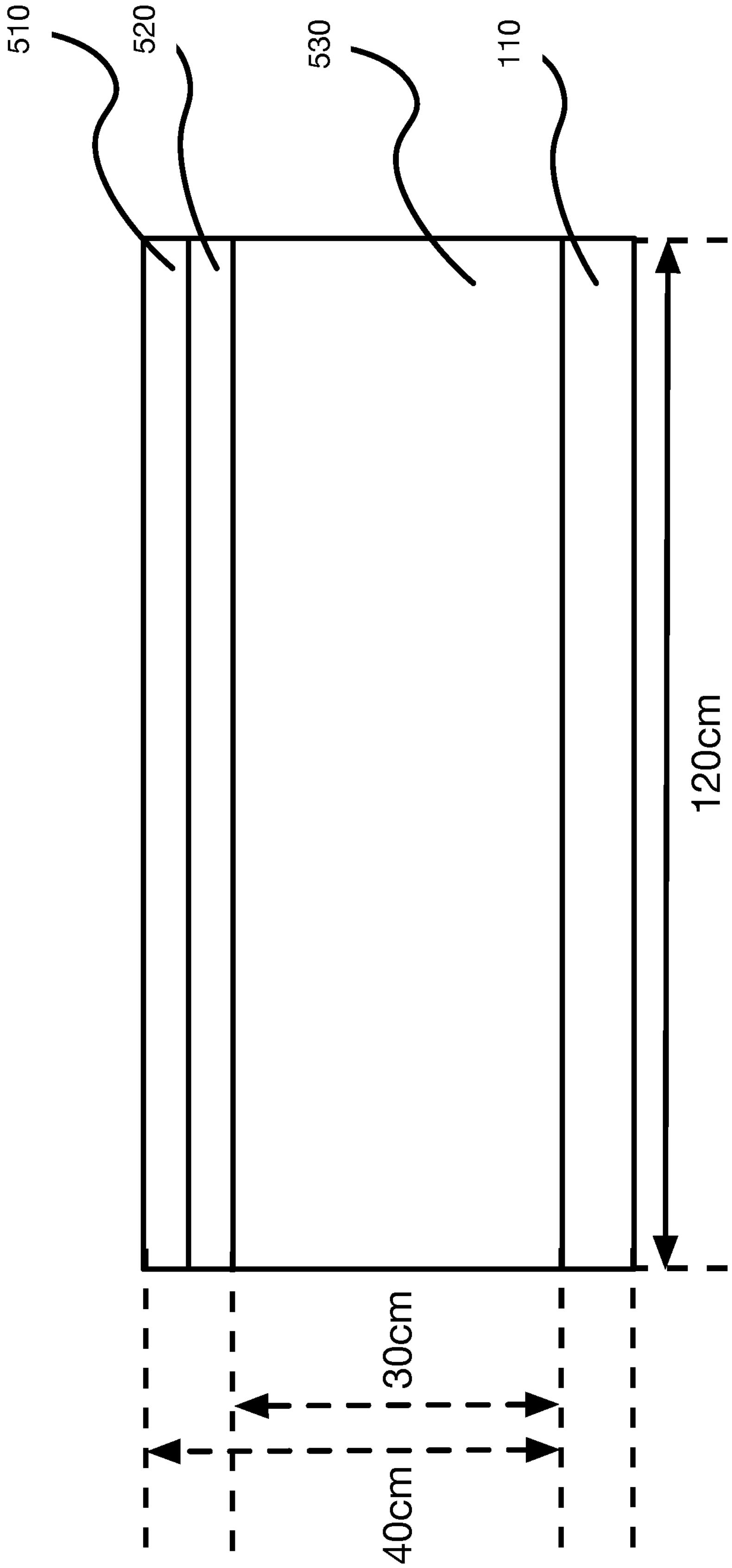

Figure 5

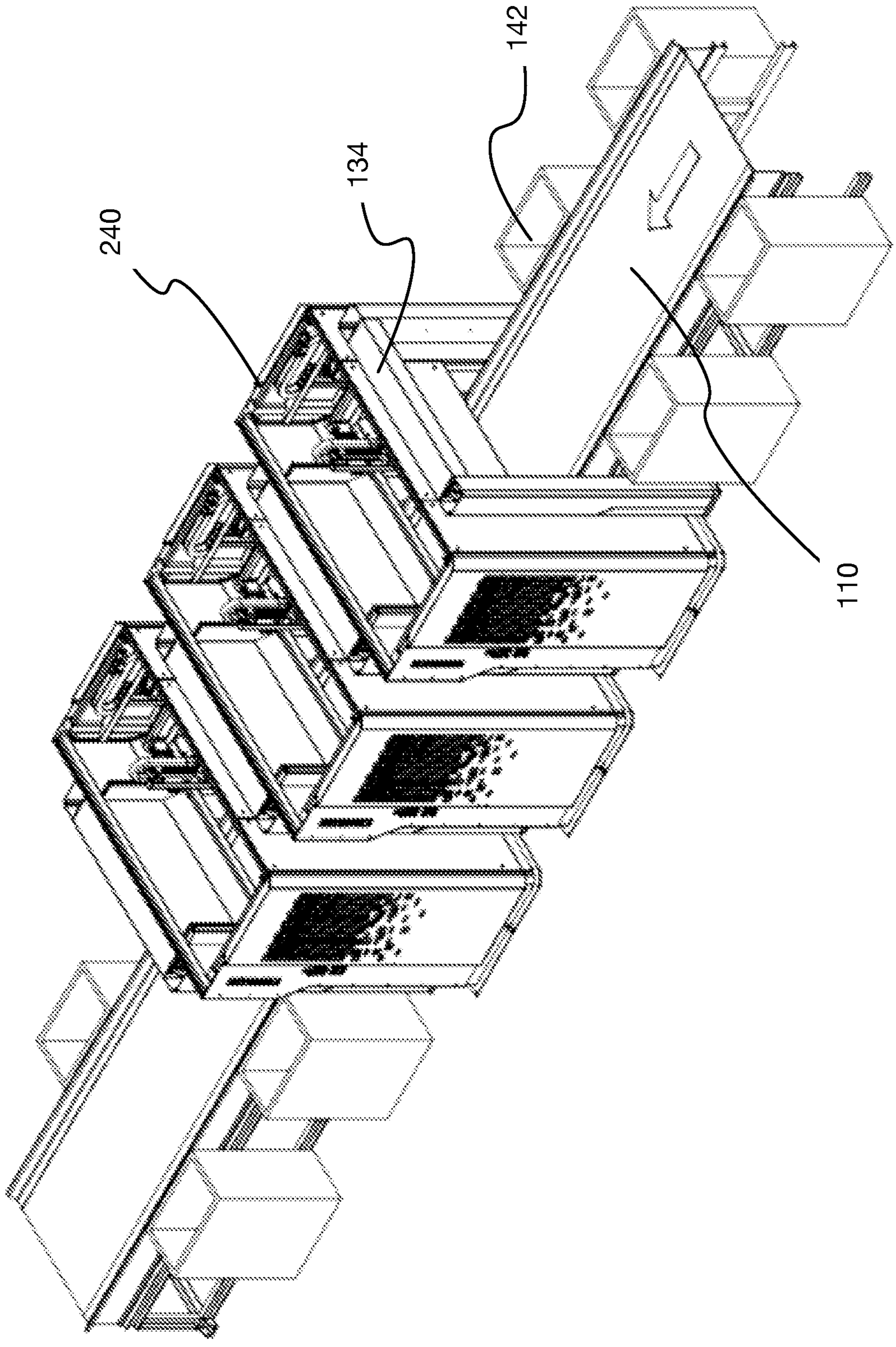

Figure 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2019/050318

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: B07C, B25J, B65G

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, BIOSIS, CHEM ABS Data, COMPENDEX, EMBASE, INSPEC, MEDLINE, IBM-TDB, Innovation Q+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20180036774 A1 (LUKKA TUOMAS ET AL), 8 February 2018 (2018-02-08); abstract; paragraphs [0025], [0026], [0031], [0032], [0034], [0035], [0052]; figures 1,3 --	1-16
A	WO 2015158962 A1 (ZENROBOTICS OY), 22 October 2015 (2015-10-22); abstract; page 9, line 35; page 10, line 15; figure 3; claim 4 --	1-16
A	JP 10202571 A (NIPPON KOKAN KK), 4 August 1998 (1998-08-04); abstract; paragraphs [0002], [0006]; figures 6,4 --	1-16

☒ 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
- "D" document cited by the applicant in the international application
- "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
22-07-2019	22-07-2019

Name and mailing address of the ISA/SE	Authorized officer
Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Johan Gulliksson Telephone No. + 46 8 782 28 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 10180668 A (NIPPON KOKAN KK), 7 July 1998 (1998-07-07); abstract; paragraph [0030] --	1-16
A	CN 103787059 A (KRONES AG), 14 May 2014 (2014-05-14); abstract; figures 3b,3a --	1-16
A	US 20180001487 A1 (MIYASAKA HIDEKATSU ET AL), 4 January 2018 (2018-01-04); paragraph [0078] --	15

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International Patent Classification (IPC)

B07C 5/00 (2006.01)
B07C 5/34 (2006.01)
B25J 9/00 (2006.01)
B65G 17/00 (2006.01)
B65G 47/00 (2006.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2019/050318

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				FI	20165603	A	15/11/2017
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				WO	2018024944	A1	08/02/2018
WO	2015158962	A1	22/10/2015	NONE			
JP	10202571	A	04/08/1998	NONE			
JP	10180668	A	07/07/1998	NONE			
CN	103787059	A	14/05/2014	DE	102012219886	A1	15/05/2014
				EP	2727689	B1	01/05/2019
US	20180001487	A1	04/01/2018	CN	107538477	A	05/01/2018
				JP	2018001315	A	11/01/2018