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(54) REFUSE COLLECTION VEHICLE CONTROLS

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B65F 3/02 (2006.01)

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(58) **Field of Classification Search**
CPC B65F 2003/023; B25J 19/089
See application file for complete search history.

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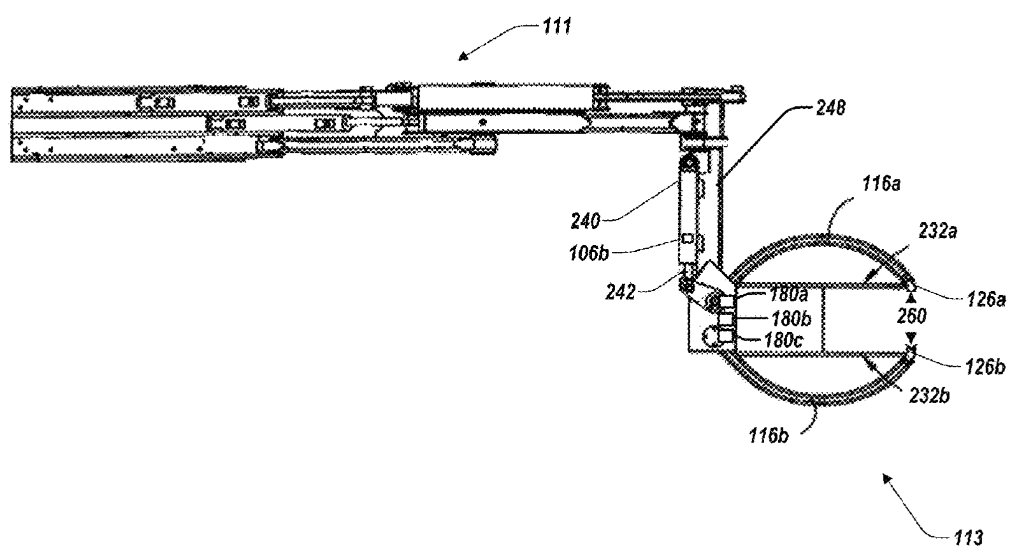
(57) **ABSTRACT**

A refuse collection vehicle includes a grabber that is operable to engage a refuse container, a lift arm that is operable to lift a refuse container, at least one sensor that is arranged to collect data indicating an angular position of the grabber, at least one sensor that is arranged to collect data indicating a relative positioning of the lift arm, a first controller for adjusting the angular position of the grabber, and a second controller adjusting the relative positioning of the lift arm. The adjustment of the angular position of the grabber is coordinated with the adjustment of the relative positioning of the lift arm.

14 Claims, 17 Drawing Sheets



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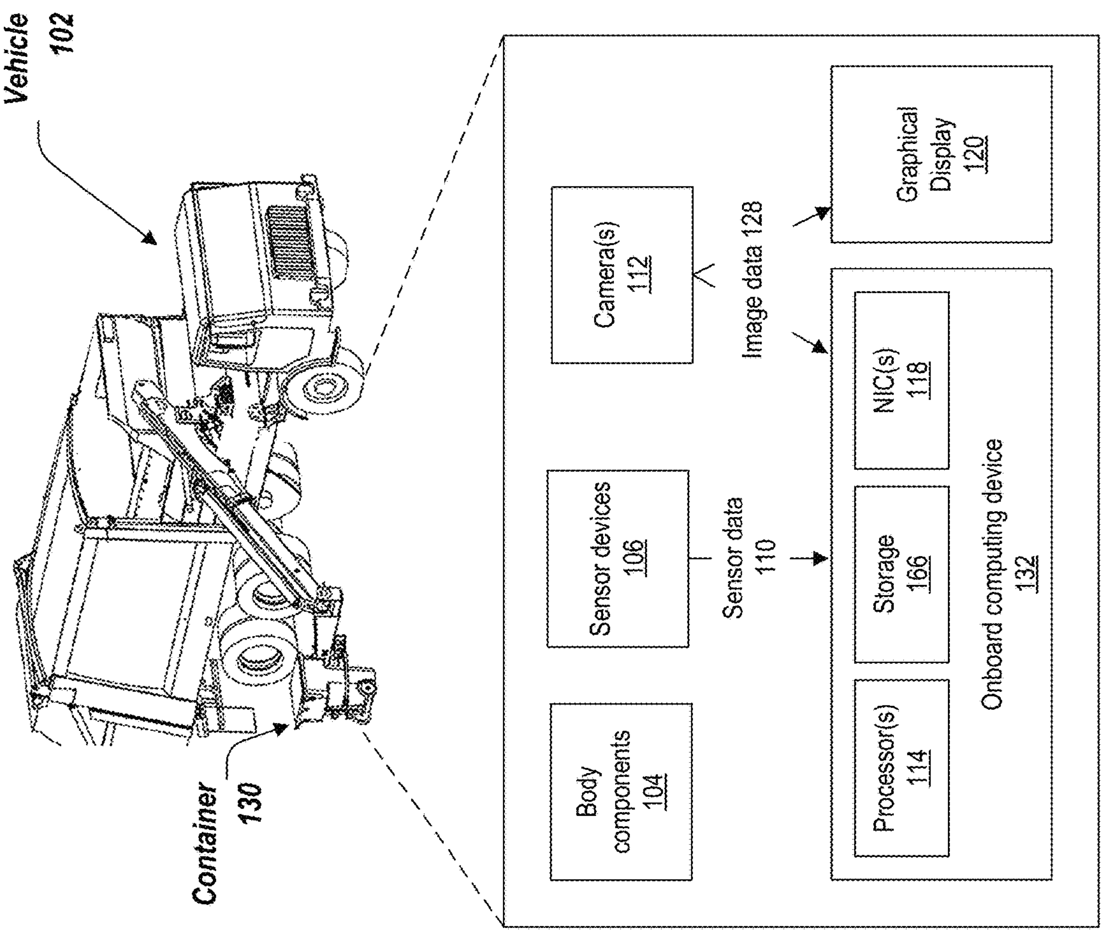
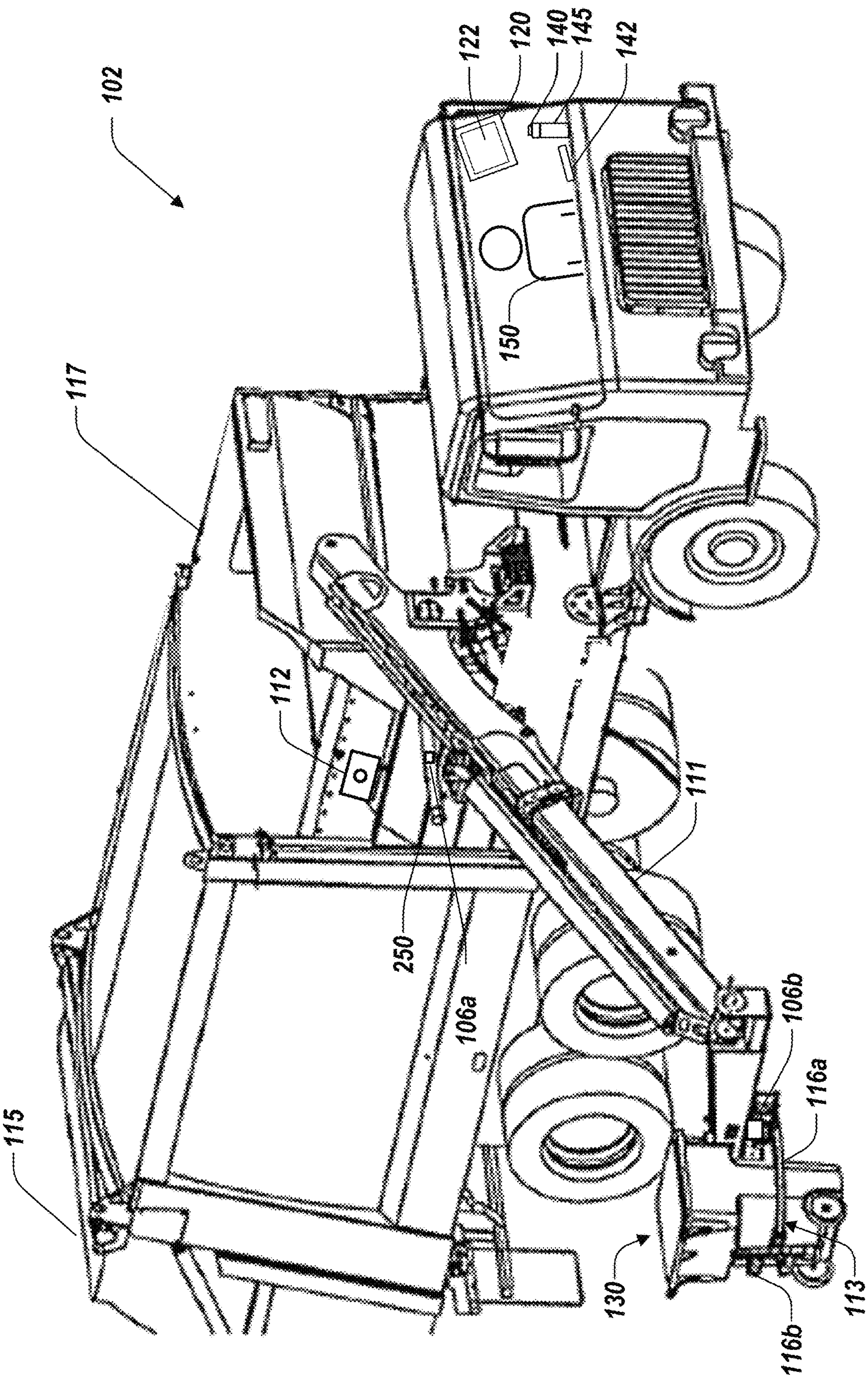


Vehicle 102
Container 130
Body components 104
Sensor devices 106
Sensor data 110
Camera(s) 112
Image data 128
Graphical Display 120
Processor(s) 114
Storage 166
NIC(s) 118
Onboard computing device 132

FIG. 1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112
111
250
106a
106b
116a
115
130
113
116b

FIG. 2A

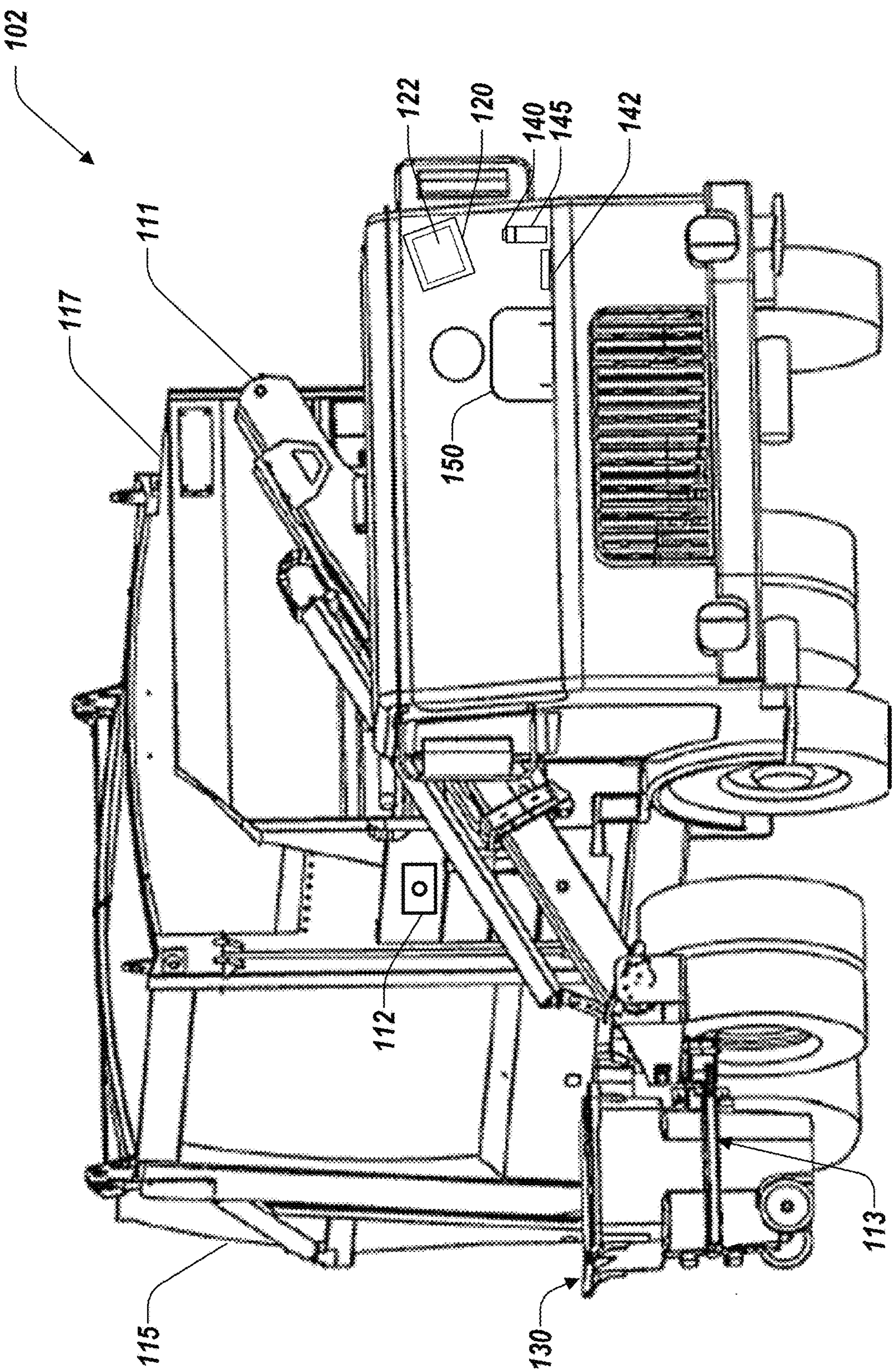
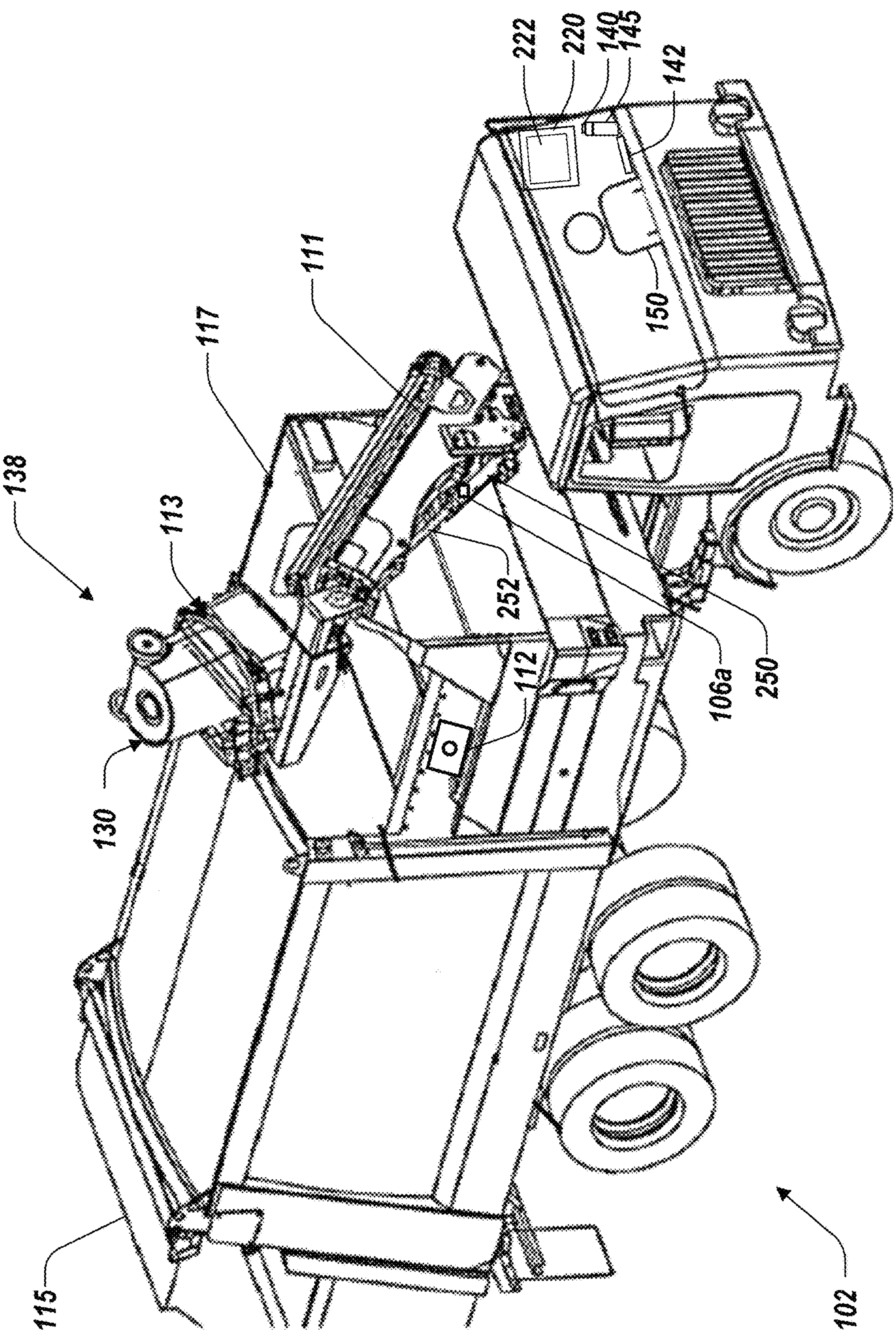


FIG. 2B


222
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145
142
111
117
150
138
113
252
112
106a
250
130
115
102

FIG. 2C

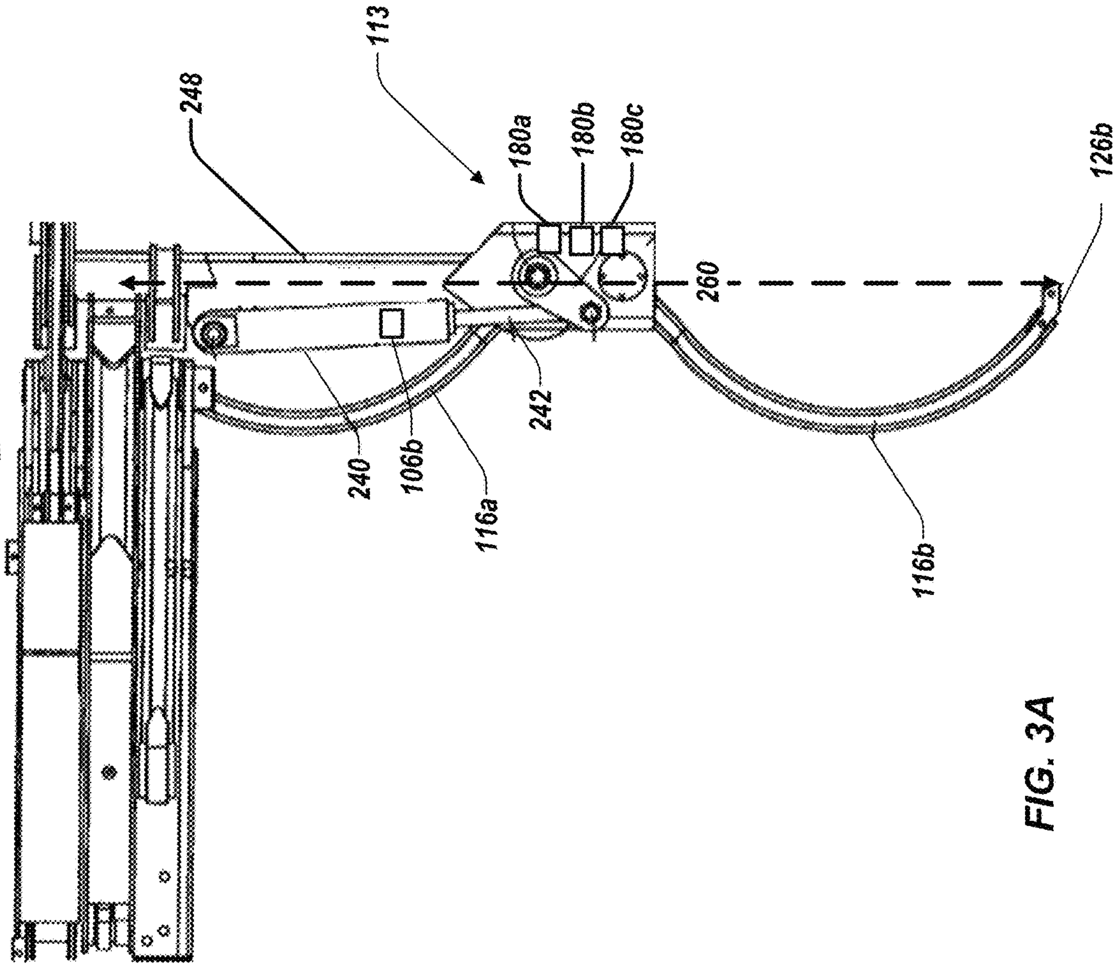

FIG. 3A

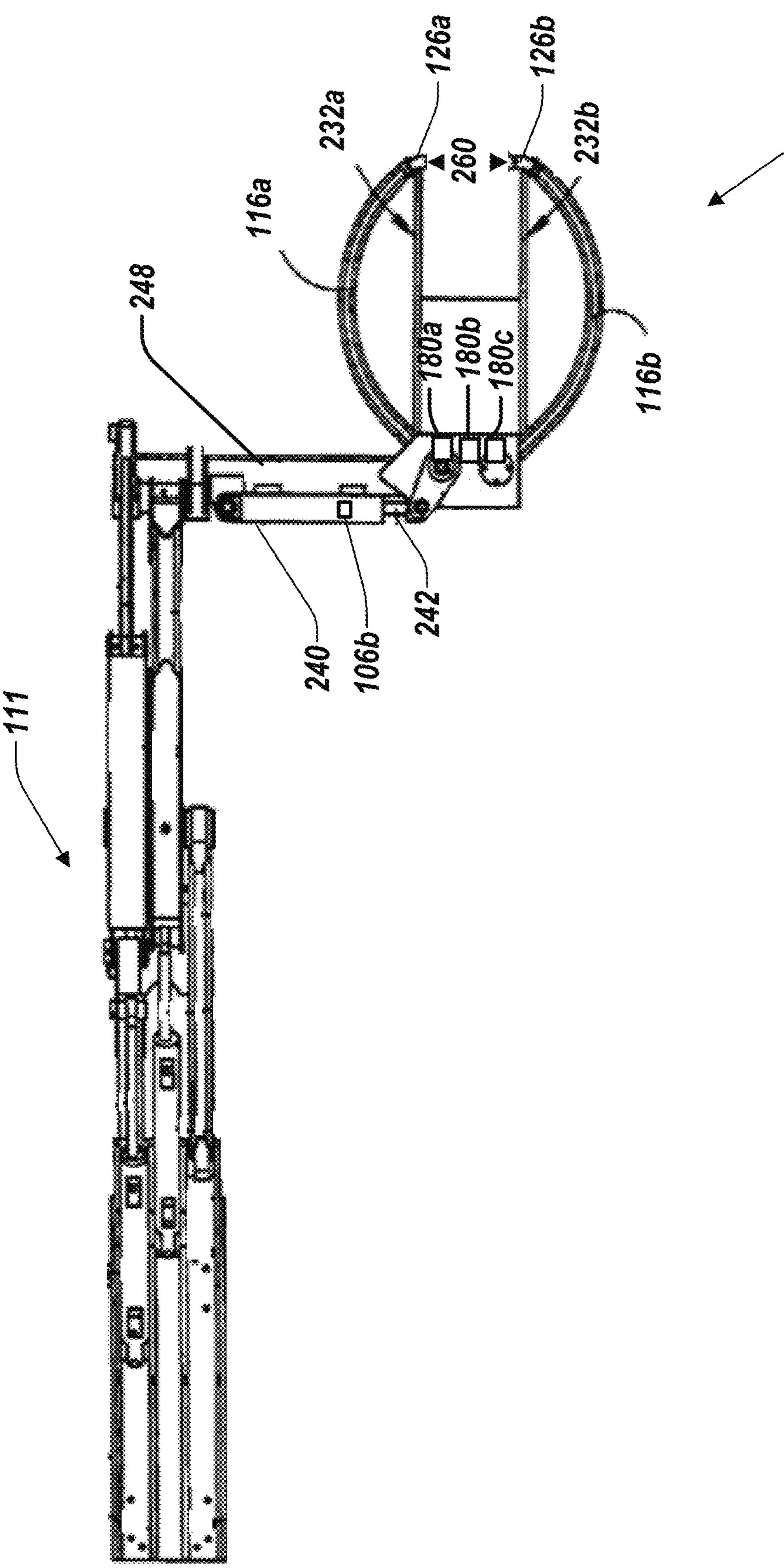
126a
126b
113
232a
260
232b
116a
248
180a
180b
180c
116b
240
106b
242
111

FIG. 3B

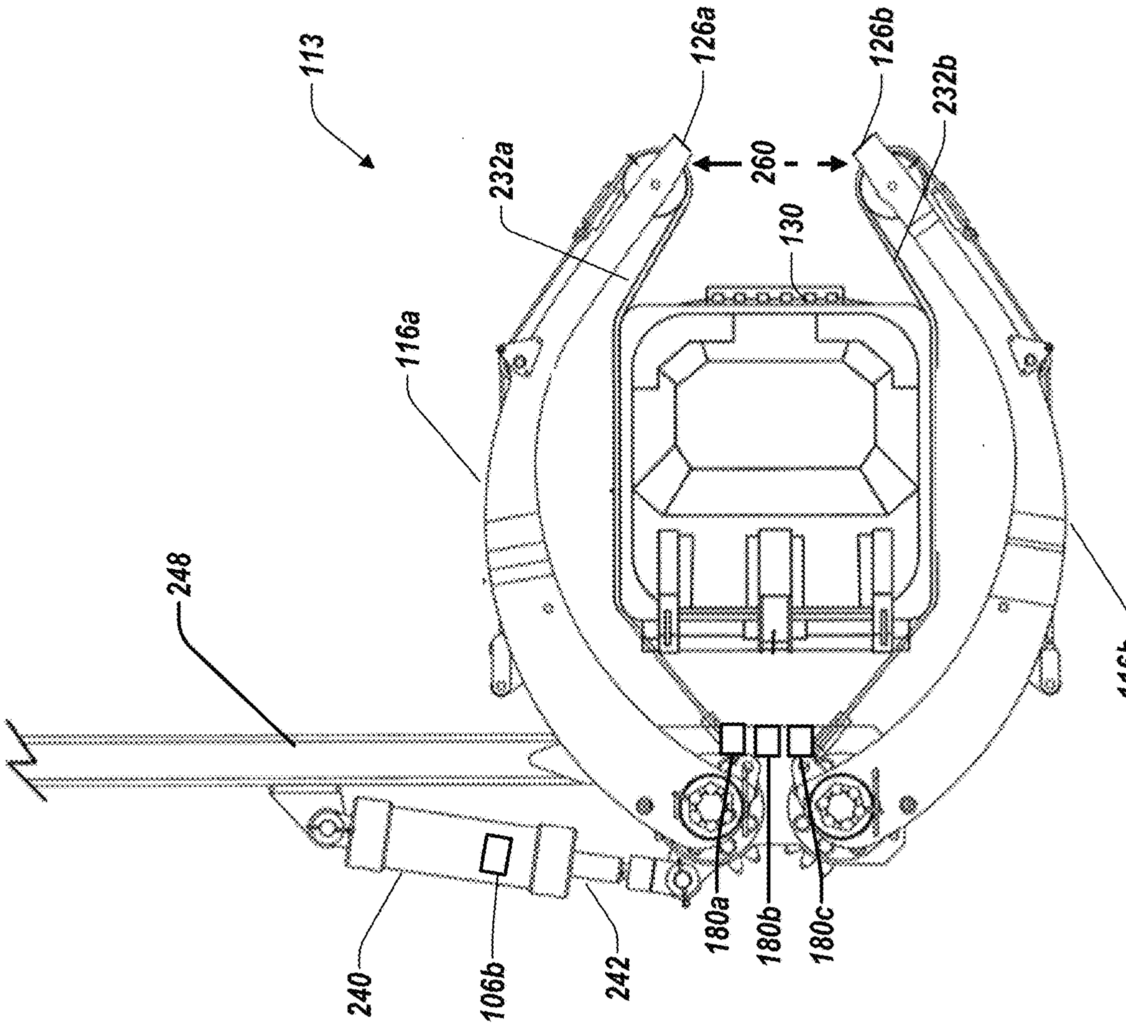
113
126a
126b
232a
232b
260
130
116a
116b
248
240
106b
242
180a
180b
180c

FIG. 3C

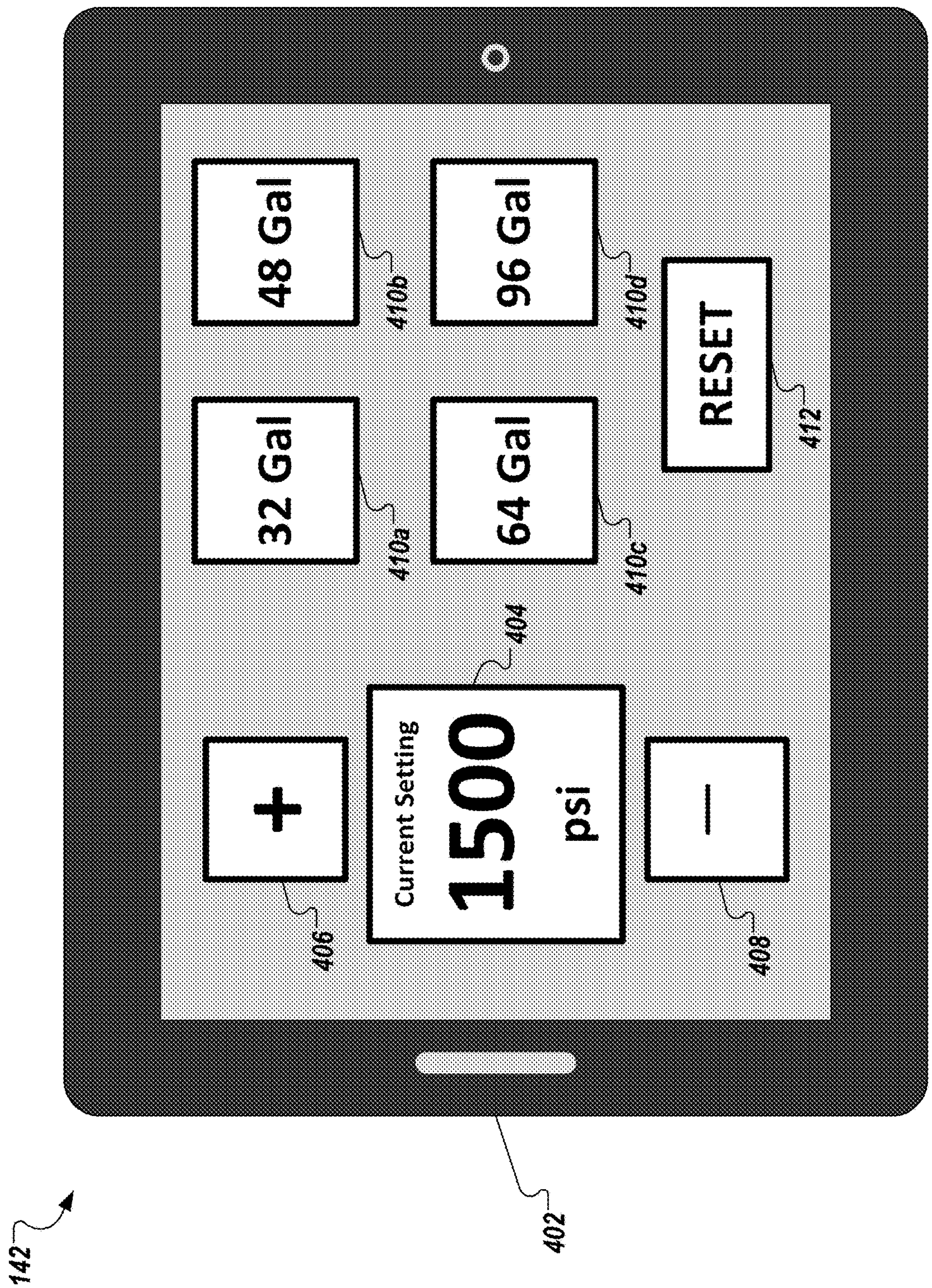
48 Gal
96 Gal
32 Gal
64 Gal
RESET
Current Setting
1500
psi
+
—
410b
410d
410a
410c
412
404
406
408
402
142

FIG. 4

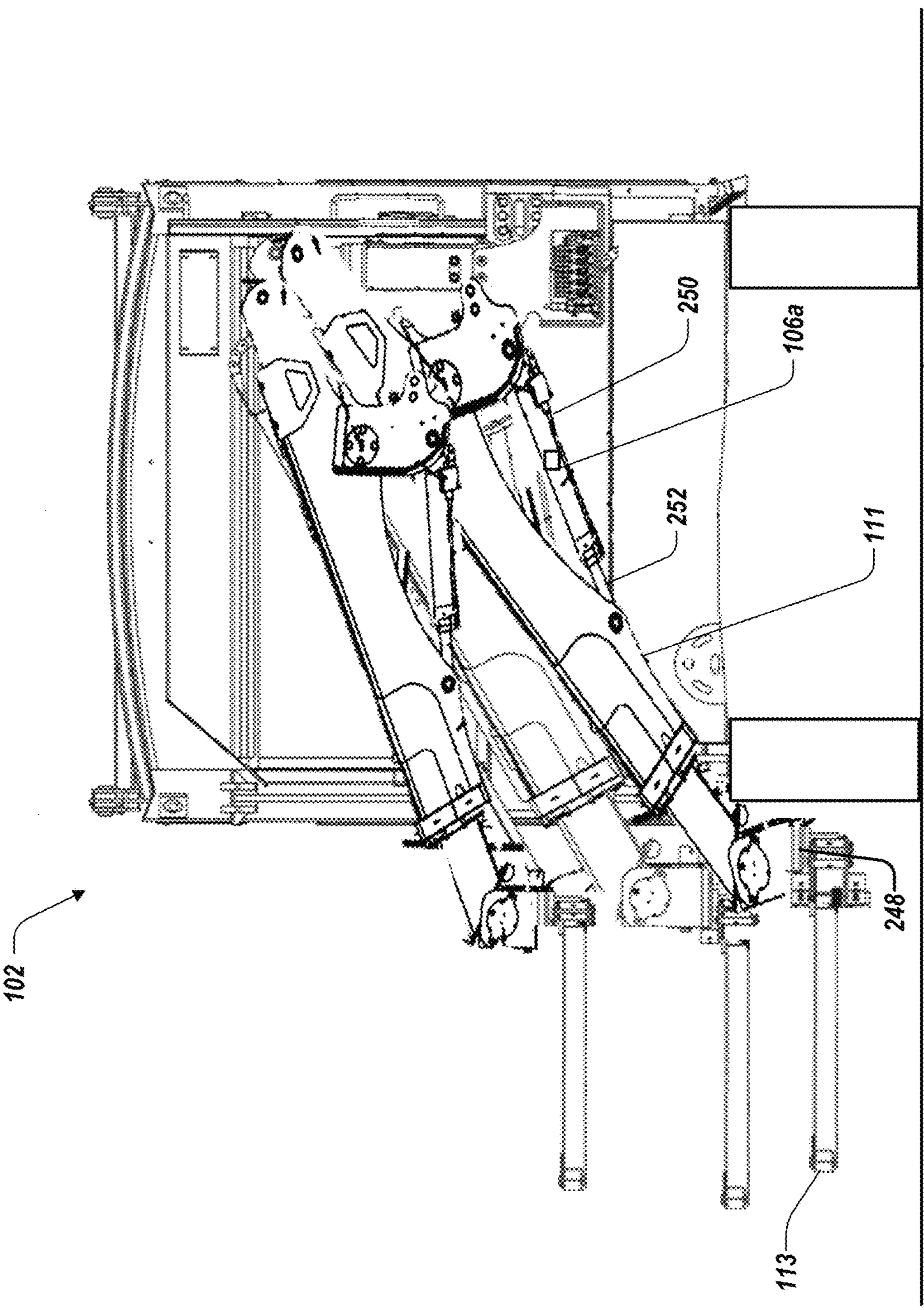

FIG. 5

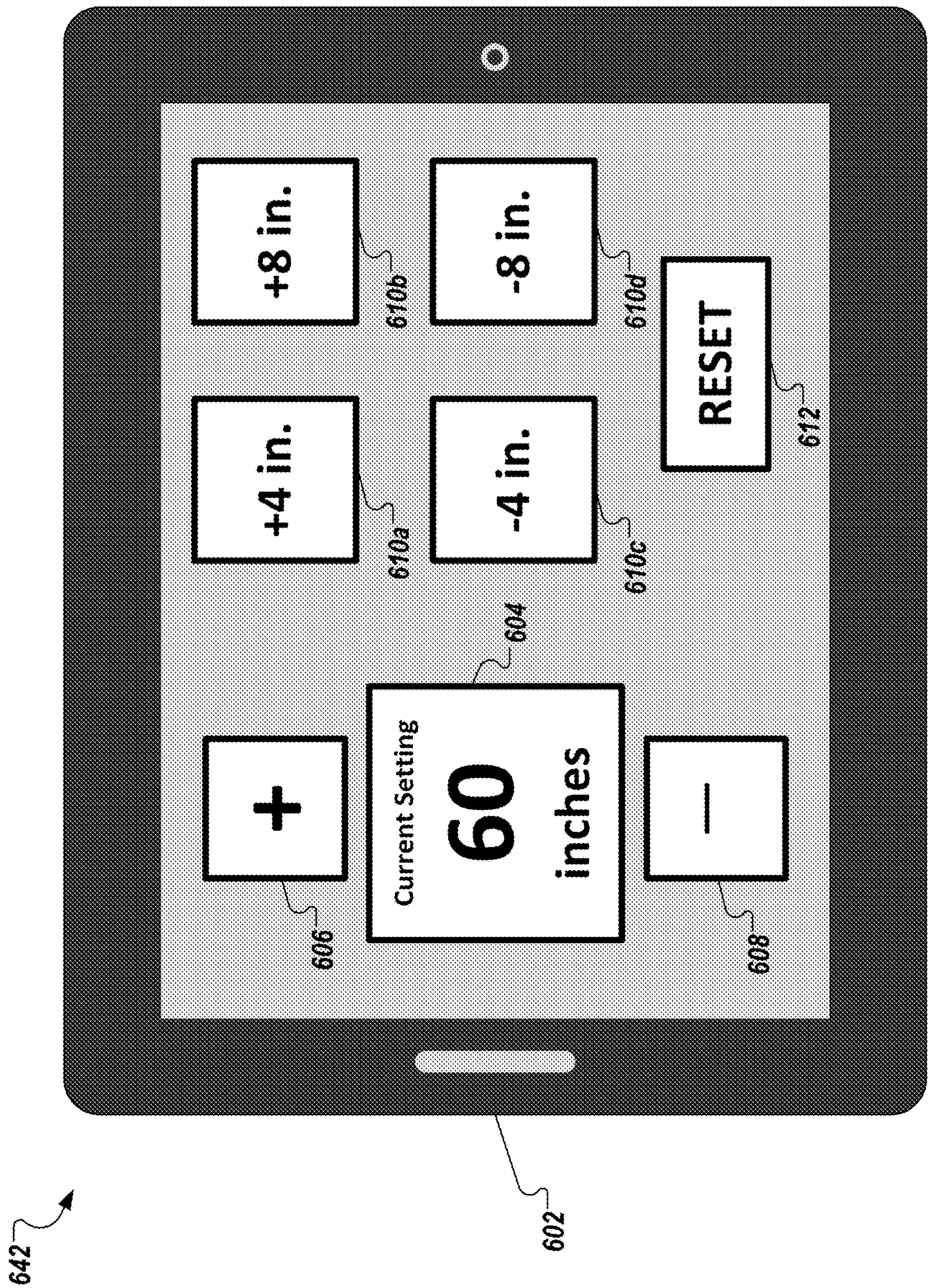
+8 in.
610b
-8 in.
610d
RESET
612
+4 in.
610a
-4 in.
610c
604
+
Current Setting
60
inches
–
606
608
602
642

FIG. 6

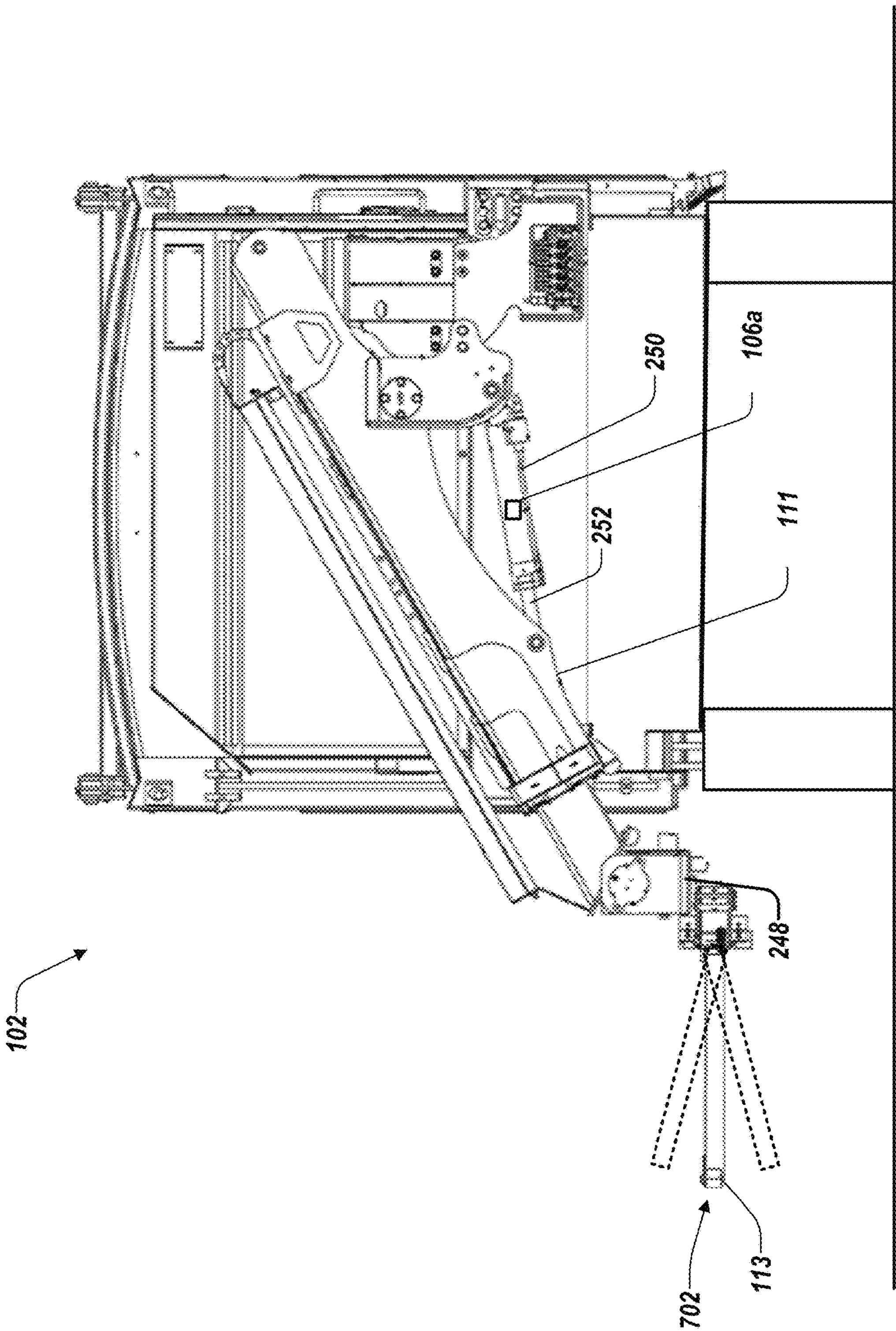

FIG. 7

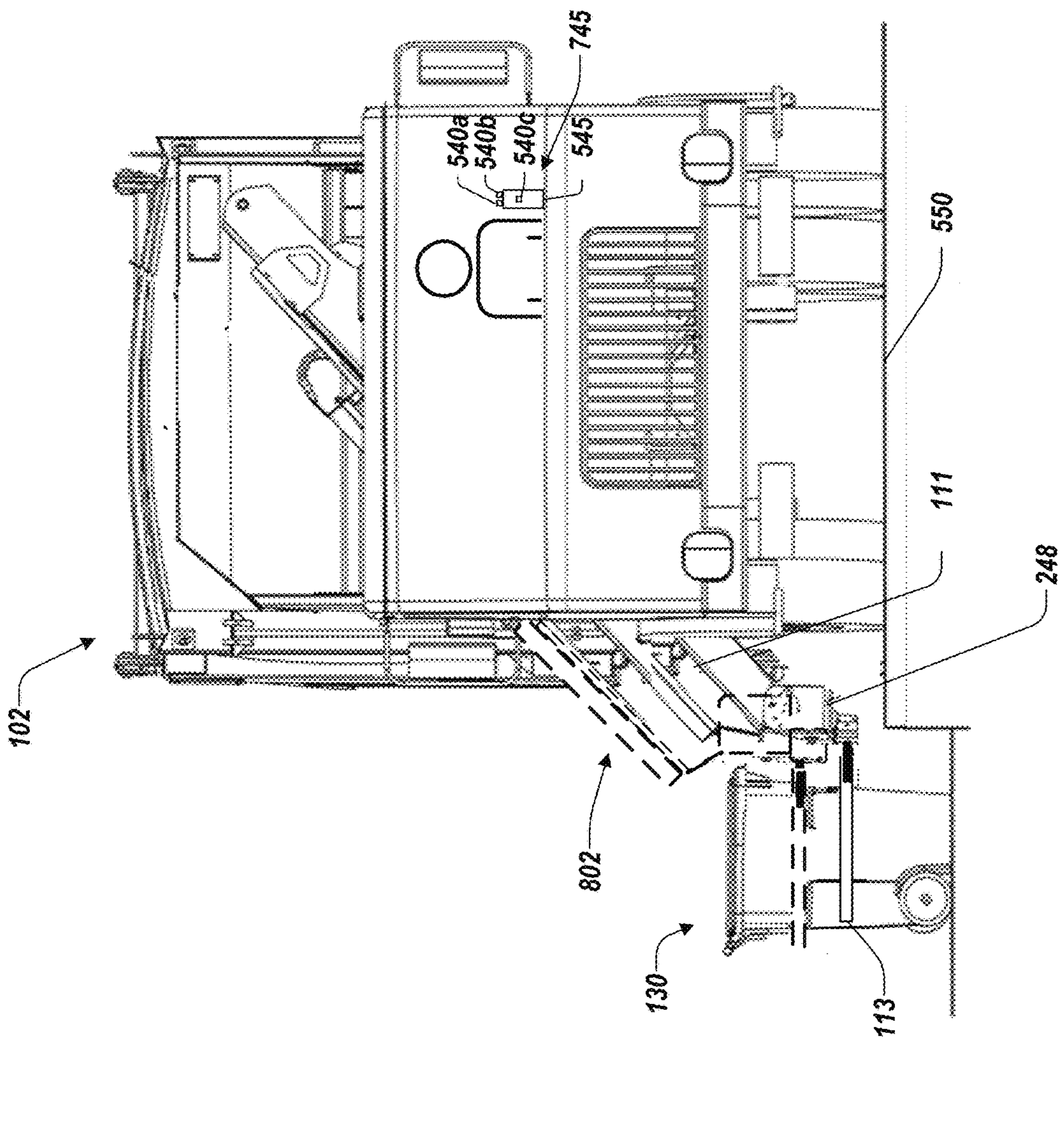

FIG. 8A

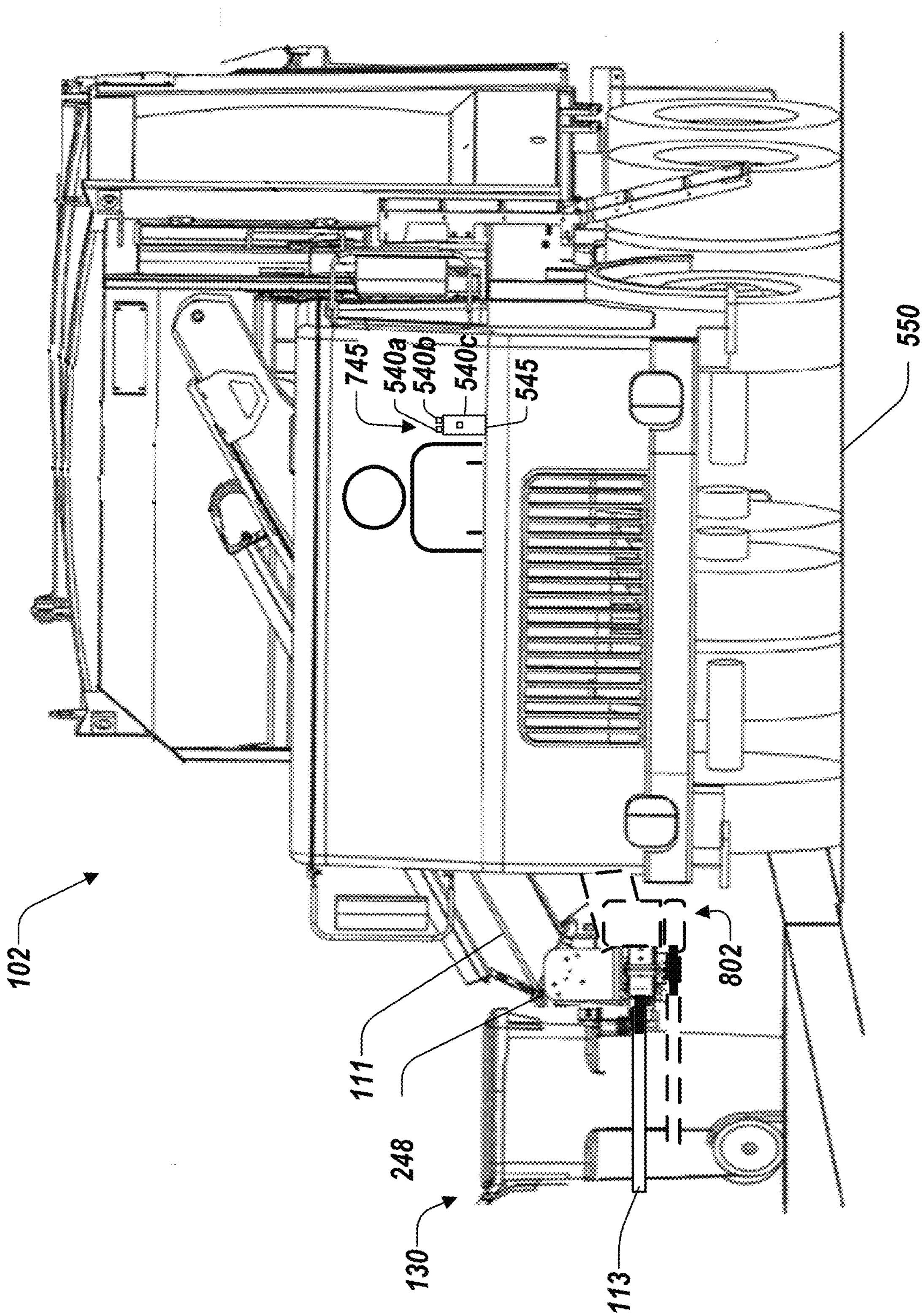

FIG. 8B

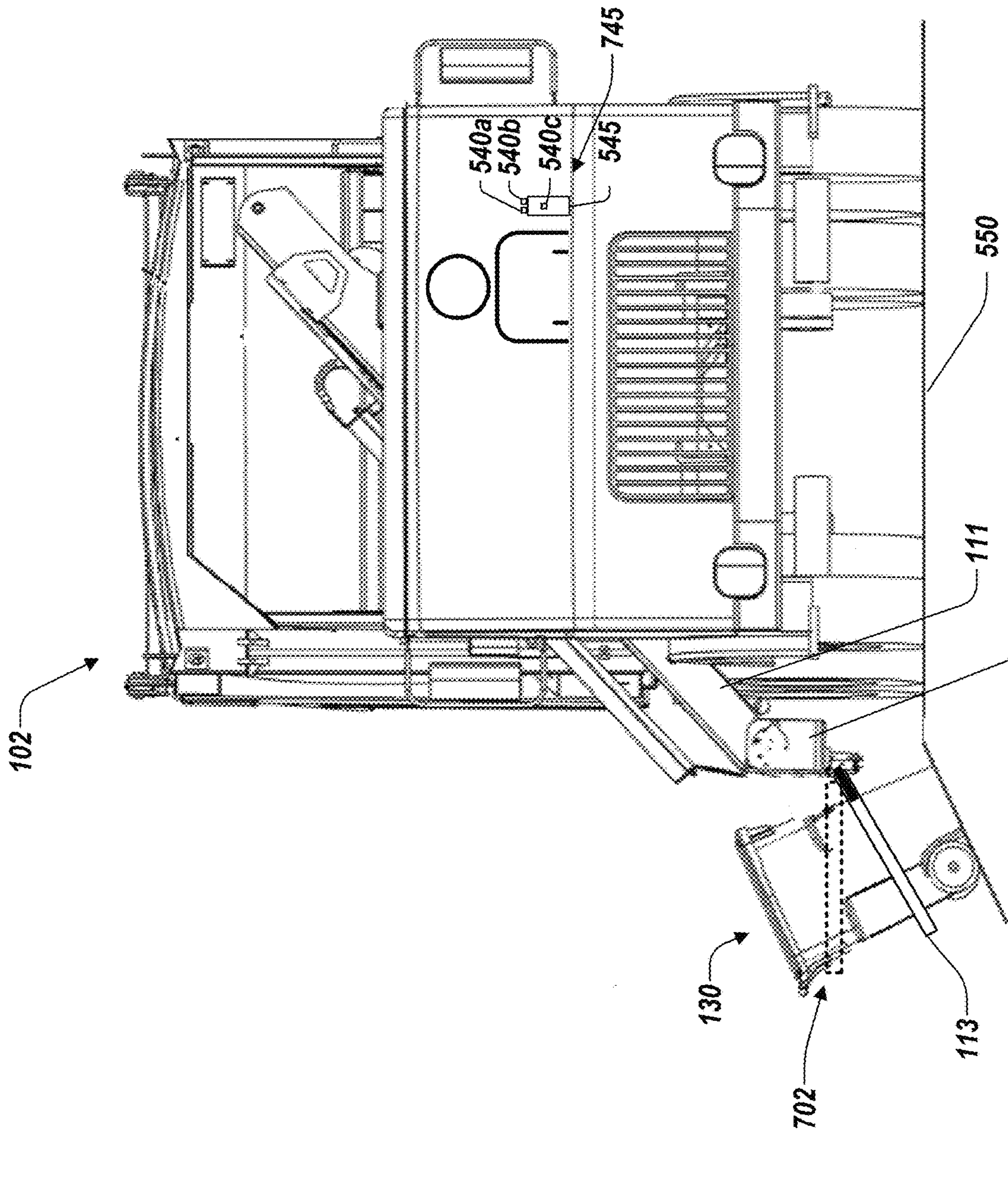

FIG. 8C

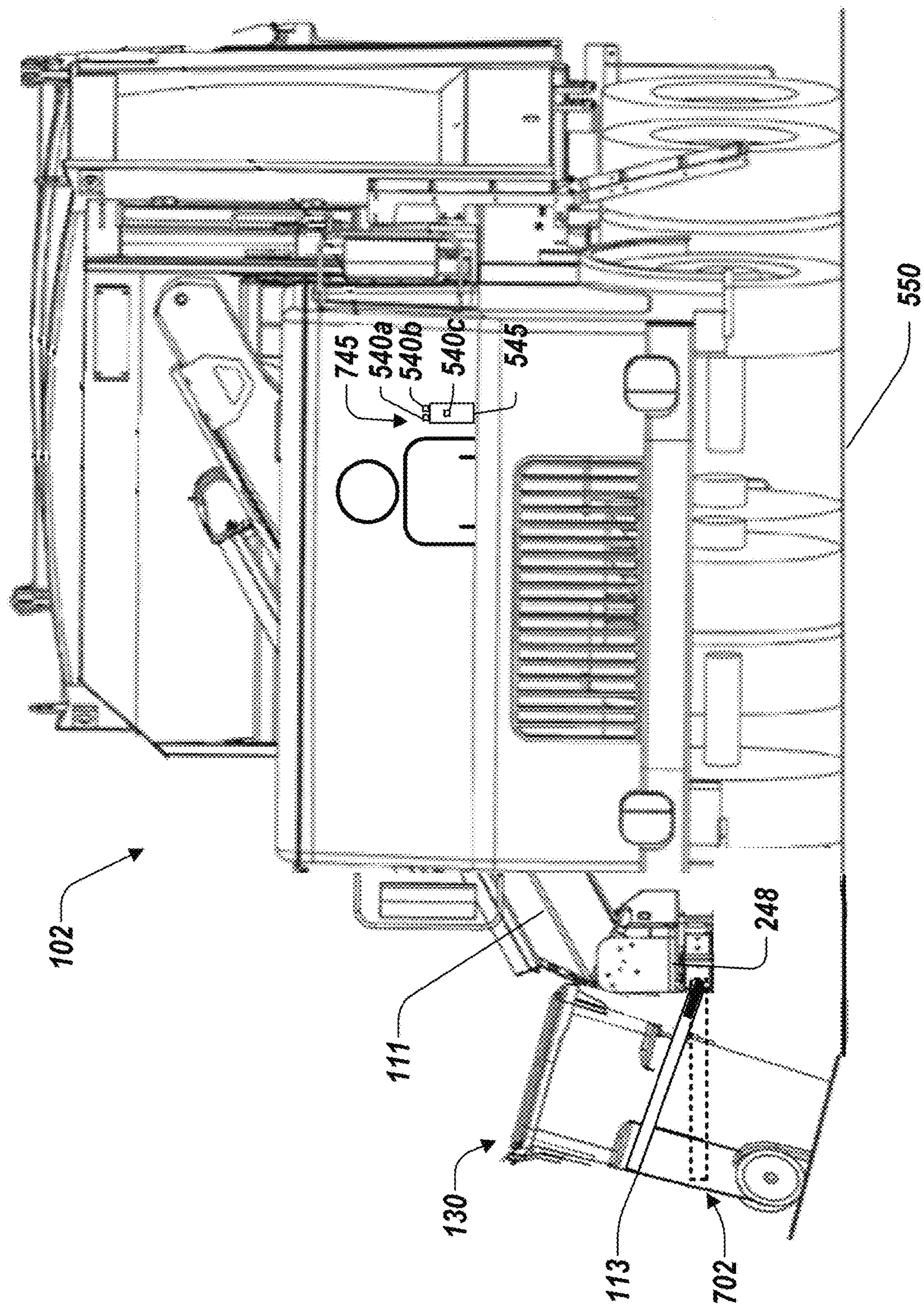

FIG. 8D

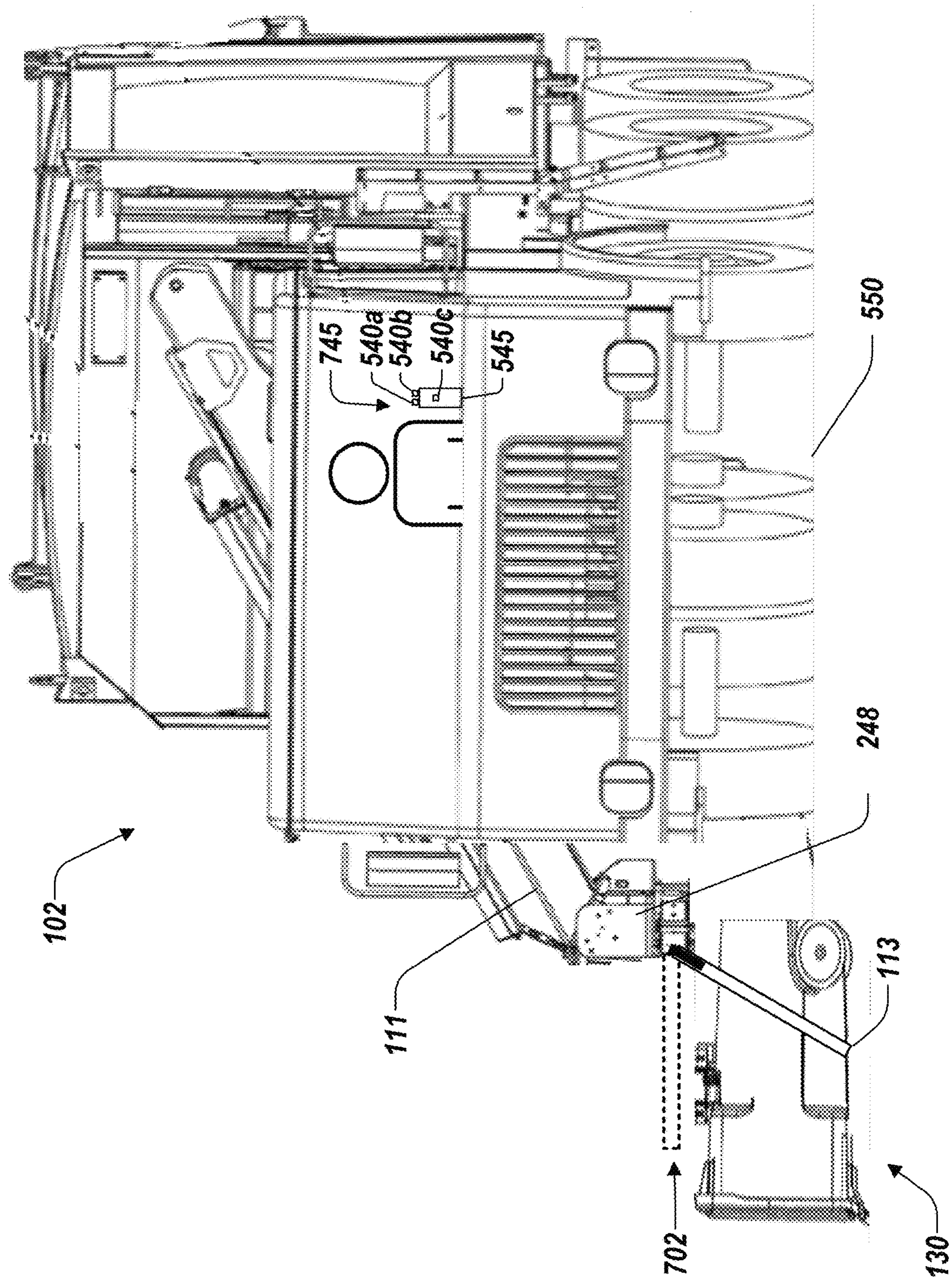

FIG. 8E

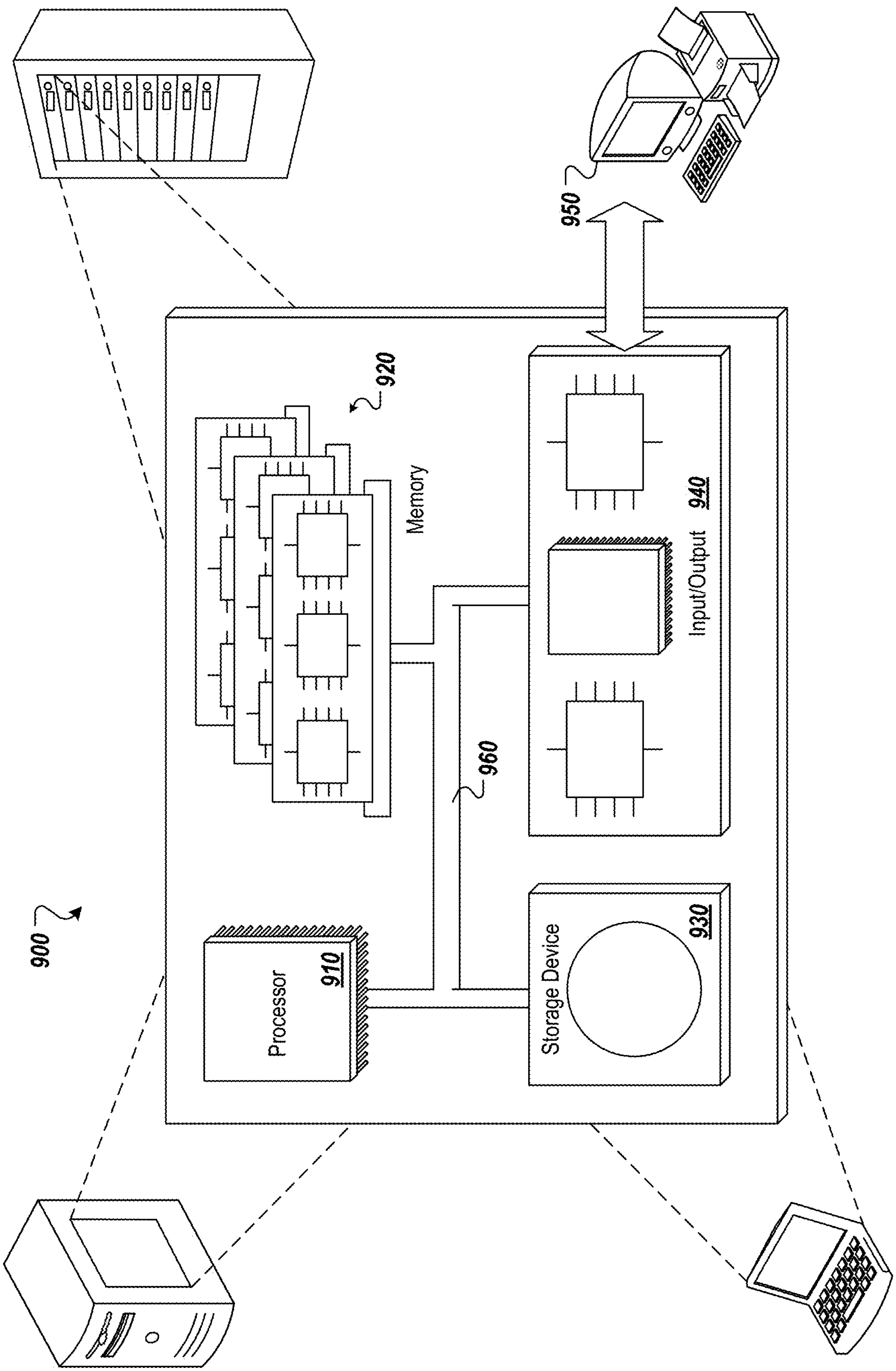
900
920
Memory
950
Processor
910
960
Storage Device
930
Input/Output
940

FIG. 9

REFUSE COLLECTION VEHICLE CONTROLS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 17/719,041, entitled "Refuse Collection Vehicle Controls," filed Apr. 12, 2022, which is a continuation of U.S. patent application Ser. No. 16/857,056, entitled "Refuse Collection Vehicle Controls," filed Apr. 23, 2020, now U.S. Pat. No. 11,453,550, which claims the benefit under 35 U.S.C. § 119(e) of U.S. patent application Ser. No. 62/837,576, entitled "Refuse Collection Vehicle Controls," filed Apr. 23, 2019, which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

This disclosure relates to systems and method for operating a refuse collection vehicle to engage a refuse container.

BACKGROUND

Refuse collection vehicles have been used for generations for the collection and transfer of waste. Traditionally, collection of refuse with a refuse collection vehicle required two people: (1) a first person to drive the vehicle and (2) a second person to pick up containers containing waste and dump the waste from the containers into the refuse collection vehicle. Technological advantages have recently been made to reduce the amount of human involvement required to collect refuse. For example, some refuse collection vehicles include features that allow for collection of refuse with a single operator, such as mechanical or robotic lift arms.

SUMMARY

Many aspects of the disclosure feature operating a mechanical lift arm and grabber **113** to perform refuse collection.

In an example implementation, a refuse collection vehicle includes a grabber that is operable to engage a refuse container, a lift arm that is operable to lift a refuse container, at least one sensor that is arranged to collect data indicating an angular position of the grabber, at least one sensor that is arranged to collect data indicating a relative positioning of the lift arm, a first controller for adjusting the angular position of the grabber, and a second controller adjusting the relative positioning of the lift arm. The adjustment of the angular position of the grabber is coordinated with the adjustment of the relative positioning of the lift arm.

In an aspect combinable with the example implementations, the first controller includes one or more push buttons.

In another aspect combinable with any of the previous aspects, adjusting the angular position of the grabber includes manually engaging at least one of the one or more push buttons.

In another aspect combinable with any of the previous aspects, manually engaging at least one of the one or more push buttons adjusts the angular position of the grabber by an incremental amount.

In another aspect combinable with any of the previous aspects, the incremental amount is 5 degrees of angular movement.

In another aspect combinable with any of the previous aspects, the grabber is parallel to a surface on which the refuse collection vehicle is positioned when the grabber is positioned in a baseline angular position.

In another aspect combinable with any of the previous aspects, the angular position of the grabber can be adjusted using the first controller in a range of −30 degrees to 30 degrees relative to a surface on which the refuse collection vehicle is positioned.

Another aspect combinable with any of the previous aspects further includes an onboard computing device coupled to the at least one sensor arranged to collect data indicating an angular position of the grabber, the at least one sensor arranged to collect data indicating a relative positioning of the lift arm, the first controller, and the second controller.

In another aspect combinable with any of the previous aspects, coordinating the adjustment of the angular position of the grabber with the adjustment of the relative positioning of the lift arm includes determining, by the onboard computing device, a current relative positioning of the lift arm based on data provided by the at least one sensor arranged to collect data indicating a relative positioning of the lift arm, determining, by the onboard computing device, that the current relative positioning of the lift arm is below a threshold position, and in response to the determining that the current relative positioning of the lift arm is below a threshold position, modifying the range in which the angular position of the grabber can be adjusted using the first controller to a modified range.

In another aspect combinable with any of the previous aspects, the modified range includes −15 degrees to 30 degrees relative to the surface.

In another aspect combinable with any of the previous aspects, the modified range includes 0 degrees to 30 degrees relative to the surface.

In another aspect combinable with any of the previous aspects, the second controller includes a touch input display.

In another aspect combinable with any of the previous aspects, the second controller includes one or more control elements.

In another aspect combinable with any of the previous aspects, the relative positioning of the lift arm is adjusted by manually engaging at least one of the one or more control elements.

In another aspect combinable with any of the previous aspects, the relative positioning of the lift arm corresponds to a height of the grabber relative to a surface on which the refuse collection vehicle is positioned.

In another aspect combinable with any of the previous aspects, manually engaging at least one of the one or more control elements adjusts height of the grabber relative to a surface on which the refuse collection vehicle is positioned by an incremental amount.

In another aspect combinable with any of the previous aspects, the incremental amount is 2.5 inches.

In another aspect combinable with any of the previous aspects, at least one of the one or more control elements corresponds to a grabber height.

In another aspect combinable with any of the previous aspects, manually engaging at least one of the one or more control elements corresponding to a grabber height adjusts the relative positioning of the lift arm to a position corresponding to the grabber height.

In another aspect combinable with any of the previous aspects, at least one of the one or more control elements corresponds to a baseline positioning of the lift arm, and manually engaging the at least one of the one or more control elements corresponding to a baseline positioning adjusts the relative positioning of the lift arm to the baseline positioning.

In another aspect combinable with any of the previous aspects, the baseline positioning includes a relative positioning of the lift arm corresponding to a height of the grabber relative to a surface on which the refuse collection vehicle is positioned.

In another aspect combinable with any of the previous aspects, the baseline positioning includes a relative positioning of the lift arm corresponding to a height of the grabber equal to 24 inches above the surface on which the refuse collection vehicle is positioned.

In another aspect combinable with any of the previous aspects, the relative positioning of the lift arm can be adjusted using the second controller such that a height of the grabber relative to a surface that the refuse collection vehicle is on can be adjusted in a range of 39 inches above the surface to 20 inches below the surface.

Potential benefits of the one or more implementations described in the present specification may include increased waste collection efficiency and reduced operator error in refuse collection. The one or more implementations may also reduce the likelihood of damaging refuse containers and refuse collection vehicles during the refuse collection process. The one or more implementations may also reduce the risk of injury to refuse collection vehicle operators by reducing the need for the operators to exit the vehicle to physically interact with the refuse containers.

It is appreciated that methods in accordance with the present specification may include any combination of the aspects and features described herein. That is, methods in accordance with the present specification are not limited to the combinations of aspects and features specifically described herein, but also include any combination of the aspects and features provided.

The details of one or more implementations of the subject matter described in this disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the subject matter will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. **1** depicts an example system for collecting refuse.

FIG. **2**A-**2**C depict example schematics of a refuse collection vehicle.

FIG. **3**A-**3**C depict schematics of an example grabber of a refuse collection vehicle.

FIG. **4** depicts an example controller interface for controlling a grabber.

FIG. **5** depicts a schematic of an example lift arm and an example grabber of a refuse collection vehicle.

FIG. **6** depicts an example controller interface for controlling a lift arm.

FIG. **7** depicts a schematic of an example lift arm and an example grabber of a refuse collection vehicle.

FIGS. **8**A-**8**E depict an example refuse collection vehicle engaging a refuse container.

FIG. **9** depicts an example computing system.

DETAILED DESCRIPTION

FIG. **1** depicts an example system for collecting refuse. Vehicle **102** is a refuse collection vehicle that operates to collect and transport refuse (e.g., garbage). The refuse collection vehicle **102** can also be described as a garbage collection vehicle, or garbage truck. The vehicle **102** is configured to lift containers **130** that contain refuse, and empty the refuse in the containers into a hopper of the vehicle **102**, to enable transporting the refuse to a collection site, compacting of the refuse, and/or other refuse handling activities.

The body components **104** of the vehicle **102** can include various components that are appropriate for the particular type of vehicle **102**. A vehicle with an automated side loader (ASL), such as the example shown in FIGS. **2**A-**2**C, may include body components **104** involved in the operation of the ASL, such as an arm and/or grabbers, as well as other body components such as a pump, a tailgate, a packer, and so forth. Body components **104** may also include other types of components that operate to bring garbage into a hopper (or other storage area) of a truck, compress and/or arrange the garbage in the hopper, and/or expel the garbage from the hopper.

The vehicle **102** can include any number of body sensor devices **106** that sense body component(s) **104** and generate sensor data **110** describing the operation(s) and/or the operational state of various body components. The body sensor devices **106** are also referred to as sensor devices, or sensors. Sensors may be arranged in the body components, or in proximity to the body components, to monitor the operations of the body components. The sensors **106** emit signals that include the sensor data **110** describing the body component operations, and the signals may vary appropriately based on the particular body component being monitored. In some implementations, the sensor data **110** is analyzed, by a computing device on the vehicle and/or by remote computing device(s), to identify the presence of a triggering condition based at least partly on the operational state of one or more body components **104**, as described in further detail below. Sensors **106** can include, but are not limited to, an analog sensor, a digital sensor, a CAN bus sensor, a magnetostrictive sensor, a radio detection and ranging (RADAR) sensor, a light detection and ranging (LIDAR) sensor, a laser sensor, an ultrasonic sensor, an infrared (IR) sensor, a stereo camera sensor, a three-dimensional (3D) camera, an in-cylinder sensor, or a combination thereof.

Sensors **106** can be provided on the vehicle body to evaluate cycles and/or other parameters of various body components. For example, as described in further detail herein, the sensors **106** can detect and measure the particular position or operational state of body components, such as the position of a lift arm **111** or the position of a grabber **113** of the vehicle **102**.

In some implementations, the sensor data **110** may be communicated from the sensors to an onboard computing device **132** in the vehicle **102**. In some instances, the onboard computing device is an under-dash device (UDU), and may also be referred to as the Gateway. Alternatively, the computing device **132** may be placed in some other suitable location in or on the vehicle. The sensor data **110** may be communicated from the sensors to the onboard computing device **132** over a wired connection (e.g., an internal bus) and/or over a wireless connection. In some implementations, a bus in conformance with International Organization of Standardization (ISO) standard 11898 connects the various sensors with the onboard computing device. In some implementations, a Controller Area Network (CAN) bus connects the various sensors with the onboard computing device. For example, a CAN bus in conformance with ISO standard 11898 can connect the various sensors with the onboard computing device. In some implementations, the sensors may be incorporated into the various body components. Alternatively, the sensors **106** may be separate from the body components. In some implementations, the sensors **106** digitize the signals that communicate the sensor data before sending the signals to the onboard computing device, if the signals are not already in a digital format.

The analysis of the sensor data **110** is performed at least partly by the onboard computing device **132**, e.g., by processes that execute on the processor(s) **114**. For example, the onboard computing device **132** may execute processes that perform an analysis of the sensor data **110** to determine the current position of the body components, such as the position of a lift arm and a grabber of the refuse collection vehicle **102**. In some implementations, an onboard program logic controller or an onboard mobile controller perform analysis of the sensor data **110** to determine the current position of the body components **104**.

The onboard computing device **132** can include one or more processors **114** that provide computing capacity, data storage **166** of any suitable size and format, and network interface controller(s) **118** that facilitate communication of the device **132** with other device(s) over one or more wired or wireless networks.

In some implementations, a vehicle includes a body controller that manages and/or monitors various body components of the vehicle. The body controller of a vehicle can be connected to multiple sensors in the body of the vehicle. The body controller can transmit one or more signals over a CAN network or aJ1939 network, or other wiring on the vehicle, when the body controller senses a state change from any of the sensors. These signals from the body controller can be received by the onboard computing device **132** that is monitoring the CAN network or the J1939 network.

In some implementations, the onboard computing device is a multi-purpose hardware platform. The device can include a UDU (Gateway) and/or a window unit (WU) (e.g., a device with cameras, speakers, and/or microphones) to record video and/or audio operational activities of the vehicle. The onboard computing device hardware subcomponents can include, but are not limited to, one or more of the following: a CPU, a memory or data storage unit, a CAN interface, a CAN chipset, NIC(s) such as an Ethernet port, USB port, serial port, I2c lines(s), and so forth, I/O ports, a wireless chipset, a global positioning system (GPS) chipset, a real-time clock, a micro SD card, an audio-video encoder and decoder chipset, and/or external wiring for CAN and for I/O. The device can also include temperature sensors, battery and ignition voltage sensors, motion sensors, CAN bus sensors, an accelerometer, a gyroscope, an altimeter, a GPS chipset with or without dead reckoning, and/or a digital can interface (DCI). The DCI cam hardware subcomponent can include the following: CPU, memory, can interface, can chipset, Ethernet port, USB port, serial port, I2c lines, I/O ports, a wireless chipset, a GPS chipset, a real-time clock, and external wiring for CAN and/or for I/O. In some implementations, the onboard computing device is a smartphone, tablet computer, and/or other portable computing device that includes components for recording video and/or audio data, processing capacity, transceiver(s) for network communications, and/or sensors for collecting environmental data, telematics data, and so forth.

In some implementations, one or more cameras **112** can be mounted on the vehicle **102** or otherwise present on or in the vehicle **102**. The camera(s) **112** each generate image data **128** that includes one or more images of a scene external to and in proximity to the vehicle **102**. In some implementations, one or more cameras **112** are arranged to capture image(s) and/or video of a refuse container **130** before, after, and/or during the operations of body components **104** to engage and empty the refuse container **130**. For example, for a side loading vehicle, the camera(s) **112** can be arranged to image objects to the side of the vehicle, such as a side that mounts the ASL to lift containers. In some implementations, camera(s) **112** can capture video of a scene external to, internal to, and in proximity to the vehicle **102**.

In some implementations, the camera(s) **112** are communicably coupled to a graphical display **120** to communicate images and/or video captured by the camera(s) **112** to the graphical display **120**. In some implementations, the graphical display **120** is placed within the interior of the vehicle. For example, as depicted in FIGS. **2A-2C**, the graphical display **120** can be placed within the cab of vehicle **102** such that the images and/or video can be viewed by an operator of the vehicle **102** on a screen **122** of the graphical display **120**. In some implementations, the graphical display **120** is a heads-up display that projects images and/or video onto the windshield of the vehicle **102** for viewing by an operator of the vehicle **102**.

In some implementations, the images and/or video captured by the camera(s) **112** can be communicated to the onboard computing device **132** in the vehicle **102**. Images and/or video captured by the camera(s) **112** can be communicated from the camera(s) **112** to the onboard computing device **132** over a wired connection (e.g., an internal bus) and/or over a wireless connection. In some implementations, a J1939 bus or a CAN bus connects the camera(s) with the onboard computing device.

In some implementations, the camera(s) **112** are incorporated into the various body components. Alternatively, the camera(s) **112** may be separate from the body components.

FIGS. **2A-2C** depict an example schematic of a refuse collection vehicle. The refuse collection vehicle **102** includes various body components including, but not limited to: a lift arm **111**, a grabber **113**, a back gate or tailgate **115**, and a hopper **117** to collect refuse for transportation.

As depicted in FIGS. **2A-2C**, the vehicle **102** also includes one or more cameras **112**. In the examples shown in FIGS. **2A-2C**, a camera **112** is positioned to visualize the environment proximate a side of the refuse collection vehicle **102**, including a refuse container **130** to be engaged by the vehicle **102**. The side view camera **112** can be aligned with a centerline of the grabber **113** to visualize a container **130** to be engaged by the grabber **113**.

The side view camera **112** helps provide the vehicle operator **150** with a clear visual line of sight of a refuse container **130** located to the side of the vehicle **102**. For example, images and/or video captured by camera **112** can be provided to a graphical display **120** for display on a screen **122** of the graphical display **120**. As shown in FIGS. **2A-2C**, a graphical display **120** is placed within the cab of vehicle **102** such that the images and/or video captured by camera **112** can be viewed on a screen **122** of the display **120** by the operator **150** of the vehicle **102**. In some implementations, the graphical display **120** is a heads-up display that projects images and/or video captured by camera **112** onto the windshield of the vehicle **102** for viewing by an operator of the vehicle **102**. In some implementations, the images and/or video captured by the camera **112** can be communicated to a graphical display **120** of an onboard computing device (such as onboard computing device **132** of FIG. **1**) in the vehicle **102**. Images and/or video captured by the camera **112** can be communicated to the graphical display **120**, over a wired connection (e.g., an internal bus) and/or over a wireless connection. In some implementations, a J1939 bus or CAN bus connects the camera(s) with the onboard computing device. The ability to visualize the side of the vehicle **102** via the side view camera **112** and the screen **122** may be particularly useful when the refuse container **130** to be engaged is within close proximity of the vehicle **102**.

In some implementations, the side view camera **112** is contained within an enclosure. For example, the camera **112** can be contained within a metal enclosure that also includes a light source. Placing the side view camera **112** in an enclosure can help protect the camera **112** from debris.

The vehicle **102** also includes a plurality of body sensors **106** positioned to determine the state and/or detect the operations of the body components **104**. In the example shown in FIGS. **2**A-**2**C, the vehicle **102** includes an arm position sensor **106***a* that is arranged to detect the relative position of the lift arm **111**. For example, data provided by the arm position sensor **106***a* can be used to determine the height of an end of the lift arm **111** relative to the surface on which the vehicle **102** is positioned. In some examples, the sensor **106***a* for detecting the relative position of the lift arm **111** is coupled to a cylinder **250** that is coupled to the lift arm **111**. For example, the sensor **106***a* can detect the relative position of the lift arm **111** based on the amount of travel of a piston **252** coupled to the lift arm **111** from the cylinder **250**. In some implementations, arm position sensor **106***a* is located inside a cylinder **250** coupled to lift arm **111**. In some implementations, position sensor **106***a* is located on the outside of a housing containing a cylinder **250** coupled to lift arm **111**. In some examples, arm position sensor **106***a* includes two sensors, with a first sensor being located inside a cylinder used for raising the lift arm **111** and a second sensor being located inside a cylinder used for extending the lift arm **111**. Body sensors **106** can include, but are not limited to, an analog sensor, a digital sensor, a CAN bus sensor, a magnetostrictive sensor, a RADAR sensor, a LIDAR sensor, a laser sensor, an ultrasonic sensor, an infrared (IR) sensor, a stereo camera sensor, a three-dimensional (3D) camera, an in-cylinder sensor, or a combination thereof.

The vehicle **102** also includes one or more grabber sensors **106***b*. The grabber sensor **106***b* can be arranged to detect the position and state of the grabber **113**. For example, the grabber sensor **106***b* can be used to detect the relative position of the gripper arms **116***a*, **116***b* of the grabber **113**. In some examples, the grabber sensor **106***b* detects a distance between the gripper arms **116***a*, **116**. In some examples, data provided by the grabber sensor **106***b* can be used to determine an angle of the grabber **113** relative to the body of the vehicle **102**. In some examples, data provided by the grabber sensor **106***b* can be used to determine the speed of movement of the gripper arms **116***a*, **116***b* of the grabber **113**. In some implementations, the grabber sensor **106***b* can be used to determine the pressure being applied to a refuse container by the gripper arms **116***a*, **116***b* of the grabber **113**.

In some examples, the grabber sensor **106***b* includes one or more sensors positioned in one or more rotary actuators coupled to the grabber **113** and is configured to detect angular movement of the grabber **113**. As shown in FIGS. **3**A-**3**C, in some examples, the grabber sensor **106***b* is coupled to a cylinder **240** that is coupled to the grabber **113**. For example, the sensor **106** can detect the relative position of the gripper arms **116***a*, **116***b* of the grabber **113** and the pressure being applied by the gripper arms **116***a*, **116***b* based on the amount of travel of a piston **242** coupled to the gripper arms **116**, **116***b* from the cylinder **240**. In some implementations, the grabber sensor **106***b* can detect the speed of travel of gripper arms **116***a*, **116***b* based on the rate of extension or retraction of a piston **242** coupled to the gripper arms **116**, **116***b* from the cylinder **240**. In some implementations, the grabber sensor(s) **106***b* for are located inside a cylinder **240** coupled to the grabber **113**. In some implementations, the grabber sensor(s) **106***b* are located on the outside of a housing containing a cylinder **240** coupled to the grabber **113**. Grabber position sensor(s) **106***b* for detecting the position of the gripper arms **116***a*, **116***b* can include, but are not limited to, an analog sensor, a digital sensor, a CAN bus sensor, a magnetostrictive sensor, a RADAR sensor, a LIDAR sensor, a laser sensor, an ultrasonic sensor, an infrared (IR) sensor, a stereo camera sensor, a three-dimensional (3D) camera, an in-cylinder sensor, or a combination thereof.

As depicted in FIGS. **2**A-**2**C, one or more controls **140**, **142**, **145** are provided to control mechanical components of the vehicle. For example, as will be described in detail herein, controllers **140**, **142** can be provided to control movement of the lift arm **111** and the grabber **113**.

As shown in FIG. **2**A, a refuse container **130** can be engaged by the grabber **113** of the refuse collection vehicle **102**. The grabber **113** includes two gripper arms **116***a*, **116***b* that are configured to encapsulate and apply pressure to a refuse container **130** to engage the refuse container **130**. As explained in further detail herein, the relative positioning of the lift arm **111** and of the grabber **113** can be adjusted to engage a refuse container **130**.

As shown in FIG. **2**A, engaging the refuse container **130** includes extending the lift arm **111** of the vehicle **102** outward from the vehicle **102** until the grabber **113** is in a position to engage the refuse container **130**. Once the grabber **113** is in close proximity to the refuse container **130**, the distance between the gripper arms **116***a*, **116***b* is reduced to engage and apply pressure to the refuse container **130**. In some implementations, the one or more gripper arms **116***a*, **116***b* continue to move inward until a threshold pressure is applied to the refuse container. As described in further detail herein, the speed of travel of the gripper arms **116***a*, **116***b* and the pressure applied to the refuse container **130** by the gripper arms **116***a*, **116***b* can be adjusted using one or more controllers **140**, **142**. In some implementations, the pressure applied to the refuse container **130** by the gripper arms **116***a*, **116***b* is automatically adjusted based on feedback from one or more sensors. For example, one or more sensors may be configured to detect the changes in hydraulic pressure of the grabber **113**, and, in response to the detected hydraulic pressure changes, the pressure applied to the refuse container **130** by the gripper arms **116***a*, **116***b* is automatically adjusted.

As depicted in FIGS. **2**B and **2**C, after the refuse container **130** is engaged by the grabber **113**, the engaged refuse container **130** is lifted to a dump position **138** and the contents of the refuse container **130** are dumped into the hopper **117** of the refuse collection vehicle **102**. The grabber **113** maintains the pressure applied by the gripper arms **116***a*, **116***b* to the refuse container **130** throughout the process of lifting the container **130** and dumping the contents of the container **130** to ensure that the container **130** is not prematurely dropped. In some implementations, the pressure provided by the gripper arms **116***a*, **116***b* is increased while the refuse container **130** is being rolled into a dump position **138**.

After the contents of the engaged refuse container **130** are dumped into the hopper **117** of the refuse collection vehicle **102**, the lift arm **111** is lowered to return the refuse container

130 to the ground (or to another surface on which the refuse container was positioned when initially engaged by the grabber **113**). Once the refuse container **130** has been lowered to the ground or other placement surface, the gripper arms **116***a*, **116***b* move apart from one another to release the refuse container **130** from the grabber **113**.

As previously discussed, the refuse collection vehicle **102** uses a grabber **113** to engage a refuse container **130** and uses a lift arm **111** to raise the engaged container **130** to release its contents into the hopper **117** of the vehicle **102**. FIGS. **3**A-**3**C depict top views of an example grabber **113**. As depicted in FIG. **3**A, the grabber **113** includes two opposing gripper arms **116***a*, **116***b*. In some examples, as depicted in FIGS. **3**B and **3**C, the grabber **113** also includes belts **232***a*, **232***b* attached to each the gripper arms **116***a*, **116***b*. The belts **232***a*, **232***b* allow for improved engagement between the grabber **113** and a refuse container **130** and allow for engagement of refuse containers **130** of various sizes. In some examples, belts **232** include one or more rubber belts. FIG. **3**C depicts a refuse container **130** engaged by the grabber **113**.

In some examples, an assembly including a cylinder **240** and a piston **242** move the gripper arms **116***a*, **116***b* between an open position (as depicted in FIG. **3**A) to a closed or grabbing position (as depicted in FIG. **3**B). For example, extension of the piston **242** from the cylinder **240** will cause the gripper arms **116***a*, **116***b* to move inward toward a closed position and reduce the distance **260** between the gripper arms **116***a*, **116***b*. Retraction of the piston **242** into the cylinder **240** causes the gripper arms **116***a*, **116***b* to move outward towards an open position and increase the distance **260** between the gripper arms **116***a*, **116***b*. In some examples, grabber sensor **106***b* is coupled to the cylinder **240** and measures the relative positioning of the gripper arms **116***a*, **116***b* based on the amount of extension of the piston **242** from the cylinder **240**.

In some examples, controls (such as controls **140**, **142** of FIG. **1**) can be provided to control the movement of the gripper arms **116***a*, **116***b* of the grabber **113**. For examples, control (such as controls **140**, **142** of FIG. **1**) can be provided to control the speed with which the gripper arms **116***a*, **116***b* move between an open position (as depicted in FIG. **3**A) and a closed or grabbing position (as depicted in FIG. **3**B).

In some implementations, the speed of gripper arm movement can be adjusted using a proportional push button control **140**. For example, a proportional push button located in the cab of the vehicle can be used to proportionally adjust the speed of movement of the gripper arms **116***a*, **116***b*. The proportional button control **140** can be configured such that the speed with which the gripper arms **116***a*, **116***b* move between an open position and a closed position is adjusted proportionally with the amount of button **140** travel. For example, if the proportional button control **140** is depressed 50%, the speed of movement of the gripper arms **116***a*, **116***b* will be set to 50% of a maximum speed. If the proportional button control **140** is fully depressed, the gripper arms **116***a*, **116***b* will move between an open position and a closed position at a maximum speed. In some examples, the proportional button control **140** is communicably coupled to the cylinder **240** and piston **242** assembly coupled to the grabber **113** such that the proportional button control **140** controls the speed of extension and retraction of the piston **242** from the cylinder **240**, which controls the speed of movement of the gripper arms **116***a*, **116***b*. In some examples, the proportional button control **140** is communicably coupled to the hydraulic system of the grabber **113** such that the proportional control **140** controls the hydraulic flow to the grabber **113**, which controls the speed of gripper arm **116***a*, **116***b* movement. In some implementations, proportional push button control **140** is communicably coupled to an onboard computing device (such as onboard computing device **132** of FIG. **1**.) For example, proportional push button control **140** may communicate with onboard computing device **132** over a J1939 network or over a CAN network.

In some examples, the proportional button control **140** for controlling gripper arm speed is integrated into a joystick controller **145**. In some examples, the joystick controller **145** is used to control movement of the lift arm **111** of the vehicle. In some examples, the proportional button control **140** for grabber arm speed is integrated into a dashboard of the cab of the refuse collection vehicle. In some examples, the proportional button control **140** for gripper arm speed includes two proportional push buttons: a first button to adjust the speed of inward movement of the gripper arms **116***a*, **116***b* and a second button to adjust the speed of outward movement of the gripper arms **116***a*, **116***b*.

As the gripper arms **116***a*, **116***b* move inward to the engage and grasp a refuse container, as shown in FIG. **2**C, the gripper arms **116***a*, **116***b* apply a pressure to the refuse container **130**. In some examples, controllers (such as controllers **140**, **142** of FIG. **2**A-**2**C) are provided to control the pressure applied to the refuse can **130** by the gripper arms **116***a*, **116***b*. For example, the gripper arms **116***a*, **116***b* may be configured to apply a baseline pressure to a refuse container **130**, and a controller **142** located within the vehicle **102** can be used to adjust the pressure applied by the gripper arms **116***a*, **116***b* to the refuse container **130**.

FIG. **4** depicts an example controller **142** for adjusting the pressure applied by the gripper arms **116***a*, **116***b* of the grabber **113**. As depicted in FIG. **4**, controller **142** may be provided as a touchscreen display **402** displaying a graphical user interface having one or more control elements **406**, **408**, **410**, **412**. Each of the control elements **406**, **408**, **410**, **412** can be used to adjust the pressure provided by the gripper arms **116***a*, **116***b* of the grabber **113**. As shown in FIG. **4**, the GUI of the controller **142** also includes a control element **404** displaying the current pressure setting for the pressure provided by the gripper arms **116***a*, **116***b*.

The GUI of the controller **142** includes a first control element **406** for increasing the pressure to be applied by the gripper arms **116***a*, **116***b* on a refuse container. In some examples, each time an operator selects the first control element **406**, the pressure to be applied by the gripper arms **116***a*, **116** is increased by a defined incremental amount. For example, if the incremental amount is 10 pounds per square inch (psi), an operator may increase the pressure to be applied by the gripper arms **116***a*, **116***b* by 30 psi by selecting the first control element **406** three times. In some examples, the pressure to be applied by the gripper arms **116***a*, **116***b* can be increased in increments in a range of 1 psi to 3000 psi using control element **406**. In some examples, the pressure to be applied by the gripper arms **116***a*, **116***b* can be increased in increments of 10 psi using control element **406**.

The GUI of the controller **142** includes a second control element **408** for decreasing the pressure to be applied by the gripper arms **116***a*, **116***b* on a refuse container. In some examples, each time an operator selects the second control element **408**, the pressure to be applied by the gripper arms **116***a*, **116** is decreased by a defined incremental amount. For example, if the incremental amount is 10 psi, an operator may decrease the pressure to be applied by the gripper arms **116***a*, **116***b* by 30 psi by selecting the second control element **408** three times. In some examples, the pressure to be applied by the gripper arms **116***a*, **116***b* can be decreased in increments in a range of 1 psi to 3000 psi using control element **408**. In some examples, the pressure to be applied by the gripper arms **116***a*, **116***b* can be decreased in increments of 10 psi using control element **408**.

The controller **142** also includes control elements **410** for automatically adjusting the pressure to be applied by the gripper arms **116***a*, **116***b* based on a selected refuse container size. Control elements **410** each correspond to a particular size of refuse container, as defined by volume. For example, as depicted in FIG. **4**, control element **410***a* corresponds to a 32-gallon refuse container, control element **410***b* corresponds to a 48-gallon refuse container, control element **410***c* corresponds to a 64-gallon refuse container, and control element **410***d* corresponds to a 96-gallon refuse container. Controller **142** can store a gripper pressure corresponding to each refuse container size associated with each control element **410**. The stored pressure associated with each refuse container size can be equal to a pressure sufficient of maintain engagement between the grabber **113** and a fully loaded refuse container of the respective size.

In response to an operator's selection of one of control elements **410**, the pressure to be applied by the gripper arms **116***a*, **116***b* is automatically adjusted to the stored gripper pressure associated with the selected control element **410**. For example, if an operator selects control element **410***c*, the pressure to be applied by the gripper arms **116***a*, **116***b* will be automatically adjusted to the stored pressure associated with control element **410***c*.

As depicted in FIG. **4**, the GUI of the controller **142** also includes a reset control element **412** that allows an operator to reset the pressure to be applied by the gripper arms **116***a*, **116***b* to a baseline pressure. In some implementations, the baseline pressure to be applied by the gripper arms **116***a*, **116***b* is in a range of 0 psi to 3000 psi. In some examples, the baseline pressure applied to the gripper arms **116***a*, **116***b* is 1200 psi. In some implementations, an operator **150** can adjust or set the baseline pressure using a controller, such as control elements **406** and **408**. In response to an operator's selection of the reset control element **412**, the pressure to be applied by the gripper arms **116***a*, **116***b* is automatically adjusted to the baseline pressure.

Control element **404** displaying the current setting of the pressure to be applied by the gripper arms **116***a*, **116***b* is automatically updated in response to each adjustment of the pressure to be applied by the gripper arms **116***a*, **116***b*. For example, if the current gripper arm pressure setting is 1250 psi, and the operator increases the pressure setting by 40 psi using control element **406**, control element **404** will be updated to display 1290 psi as the current setting of the pressure to be applied by the gripper arms **116***a*, **116***b*.

The controller **142** can be used to adjust the pressure applied by the gripper arms **116***a*, **116***b* within a predetermined range. For example, controller **142** can be used to adjust the pressure applied by the gripper arms **116***a*, **116***b* between 0 psi and 3000 psi. In some implementations, controller **142** can be used to adjust the pressure applied by the gripper arms **116***a*, **116***b* between 1000 psi and 1800 psi

In some examples, the one or more of the gripper arms **116***a*, **116***b* continue to move inward until the pressure selected by the operator using the controller **142** is applied to the refuse container **130** by the gripper arms **116***a*, **116***b*. In some examples, the pressure being applied to the gripper arms **116***a*, **116***b* is detected by a sensor **106***b* coupled to the cylinder **240** that is coupled to the grabber **113**. In some implementations, the sensor **106***b* for detecting pressure applied by the gripper arms **116***a*, **116***b* is located in a cylinder **240** coupled to the grabber **113**. In some implementations, the sensor **106***b* for detecting pressure applied by the gripper arms **116***a*, **116***b* is located on the outside of a housing containing a cylinder **240** coupled to the grabber **113**. In some examples, pressure sensors **106***b* are arranged on each gripper arm **116***a*, **116***b* of the grabber **113** to detect the pressure being applied to a refuse container **130** by the gripper arms **116***a*, **116***b*. In some implementations, the sensor **106***b* for detecting pressure applied by the gripper arms **116***a*, **116***b* is located in the valve section of the grabber **113** that controls gripper movement. In some examples, the sensor **106***b* for detecting the pressure applied by the gripper arms **116***a*, **116***b* is located outside the valve section and within the grabber circuit. For example, the sensor **106***b* for detecting pressure applied by the gripper arms **116***a*, **116***b* may be located in a hydraulic hose connected to the grabber **113**.

As depicted in FIG. **5**, the height of the grabber **113** can be adjusted relative to the surface **550** that the vehicle **102** is positioned on by raising or lowering the lift arm **111**. For example, as the lift arm **111** is raised, the grabber **113** is also raised.

The position of the lift arm **111** can be adjusted by a controller, such as controller **142**, located within the refuse collection vehicle **102**. For example, controller **142** located within the vehicle **102** can be used to adjust relative position of the lift arm **111**.

FIG. **6** depicts an example controller **642** for controlling the relative positioning of the lift arm **111**. As depicted in FIG. **6**, the controller **642** may be provided as a touchscreen display **602** displaying a graphical user interface (GUI) having one or more control elements **606**, **608**, **610**, **612**. Each of the control elements **606**, **608**, **610**, **612** can be used to adjust the relative positioning of the lift arm **111**, which adjusts the height of the grabber **113** relative to the surface **550** the tires of the vehicle **102** are positioned on.

As shown in FIG. **6**, the GUI of the controller **142** also includes a control element **604** displaying the current relative positioning of grabber **113**. In some examples, the grabber **113** positioning displayed by control element **604** is the height of the center of the ends **126***a*, **126***b* of the gripper arms **116***a*, **116***b* relative to the surface **550** on which the tires of the refuse collection vehicle are positioned.

The GUI of the controller **142** includes a first control element **606** for raising the lift arm **111**. In some examples, each time an operator selects the first control element **606**, the lift arm **111** is raised to increase the height the grabber **113** relative to the surface **550** on which the vehicle **102** is positioned by a defined incremental distance. For example, if the incremental travel distance is 1 inch, an operator may raise the lift arm **111** and increase the height of the grabber **113** relative to the surface **550** on which the vehicle **102** is positioned by three inches by selecting the first control element **606** three times. In some examples, the height of the grabber **113** relative to the surface **550** on which the vehicle **102** is positioned can be increased in increments of 2.5 inches by raising the lift arm **111** using control element **606**. In some implementations, the height of the grabber **113** can be increased to a maximum height of approximately 39 inches above the surface **550** on which the vehicle **102** is positioned using controller **142**.

The GUI of the controller **142** includes a second control element **608** for lowering the lift arm **111**. In some examples, each time an operator selects the second control element **608**, the lift arm **111** is lowered to decrease the height of the grabber **113** relative to the surface **550** on which the vehicle **102** is positioned by a defined incremental distance. For example, if the incremental travel distance defined for control element **608** is 1 inch, an operator may lower the lift arm **111** and decrease the height of the grabber **113** relative to the surface on which the vehicle **102** is sitting by three inches by selecting the second control element **608** three times. In some examples, the height of the grabber **113** relative to the surface **550** on which the vehicle **102** is positioned can be decreased in increments of 2.5 inches by lowering the lift arm **111** using control element **608**

The controller **142** also includes control elements **610** for automatically adjusting the relative positioning of the lift arm **111** based on preset grabber **113** heights. Control elements **610** each correspond to a height of the grabber **113** relative to the surface on which the vehicle **102** is positioned. For example, as depicted in FIG. **6**, control element **610***a* corresponds to a preset grabber **113** height of 4 inches above the surface **550** on which the vehicle **102** is positioned, control element **610***b* corresponds to a preset grabber **113** height of 8 inches above the surface **550** on which the vehicle **102** is positioned, control element **610***c* corresponds to a preset grabber **113** height of 4 inches below the surface **550** on which the vehicle **102** is positioned, and control element **610***d* corresponds to a preset grabber **113** height of 8 inches below the surface **550** on which the vehicle **102** is positioned. Control elements **610** can be provided for preset heights including, but not limited to, 4 inches above the surface on which the vehicle **102** is positioned, 8 inches above the surface on which the vehicle **102** is positioned, 12 inches above the surface on which the vehicle **102** is positioned, 16 inches above the surface on which the vehicle **102** is positioned, 20 inches above the surface on which the vehicle **102** is positioned, 24 inches above the surface on which the vehicle **102** is positioned, 4 inches below the surface on which the vehicle **102** is positioned, 8 inches below the surface on which the vehicle **102** is positioned, 12 inches below the surface on which the vehicle **102** is positioned, 16 inches below the surface on which the vehicle **102** is positioned, and 20 inches below the surface on which the vehicle **102** is positioned.

In some implementations, in response to an operator's selection of one of control elements **610**, the lift arm **111** is automatically adjusted such that the center of the ends **126***a*, **126***b* of the gripper arms **116***a*, **116***b* of the grabber **113** are positioned at the preset height associated with the selected control element **610**. For example, in response to an operator's selection of a refuse container size using a control element **610**, the current height of the grabber **113** relative to the surface **550** on which the vehicle **102** is positioned is determined based on data from arm sensor **106***a*, and the lift arm **111** is automatically moved up or down, based on the current grabber **113** height and the preset height associated with the selected refuse container size, until sensor **106***a* detects that the lift arm **111** has reached the relative positioning corresponding to a grabber **113** height equal to the preset height associated with the selected control element **610**. For example, if an operator selects control element **610***c*, the lift arm **111** will be automatically repositioned to such that the height of the center of the ends **126***a*, **126***b* of the gripper arms **116***a*, **116***b* of the grabber **113** is equal to the preset height associated with control element **610***c* (i.e., 4 inches below the surface **550** the vehicle is positioned on).

In some examples, the controller **142** may include control elements **610** for automatically adjusting the relative positioning of the lift arm **111** based on a selected refuse container size. For example, one or more control elements **610** may each correspond to a particular size of refuse container **130**, as defined by volume, such as a 32-gallon refuse container, a 48-gallon refuse container, a 64-gallon refuse container, and/or a 96-gallon refuse container. Controller **142** can store a relative lift arm **111** positioning corresponding to each refuse container size associated with each control element **610**. For example, controller **142** can store a relative lift arm **111** positioning for each refuse container size for which the height of the grabber **113** relative the surface **550** the vehicle **102** is sitting on is optimized to engage the respective size of container **130** based on the height of the respective size of container **130**.

In some implementations, in response to an operator's selection of one of control elements **610**, the lift arm **111** is automatically adjusted to the stored relative position associated with the refuse container size of the selected control element **610**. For example, in response to an operator's selection of a 64-gallon refuse container size using a control element **610**, the current relative positioning of the lift arm **111** is determined based on data from arm sensor **106***a*, and the lift arm **111** is automatically moved up or down, based on the current lift arm **111** position and the stored relative lift arm **111** positioning associated with a 64-gallon refuse container size, until sensor **106***a* detects that the lift arm **111** has reached the stored position.

As depicted in FIG. **6**, the GUI of the controller **142** also includes a reset control element **612** that allows an operator to reset the relative position of the lift arm **111** to a baseline positioning. In some implementations, the baseline positioning includes a lift arm **111** positioning such that the height of the grabber **113** is 24 inches above the surface on which the vehicle **102** is positioned. In some implementations, the baseline positioning of the lift arm **111** may be adjusted or set by an operator **150** using a controller (such as controller **142**).

In response to an operator's selection of the reset control element **612**, the current relative positioning of the lift arm **111** is determined based on data from arm sensor **106***a*, and the lift arm **111** is automatically moved up or down, based on the current lift arm **111** positioning and the baseline positioning, until sensor **106***a* detects that the lift arm **111** has reached the baseline positioning. For example, if the baseline positioning of the lift arm **111** positions the grabbers 24 inches above the surface **550** on which the vehicle **102** is positioned, and the current positioning of the lift arm **111**, as detected by sensor **106**, corresponds to a grabber **113** height of 26 inches above the surface **550** on which the vehicle **102** is positioned, a selection of the reset control element **612** will cause the lift arm **111** to be lowered until the height of the grabber **113** is 24 inches above the surface **550** on which the vehicle **102** is positioned, as detected by sensor **106***a*.

Control element **604** displaying the current grabber **113** height is automatically updated in response to each adjustment of the position of lift arm **111**. For example, if the current grabber **113** is 8 inches below the surface **550** on which the vehicle **102** is positioned, and the operator increases the grabber **113** height by 5 inches by using control element **606** to raise the lift arm **111**, touchscreen element **604** will be updated to display 3 inches below the surface **550** on which the vehicle **102** is positioned as the current grabber **113** height.

In some implementations, the controller **142** can be used to adjust the height of the grabber **113** within a predetermined range. For example, controller **142** can be used to adjust the relative positioning of the lift arm **111** such that the height of the grabber **113** can be adjusted between 39 inches above the surface **550** on which the vehicle **102** is positioned to 20 inches below the surface **550** on which the vehicle **102** is positioned. As described in further detail herein, in some examples, the range of grabber **113** height adjustment using controller **142** may be reduced based on the angular positioning of the grabber **113**. For example, in some implementations, the height of the grabber **113** can be adjusted between 18 inches above the surface **550** on which the vehicle **102** is positioned to 30 inches above the surface **550** on which the vehicle **102** is positioned.

In some examples, an assembly including a cylinder **250** and a piston **252** is used to raise and lower the lift arm **111**. For example, retraction of the piston **252** into the cylinder **250** will cause the lift arm **111** to be lowered from its current relative positioning. Extension of the piston **252** outward from the cylinder **250** causes the lift arm **111** to be raised from its current relative positioning.

In some examples, the lift arm **111** continues to be raised or lowered until the amount of height adjustment of the grabber **113** selected by the operator using the controller **142** is reached. In some examples, the amount of height adjustment of the grabber **113** and the current height of the grabber **113** is detected by a sensor **106***a* coupled to the cylinder **250** coupled to the lift arm **111**. In some implementations, the sensor **106***a* for detecting lift arm **111** positioning and grabber **113** height is located in a cylinder **250** coupled to the lift arm **111**. In some examples, sensor **106***a* includes two sensors, with a first sensor being located inside a cylinder used for raising the lift arm **111** and a second sensor being located inside a cylinder used for extending the lift arm **111**. In some implementations, the sensor for detecting lift arm **111** positioning and grabber **113** height is located on the outside of a housing containing a cylinder **250** coupled to the lift arm **111**. In some examples, the sensors **106***a* used to detect lift arm **111** positioning and grabber **113** height are magnetostrictive sensors. As previously discussed, in some examples, feedback provided by the sensors for detecting lift arm **111** movement can be used to determine the relative position of the grabber **113**. Sensor(s) **106***a* can include, but are not limited to, an analog sensor, a digital sensor, a CAN bus sensor, a magnetostrictive sensor, a RADAR sensor, a LIDAR sensor, a laser sensor, an ultrasonic sensor, an infrared (IR) sensor, a stereo camera sensor, a three-dimensional (3D) camera, an in-cylinder sensor, or a combination thereof.

In some implementations, a first controller can be used to set the baseline lift arm positioning relative to the surface on which the refuse collection vehicle **102** is positioned, and a second controller can be used to adjust the height of the lift arm **111** within a range around the baseline lift arm positioning. For example, in some implementations a touchscreen display controller (such as controller **542**) is used to set the baseline lift arm positioning (e.g., positioning **802** depicted in FIGS. **8**A and **8**B). Once the baseline lift arm positioning is set, a second controller can be used to adjust the height of the lift arm **111** within a predetermined range. For example, after setting the baseline positioning, a driver of vehicle can use a pushbutton controls (e.g., pushbutton **540***a* and **540***b* of FIGS. **8**A-**8**E) to adjust the height of the lift arm **111** up or down in set increments within a range outside the baseline positioning. In some implementations, after setting the baseline positioning, a driver of vehicle can use a joystick controller (e.g., **745** of FIGS. **8**A-**8**E) to fluidly adjust the height of the lift arm **111** within a range outside the baseline positioning. For example, the driver of the vehicle can pull back or push forward on the joystick controller **745** to move the arm height up or down, respectively, within the confines of relative positioning range of 6 inches above the baseline positioning to 6 inches below the baseline positioning.

In some implementations, the height of the lift arm **111** is automatically returned to the baseline positioning **802** following completion of a dump cycle. For example, based on data received from the body sensors **160** on the vehicle **102**, an onboard computing device **132** can determine that the vehicle has completed a dump cycle and has released the refuse container **130** to the ground **550**. In response to detecting that the dump cycle is complete, onboard computing device **132** can determine the current relative positioning of the lift arm **111** based on data received from the body sensors **106***a* and **106***b*, and determines the amount of lift arm **111** travel required to reposition the lift arm **111** in the baseline positioning. Based on this determination, the lift arm **111** is automatically moved the amount required to reposition the lift arm **111** in the baseline positioning.

Adjustment of the position of the lift arm **111** may allow for greater control and stability in engaging a refuse **130**. For example, as depicted in FIG. **8**A, when a refuse container **130** to be engaged by the refuse collection vehicle **102** is positioned on a surface that is below street grade **550**, the lift arm **111** can be lowered from the baseline lift arm positioning **802** in order to improve engagement of the refuse container **130**. As depicted in FIG. **8**B, whenever a refuse container **130** is positioned on a surface above street grade **550**, the lift arm **111** can be raised from the baseline lift arm positioning **802** in order to improve engagement of the refuse container **130**.

A controller **142** may also be provided to adjust the maximum speed of the lift arm **111** movement. In some examples, the controller **142** is communicably coupled to the cylinder **250** and piston **252** assembly such that the controller **142** controls the speed of extension and retraction of the piston **252** from the cylinder **250**, which controls the speed at which the lift arm **111** is raised and lowered. In some implementations, the controller **142** is provided as a touchscreen display, such as touchscreen **602** of FIG. **6**, and the maximum speed of the lift arm **111** may be adjusted using one or more control elements displayed on the touchscreen display. For example, the controller **142** for adjusting lift arm **111** speed can be provided as a touchscreen display that includes a first touchscreen element for increasing the maximum speed of lift arm **111** movement in increments of a set amount and a second touchscreen element for decreasing the maximum speed of lift arm **111** movement in increments of a set amount. In some examples, each time the user selects a control element of the controller **142**, the maximum speed of the lift arm **111** movement is adjusted by the predetermined incremental amount. In some examples, after setting the maximum speed for the lift arm **111** movement using controller **142**, an operator can move the lift arm **111** using a joystick **545**, and the speed of the lift arm **111** movement is proportional to movement of the joystick **545**. For example, if an operator **150** sets a maximum speed for lift arm **111** movement using controller **142** and engages the joystick **545** 50% of full engagement, the lift arm **111** will be moved at a rate equal to 50% of the maximum speed set with controller **142**.

As depicted in FIG. **7**, the angle of the grabber **113** is adjustable. For example, the angle of the grabber **113** can be adjusted above or below a baseline angular position **702**. In some implementations, the baseline angular position **702** of the grabber **113** is in a range of −45 degrees to 45 degrees relative to the surface **550** on which the vehicle **102** is positioned. In some implementations, the baseline angular position **702** of the grabber **113** is in a range of −15 degrees to 30 degrees relative to the surface **550** on which the vehicle **102** is positioned. In some implementations, the baseline angular position **702** for grabber **113** corresponds to the longitudinal axis of the gripper arms **116***a*, **116***b* of the grabber **113** being substantially parallel to the surface **550** on which the vehicle **102** is positioned. In some implementations, the baseline angular position **702** may be set by an operator **150** using a controller **745**.

Adjustment of the angle of the grabber **113** may allow for greater control and stability in engaging a refuse **130**. For example, FIG. **8**C depicts a refuse container **130** positioned on a surface that is sloping downward from street grade **550**. As depicted in FIG. **8**C, the grabber **113** can be angled downward from baseline angular position **702** such that the grabber **113** is substantially perpendicular to a side of the refuse container **130** for improved engagement of the refuse container **130**. FIG. **8**D depicts a refuse container **130** positioned on a surface sloping upward from street grade **550**. As depicted in FIG. **8**D, the grabber **113** can be angled upward from a baseline angular position **702** such that the grabber **113** is substantially perpendicular to the side of refuse container **130** for improved engagement of the refuse container.

A controller **745** is provided for adjustment of the angle of the grabber **113** relative to the refuse collection vehicle **102**. In some examples, the controller **745** can be used to adjust the angle of the grabber **113** within a predetermined range. For example, controller **745** can be used to adjust the angle of the grabber **113** 30 degrees above the baseline angular position **702** and 30 degrees below the baseline angular position **702**. As will be discussed in further detail herein, in some implementations, the controller **745** can be used to adjust the angle of the grabber **113** 30 degrees above the baseline angular position **702** and 15 degrees below the baseline angular position **702** when the grabber **113** is positioned below a threshold height.

In some examples, the controller **745** is communicably coupled to a rotary actuator that is coupled to the grabber **113**. As depicted in FIGS. **8**A-**8**E, the controller **745** for adjusting the angle of the grabber **113** can include a first push button **540***a* and a second push button **540***b*. The first push button **540***a* is configured to adjust the angle of the grabber **113** upwards relative to the surface on which the refuse collection vehicle **102** is positioned. The second push button **540***b* is configured to adjust the angle of the grabber **113** downward relative to the surface on which the refuse collection vehicle **102** is positioned. In some implementations, buttons **540***a*, **540***b* are provided as a spring-loaded, momentary contact button. In some examples, buttons **540***a*, **540***b* are provided as a potted and sealed push button with finger guards.

In some examples, each time the operator presses a push button **540***a*, **540***b* of the controller **745**, the angle of the grabber **113** is adjusted by a predetermined incremental amount. For example, if the incremental amount is 1 degree of angular movement, an operator can press the first push button **540***a* three times to adjust the angle of the grabber **113** upwards from its current position by three degrees. Similarly, for example, the operator can press the second push button **540***b* three times to adjust the angle of the grabber **113** downwards from its current position by three degrees. In some examples, the angle of the grabber **113** can be adjusted up or down using the controller **745** in increments of one degree to five degrees.

In some implementations, the angle of the grabber **113** can be adjusted continuously at a preset speed, rather than is increments of set degrees, by pressing and holding one of push button controls **540**. For example, a first push button **540***a* located in the cab of the vehicle can be used to continuously adjust the angle of the grabber **113** upwards and a second push button **540***b* located in the cab of the vehicle can be used to continuously adjust the angle of the grabber **113** downwards. In some examples, if an operator presses and holds button **540***a*, the grabber **113** is rotated upwards continuously at a preset speed, up to a maximum upwards angle, until the operator releases the button **540***a*. In some examples, if an operator presses and holds button **540***b*, the grabber **113** is rotated downwards continuously at a preset speed, down to a maximum downwards angle, until the operator releases the button **540***b*.

The controller **745** can also include a third push button **540***c* to reset the angle of the grabber **113** back to the baseline angular position **702**. An operator **150** can press push button **540***c* to automatically reset the angle of the grabber **113** back to the baseline angular position **702**. In response to an operator engaging the third push button **540***c*, the current angular position of the grabber **113** is determined based on data from grabber sensor **106***b*, and the grabber **113** is automatically tilted upwards or downwards, based on the current angular position of the grabber **113** and the baseline angular position **702**, until the grabber sensor **106***b* detects that the grabber **113** has reached the baseline angular position **702**.

In some implementations, the relative position of the lift arm **111** and the angle of the grabber **113** are coordinated. Interlocks may be provided to limit the range that an operator can adjust the angular position of the grabber **113** using controller **745** based on the current relative positioning of the lift arm **111**. For example, when the lift arm **111** is lowered below a threshold height, the range that the angle the grabber **113** can be adjusted below the baseline angular position **702** using controller **745** is reduced. In some implementations, once the lift arm **111** is lowered below a threshold height, the control push button **540***b* is disengaged to prevent an operator from adjusting the angle of the grabber **113** below the baseline angular position **702**. Restricting or eliminating the operator's ability to adjust the grabber **113** angle below the baseline angular position **702** when the lift arm **111** is positioned below a threshold height reduces the risk of damage to the vehicle **102** by preventing the grabber **113** from hitting the ground.

In some implementations, the controller **745** can be used to adjust the angle of the grabber **113** freely from about 90 degrees above and to about 90 degrees below the angle of the surface **550** on which the vehicle **102** is positioned. In some examples, a controller **745** can be used to adjust the angle of the grabber **113** up and down between 75 degrees above and about 75 degrees below the angle of the surface on which the vehicle **102** is positioned.

As depicted in FIG. **8**E, the free rotation feature of the controller **745** can be used to rotate the grabber to engage a refuse container **130** that has fallen over or is otherwise outside the reach of the grabber **113** within the predetermined angle range of the standard controller **745** settings. In some examples, the operator can engage the free rotation function by pressing and holding one of the push control buttons **540***a*, **540***b* for a threshold amount of time (e.g., 5 seconds). In some implementations, the free rotation function can be engaged by pressing a particular push control button designated for free rotation control (e.g., **540***c*).

Once the free rotation function is engaged, the operator **150** can use the first push control button **540***a* to adjust the angle of the grabber **113** upwards to about 90 degrees above the angle of the surface **550** on which the vehicle **102** is positioned such that the grabber **113** is pointing upwards and is substantially perpendicular with the surface **550** on which the vehicle **102** is sitting. In free rotation mode, the operator **150** can use the second push control button **540***b* to adjust the angle of the grabber **113** downward to about 90 degrees below the angle of the surface **550** on which the vehicle **102** is positioned such that the grabber **113** is pointing downwards and substantially perpendicular with the surface **550** on which the vehicle **102** is sitting. In some examples, the push control buttons **540***a*, **540***b* function as continuous push control buttons in free rotation mode such that the angle of the grabber **113** is adjusted continuously as long as one of the buttons **520** is engaged, as described above. In some implementations, the push control button **540***a*, **540***b* can be used in free rotation mode to adjust the angular position of the grabber **113** in defined increments within the free rotation angular range.

In some implementations, the controller **745** for the grabber **113** is returned to a standard mode from free rotation mode by pressing the first push control button **540***a*. In some examples, the controller **745** for the grabber **113** can be returned to a standard mode from free rotation mode by pressing a third push control button **560***c*. Pressing the third push control button **560***c* also resets the angle of the grabber **113** to the baseline angular position **702**.

Certain features of the refuse collection vehicle may be disabled while the controller **745** for the grabber **113** is in free rotation mode. For example, automatic levelling of the grabber **113** while the vehicle **102** is performing a dump cycle may be disabled when the grabber **113** is in free rotation mode. In some implementations, interlocks coordinating the range of angular movement of the grabber **113** with the height of the lift arm **111** are disengaged when the grabber **113** is in free rotation mode.

In some implementations, a first controller can be used to set the baseline angular position **702** for the grabber **113**, and a second controller can be used to adjust the angle of the grabber **113** within a range around the baseline angular position **702**. For example, in some implementations a touchscreen display controller (such as controller **542**) is used to set the baseline angular position **702**. Once the baseline angular position **702** is set, a second controller can be used to adjust the angle of the grabber **113** within a predetermined range. For example, after setting the baseline positioning, a driver of vehicle can use press and hold pushbutton on a joystick controller (e.g., pushbutton **540***a* on joystick **745** of FIGS. **8**A-**8**E) and, while maintaining engagement of the pushbutton, move the joystick controller **745** left or right to change the angle of the grabber upwards or downward relative to the surface **550** the tires of the vehicle **102** are positioned on. In some implementations, the joystick controller **745** can be used to adjust the angle of the grabber **113** within a predetermined range around the baseline angular position **702** (e.g., 6 degrees above the baseline angular position **702** to 3 degrees below the baseline angular position **702**.

In some implementations, the angle of the grabber **113** is automatically returned to the baseline angular position **702** following completion of a dump cycle. For example, based on data received from the body sensors **160** on the vehicle **102**, an onboard computing device **132** can determine that the vehicle has completed a dump cycle and has released the refuse container **130** to the ground **550**. In response to detecting that the dump cycle is complete, onboard computing device **132** can determine the current angular positioning of the grabber **113** based on data received from the grabber sensor **106***b*, and determines the amount angular adjustment of the grabber **113** required to reposition the grabber **113** in the baseline angular position **702**. Based on this determination, the grabber is automatically moved the amount required to reposition the grabber **113** in the baseline angular position **702**.

In some implementations, the lift arm **111** and the grabber **113** of the vehicle **102** can be automatically positioned to engage a refuse container **130** detected based on one or more images captured by a camera **112** on the vehicle **102** and processed by a computing device (e.g. computing device **132**). A computing device can receive one or more images from camera **112** and process the images using machine learning based image processing techniques to detect the presence of a refuse container **130** in the image. For example, a computing device can receive an image from camera **112** and determine, based on machine learning image processing techniques, that the vehicle **102** is positioned within a sufficient distance to engage a refuse container **130**. In some implementations, a video feed of the refuse container **130** is provided by the side view camera **112** and transmitted to a computing device for machine learning based image processing techniques to detect the presence of a refuse container **130**. U.S. patent application Ser. No. 16/781,857 filed Feb. 4, 2020 discloses systems and methods for determining the location of a refuse container using image processing techniques. The entire content of U.S. patent application Ser. No. 16/781,857 is incorporated by reference herein.

In some examples, a computing device can process the images provided by camera **112** to determine a location of each side of a detected refuse container **130**. In some examples, the locations of the sides of the detected refuse container **130** determined by image processing are provided as GPS coordinates, and based on these coordinates, the width of the refuse container **130** can be determined. In some examples, the width of the refuse container **130** is determined by processing the image using machine learning techniques to detect two opposing sides of the refuse container **130** and determine the distance between the sides.

In some examples, a computing device can process the images provided by camera **112** to determine a location of one or more corners of the detected refuse container **130**. The detected corners of the detected refuse container **130** can be provided as GPS coordinates, and based on these coordinates, the height and angular position of the refuse container **130** relative to the vehicle **102** can be determined. In some implementations, a distance value from the closest point of the detected container to the grabber beam **248** is determined based on a global coordinate of the camera location in relation to the location of the grabber beam **248**.

In response to detecting the presence of a refuse container **130** and determining the position of the container **130** relative to the vehicle **102** based on image processing of an image captured by camera **112**, a signal is sent to a computing device **132** of the vehicle **102** to automatically adjust the position of the lift arm **111** and/or the position of grabber **113** of the vehicle **102**. For example, a signal is sent to the computing device **132** of the vehicle **102** to automatically adjust the height of the lift arm **111** and the angular position **113** to engage a refuse container **130** at the position determined based on the machine learning image processing of the image of the container **130**.

Upon receiving a signal conveying the position of a refuse container **130** determined based on processing an image of the container **130**, an onboard computing device **132** determines the relative position of lift arm **111** based on data received from arm sensor **106***a*. Based on the current lift arm **111** position, the computing device **132** determines the amount of lift arm **111** travel required to adjust the lift arm **111** from the current position to an optimal position for engaging the refuse container **130** at the position detected based on image processing. The lift arm **111** is automatically raised or lowered, based on the current lift arm **111** position and the detected refuse container **130** position, until the lift arm sensor **106***a* detects that the lift arm **111** has reached the optimal position for engaging the refuse container **130**.

Upon receiving a signal conveying the position of a refuse container **130** determined based on processing an image of the container **130**, an onboard computing device **132** determines the current angular position of the grabber **113** based on data received from grabber sensor **106***b*. Based on current angular position of the grabber **113**, the computing device **132** determines the amount of rotation of the grabber **113** required to adjust the angular position of the grabber **113** from the current angular position to an optimal angle for engaging the refuse container **130** at the position detected based on image processing. The grabber **113** is automatically tilted upwards or downwards, based on the current angular position of the grabber **113** and the detected refuse container **130** position, until the grabber sensor **106***b* detects that the angular position of the grabber **113** is equal to an optimal angle for engaging the refuse container **130**.

The automatic positioning of the lift arm **111** and/or the grabber **113** of the refuse collection vehicle **102** based on processing image(s) of the refuse container **130** by a computing device can be conducted automatically with minimal or no operator involvement. For example, as described above, the relative positioning the lift arm **111** and the grabber **113** can be automatically adjusted without operator input in response to receiving a signal from a computing device conveying the position of the refuse container **130** as determined by processing an image of the container **130** received from camera **112**. In some examples, the position of the lift arm **111** and the grabber **113** are automatically adjusted based on receiving data conveying the position of the refuse container **130** and in response to an operator **150** of the vehicle manually engaging a switch to initiate a dump cycle (as depicted in FIGS. **2**A-**2**C). In some implementations, the switch to initiate the dump cycle is provided as one or more foot pedals positioned on the floorboard of the vehicle **102**. U.S. patent application Ser. No. 16/781,857 filed Feb. 4, 2020 discloses foot pedals for initiating and controlling a dump cycle. The entire content of U.S. patent application Ser. No. 16/781,857 is incorporated by reference herein.

In some implementations, the refuse collection vehicle **102** includes one or more container detection sensors **180***a*, **180***b*, **180***c* and the lift arm **111** and the grabber **113** are automatically positioned to engage a refuse container **130** based on data received from the one or more container detection sensors **180***a*, **180***b*, **180***c*. As depicted in FIGS. **3**A-**3**C, the vehicle **102** can include one or more container detection sensors **180***a*, **180***b*, **180***c*. In some implementations, the container detection sensors **180***a*, **180***b*, **180***c* are coupled to the grabber beam **248** of the refuse collection vehicle **102**. In some examples, the vehicle **102** includes three refuse container sensors **180***a*, **180***b*, **180***c*. In some implementations, as depicted in FIGS. **3**A-**3**C, each of the refuse container sensors **180***a*, **180***b*, **180***c* is coupled to the grabber beam **248** proximate the grabber **113** and is positioned at a different angle. For example, a first sensor **180***a* can be positioned perpendicular to a longitudinal axis of the grabber beam **248**, a second sensor **180***b* can be positioned at a 30 degree angle relative to the longitudinal axis of the grabber beam **248**, and a third sensor **180***c* can be positioned at a 45 degree angle relative to the longitudinal axis of the grabber beam **248**. In some implementations, the vehicle **102** includes two refuse container sensors (e.g., sensors **180***a* and **180***c*). Multiple container detection sensors **180***a*, **180***b*, **180***c* can be implemented to provide redundancy in refuse container detection.

In some implementations, the one or more container detection sensors **180***a*, **180***b*, **180***c* are contained within an enclosure. For example, the container detection sensors **180***a*, **180***b*, **180***c* can be contained within a metal enclosure. Placing the container detection sensors **180***a*, **180***b*, **180***c* in an enclosure can help protect the container detection sensors **180***a*, **180***b*, **180***c* from debris.

Container detection sensors **180***a*, **180***b*, **180***c* for detecting the position of a refuse container **130** proximate the vehicle **102** can include, but are not limited to, an analog sensor, a digital sensor, a CAN bus sensor, a magnetostrictive sensor, a RADAR sensor, a LIDAR sensor, a laser sensor, an ultrasonic sensor, an infrared (IR) sensor, a stereo camera sensor, a three-dimensional (3D) camera, an in-cylinder sensor, or a combination thereof. In some examples, container detection sensors **180***a*, **180***b*, **180***c* include optical sensors. In some implementations, container detection sensors **180***a*, **180***b*, **180***c* include two or more analog ultrasonic sensors coupled to the grabber beam **248**.

A computing device (such as onboard computing device **132** of FIG. **1**) can receive data from the container detection sensors **180***a*, **180***b*, **180***c* indicating the presence and position of a refuse container **130**. In some implementations, the position of lift arm **111** and/or the position of the grabber **113** are automatically positioned to updated positions provided by the operator **150** using one or more controllers (such as controller **642** and controller **142**) in response to a computing device receiving data from the container detection sensors **180***a*, **180***b*, **180***c* indicating the presence of a refuse container **130**. For example, computing device **132** can receive data from the container detection sensors **180***a*, **180***b*, **180***c* and determine, based on the data received, that the vehicle **102** is positioned within a distance sufficiently close to a refuse container **130** to engage the refuse container **130**. In some examples, in response to a determination by the computing device **132** that the vehicle **102** is in proximity to engage a refuse container, the lift arm **111** and the grabber **113** are automatically moved to a position selected by the operator **150** using controller **642** and controller **142**.

In some implementations, a computing device can determine a distance value from the closest point of the detected container **130** to the grabber beam **248** based on the data received from the container detection sensors **180***a*, **180***b*, **180***c*. For example, computing device **132** can receive data from the container detection sensors **180***a*, **180***b*, **180***c* and determine, based on the data, that the vehicle **102** is positioned within a sufficient distance to engage a refuse container **130**. In some examples, the speed of travel of the lift arm **111** is automatically changed to a default speed for container engagement in response to a determination that the vehicle **102** is within a threshold distance of the refuse container **130** based on the data received from container detection sensors **180***a*, **180***b*, **180***c*.

In response to the container detection sensors **180***a*, **180***b*, **180***c* detecting the presence of a refuse container **130** and the computing device **132** determining the position of the detected container **130** relative to the vehicle **102** based on data received from the container detection sensors **180***a*, **180***b*, **180***c*, a signal is sent to the computing device **132** of the vehicle **102** to automatically adjust the relative position the lift arm **111** and/or the grabber **113**. For example, a signal is sent to the computing device **132** of the vehicle **102** to automatically adjust the height of the lift arm **111** and/or the angular position of the grabber **113** based on the data received from the container detection sensors **180***a*, **180***b*, **180***c*. For example, upon receiving a signal conveying the a distance value from the closest point of the detected container **130** to the grabber beam **248** as determined based on data captured by the container detection sensors **180***a*, **180***b*, **180***c*, an onboard computing device **132** determines the current relative positioning of the lift arm **111** and grabber **113** based on data received from the body sensors **106***a* and **106***b*, and determines the amount of lift arm **111** travel and/or angular adjustment of the grabber **113** required to engage the detected refuse container **130**.

The automatic positioning of the lift arm **111** and the grabber **113** of the refuse collection vehicle **102** based on data captured by the container detection sensors **180***a*, **180***b*, **180***c* and processed by a computing device **132** can be conducted automatically with minimal or no operator involvement. For example, as described above, the relative positioning the lift arm **111** and the angular position of the grabber **113** can be automatically adjusted without operator input in response to receiving a signal from a computing device conveying the position of the refuse container **130** as determined by data captured by the container detection sensors **180***a*, **180***b*, **180***c*. In some examples, the lift arm **111** and the grabber **113** are automatically adjusted based on receiving data conveying the position of the refuse container **130** and in response to an operator **150** of the vehicle manually engaging a switch to initiate a dump cycle (as depicted in FIGS. **2**A-**2**C).

FIG. **9** depicts an example computing system, according to implementations of the present disclosure. The system **900** may be used for any of the operations described with respect to the various implementations discussed herein. For example, the system **900** may be included, at least in part, in one or more of the onboard computing device **132**, and/or other computing device(s) or system(s) described herein. The system **900** may include one or more processors **910**, a memory **920**, one or more storage devices **930**, and one or more input/output (I/O) devices **950** controllable via one or more I/O interfaces **940**. The various components **910**, **920**, **930**, **940**, or **950** may be interconnected via at least one system bus **960**, which may enable the transfer of data between the various modules and components of the system **900**.

While this specification contains many specifics, these should not be construed as limitations on the scope of the disclosure or of what may be claimed, but rather as descriptions of features specific to particular implementations. Certain features that are described in this specification in the context of separate implementations may also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation may also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination may in some examples be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the implementations described above should not be understood as requiring such separation in all implementations, and it should be understood that the described program components and systems may generally be integrated together in a single software product or packaged into multiple software products.

A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. For example, various forms of the flows shown above may be used, with steps re-ordered, added, or removed. Accordingly, other implementations are within the scope of the following claim(s).

What is claimed is:

1. A refuse collection vehicle (RCV), comprising:
- a grabber operable to engage a refuse container;
- a lift arm operable to lift the refuse container;
- at least one camera configured to capture image data of an environment proximate the RCV; and
- at least one computing device configured to:
  - process the image data to determine a position of the refuse container relative to the RCV;
  - determine that the determined position of the refuse container relative to the RCV satisfies at least one predetermined condition; and
  - in response to the determining that the position of the refuse container relative to the RCV satisfies the at least one predetermined condition, cause the RCV to automatically adjust at least one of a positioning of the lift arm or a positioning of the grabber based at least in part on the determined position of the refuse container and sensor data indicating at least one of the grabber positioning or the lift arm positioning, wherein, to cause the RCV to automatically adjust at least one of the positioning of the lift arm or the positioning of the grabber, the at least one computing device is configured to:
    - determine, based at least in part on the processed image data, a target angular position of the grabber;
    - determine, based at least in part on the sensor data and the target angular position of the grabber, a target position of the lift arm;
    - cause the grabber to move from a current angular position to the target angular position; and
    - cause the lift arm to move from a current position to the target position in a coordinated manner with the movement of the grabber from the current angular position to the target angular position.

2. The refuse collection vehicle of claim **1**, further comprising:
- at least one grabber sensor configured to collect grabber position data indicating the grabber positioning; and
- at least one arm sensor configured to collect arm position data indicating the lift arm positioning.

3. The refuse collection vehicle of claim **2**, wherein, to determine that the determined position of the refuse container relative to the RCV satisfies the at least one predetermined condition, the at least one computing device is configured to determine that a distance between the grabber and the refuse container is within a threshold distance.

4. The refuse collection vehicle of claim 1, wherein, to determine the target angular position of the grabber, the at least one computing device is configured to:

determine, based at least in part on the processed image data, an angular position associated with at least one of the refuse container or a surface on which the refuse container is positioned, relative to a surface on which the RCV is positioned; and

determine the target angular position of the grabber based at least in part on the determined angular position.

5. The refuse collection vehicle of claim 4, wherein:

the target angular position corresponds to a position in which the grabber is angled downward relative to the surface on which the RCV is positioned when the surface on which the refuse container is positioned slopes downward relative to the surface on which the RCV is positioned; and

the target angular position corresponds to a position in which the grabber is angled upward relative to the surface on which the RCV is positioned when the surface on which the refuse container is positioned slopes upward relative to the surface on which the RCV is positioned.

6. The refuse collection vehicle of claim 1, wherein the movement of the lift arm from the current position to the target position comprises movement that adjusts a height of the grabber relative to a surface on which the RCV is positioned.

7. A system for controlling operations of a refuse collection vehicle (RCV), the system comprising:

at least one camera configured to capture image data of an environment proximate the RCV;

at least one grabber sensor configured to collect grabber position data indicating a positioning of a grabber of the RCV, the grabber operable to engage a refuse container;

at least one arm sensor configured to collect arm position data indicating a positioning of a lift arm of the RCV, the lift arm operable to lift the refuse container;

at least one processor communicably coupled to the at least one grabber sensor and the at least one arm sensor; and

memory communicably coupled to the at least one processor, the memory storing instructions which, when executed, cause the at least one processor to perform operations comprising:

processing the image data to determine a position of the refuse container relative to the RCV;

determining that the determined position of the refuse container relative to the RCV satisfies at least one predetermined condition; and

in response to the determining that the position of the refuse container relative to the RCV satisfies the at least one predetermined condition, causing the RCV to automatically adjust at least one of a positioning of the lift arm or a positioning of the grabber based at least in part on the determined position of the refuse container and sensor data comprising at least one of the grabber position data or the arm position data, wherein the causing the RCV to automatically adjust at least one of the positioning of the lift arm or the positioning of the grabber comprises:

determining, based at least in part on the processed image data, a target angular position of the grabber;

determining, based at least in part on the sensor data and the target angular position of the grabber, a target position of the lift arm;

causing the grabber to move from a current angular position to the target angular position; and

causing the lift arm to move from a current position to the target position in a coordinated manner with the movement of the grabber from the current angular position to the target angular position.

8. The system of claim 7, wherein the determining that the determined position of the refuse container relative to the RCV satisfies the at least one predetermined condition comprises determining that a distance between the grabber and the refuse container is within a threshold distance.

9. The system of claim 7, wherein the causing the RCV to automatically adjust at least one of the positioning of the lift arm or the positioning of the grabber comprises causing angular movement of the grabber relative to the lift arm.

10. The system of claim 7, wherein the determining the target angular position comprises:

determining, based at least in part on the processed image data, an angular position associated with at least one of the refuse container or a surface on which the refuse container is positioned, relative to a surface on which the RCV is positioned; and

determining the target angular position of the grabber based at least in part on the determined angular position.

11. A method for controlling operations of a refuse collection vehicle (RCV), the method performed by at least one processor, the method comprising:

capturing, using at least one camera, image data of an environment proximate the RCV;

processing the image data to determine a position of a refuse container relative to the RCV, the RCV comprising:

a grabber operable to engage the refuse container; and

a lift arm operable to lift the refuse container;

determining that the determined position of the refuse container relative to the RCV satisfies at least one predetermined condition; and

in response to the determining that the position of the refuse container relative to the RCV satisfies the at least one predetermined condition, causing the RCV to automatically adjust at least one of a positioning of the lift arm or a positioning of the grabber based at least in part on the determined position of the refuse container and sensor data indicating at least one of grabber positioning or lift arm positioning, wherein the causing the RCV to automatically adjust at least one of the positioning of the lift arm or the positioning of the grabber comprises:

determining, based at least in part on the processed image data, a target angular position of the grabber;

determining, based at least in part on the sensor data and the target angular position of the grabber, a target position of the lift arm;

causing the grabber to move from a current angular position to the target angular position; and

causing the lift arm to move from a current position to the target position in a coordinated manner with the movement of the grabber from the current angular position to the target angular position.

12. The method of claim 11, wherein the determining that the determined position of the refuse container relative to the RCV satisfies the at least one predetermined condition

comprises determining that a distance between the grabber and the refuse container is within a threshold distance.

13. The method of claim **11**, wherein the causing the RCV to automatically adjust at least one of the positioning of the lift arm or the positioning of the grabber comprises causing angular movement of the grabber relative to the lift arm.

14. The method of claim **11**, wherein the causing the lift arm to move from the current position to the target position comprises causing the lift arm to move so as to adjust a height of the grabber relative to a surface on which the RCV is positioned.

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