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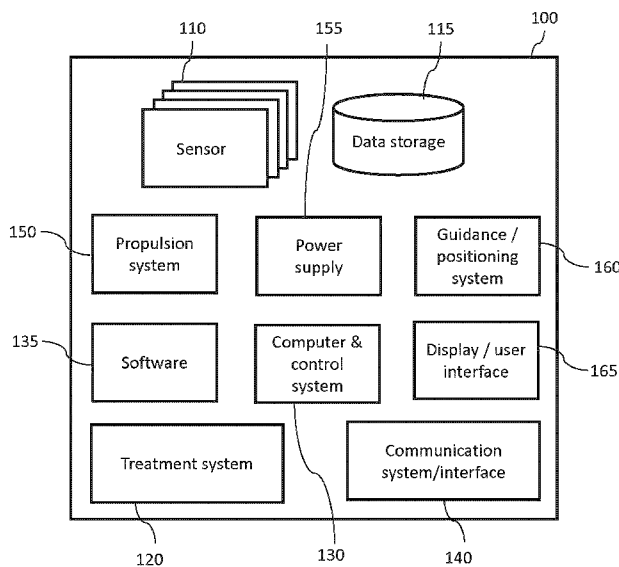


FIG. 1

(57) Abstract: A mobile crop monitoring and treatment system (100, 300, 710) includes a vehicle (305) with a propulsion system (150) and multiple sensors (110, 340, 342, 345) mounted on the vehicle. Each sensor is configured to capture data pertaining to at least one plant-related parameter when the sensor is positioned proximate to a plant in a crop. The system also includes a storage system (210, 220, 230, 350a-350c) configured to house multiple treatment agents, including at least one chemical pesticide and at least one biological control agent, on-board the vehicle. The system further includes an application system (120, 260, 265, 360, 365) configured to apply one or more of the treatment agents to the plant. In addition, the system includes a controller (130, 250, 370, 375) configured to control movement of the vehicle and operation of the sensors and application system. The controller is configured to cause the application system to apply one or more treatment agents to the plant in response to one or more signals from one or more sensors.



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MOBILE PLATFORM FOR CROP MONITORING AND TREATMENT

CROSS-REFERENCE TO RELATED APPLICATION AND PRIORITY CLAIM

[0001] This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 62/885,448 filed on August 12, 2019, and to U.S. Patent Application No. 16/990,212 filed on August 11, 2020, which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

[0002] This disclosure relates to mobile platforms for crop monitoring and treatment and methods for operating the same. Some embodiments of this disclosure relate to mobile platforms for simultaneous, targeted administration of both biological and chemical agents.

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BACKGROUND

[0003] When food and other crops are grown on a large scale, either in protected cultivation (such as in a greenhouse) or outdoors, growers face several challenges. For example, it can be difficult for a grower to know if, where, and when a crop has a problem (such as a problem related to a pest, disease, water, other abiotic stress, or nutritional deficiency) and the extent of the problem until it is readily visible to human scouts, who are often employed to visually inspect the crop. By that stage, the problem may often require expensive and extensive intervention. In some cases, rather than having human scouts identify individual plants or areas of a crop that have problems and then treating them, some crop management practices and treatments are employed prophylactically across the entire crop, even though crops are rarely uniform and problems tend to be localized.

[0004] More recently, various sensor-based systems have been developed for crop monitoring. For example, some systems use a static grid of sensors suspended above a crop or positioned among plants in the crop. Such sensory grids can be used to monitor environmental conditions or general responses from plants on a coarse-grained scale. Some sensory devices clip to plants or otherwise contact the plants. Some systems rely on visual detection of causal factors (such as pests or diseases) using motion detection or visual pattern recognition. Some sensory devices and systems are geared toward specific indicators. Some sensory systems can collect very general information (such as temperature and humidity) but cannot accurately pinpoint problems at the level of individual plants nor convey information in real-time to precipitate immediate action or responses. Mobile systems for crop health monitoring, assessment, and diagnosis that include mobile sensory platforms or vehicles equipped with arrays of sensors are also known, and there is an increasing trend toward automation of such systems.

[0005] Pesticides are widely used in crop cultivation and can be extremely effective. However, there is increasing concern about the effects of pesticides on the environment and on other organisms, including on human and animal health. Another problem with using pesticides to control pests is that, in some cases, the pests may develop resistance to the pesticide over time.

[0006] The use of biological control agents for pest and disease control involves the use of another living organism or natural product, rather than a chemical, to reduce or eliminate a pest or a disease. Classical biological control generally involves the introduction of natural predators, parasites, or pathogens of a pest into an area to protect or treat a crop. Some

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advantages of biological control agents are that they do not cause environmental contamination, and pests do not become resistant to the biological control agents. However, in most cases, live biological control agents cannot be used simultaneously with chemical pesticides to treat the same plant or crop, as the pesticides can be fatal to the live biological control agents or at least have an adverse effect on them. Some chemical pesticides can also have residual effects on the biological control agents, and for that reason there is generally a waiting period before biological control agents can be introduced after a pesticide application.

[0007] Because of costs and other factors, it is generally desirable to reduce the amounts of pesticides and biological control agents that are used by applying them only where and when they are needed, rather than treating an entire crop or treating a crop as a matter of course even in absence of a problem. Early and rapid identification of problems in a crop followed by immediate and precise intervention focused on where it is needed can allow growers to make efficient use of chemical pesticides and biological control agents and to achieve higher yields of their crops.

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SUMMARY

[0008] This disclosure relates to mobile platforms for crop monitoring and treatment and methods for operating the same.

[0009] In a first embodiment, a mobile crop monitoring and treatment system includes a vehicle with a propulsion system and multiple sensors mounted on the vehicle. Each sensor is configured to capture data pertaining to at least one plant-related parameter when the sensor is positioned proximate to a plant in a crop. The mobile crop monitoring and treatment system also includes a storage system configured to house multiple treatment agents that include at least one chemical pesticide and at least one biological control agent on-board the vehicle. The mobile crop monitoring and treatment system further includes an application system configured to apply one or more of the treatment agents to the plant. In addition, the mobile crop monitoring and treatment system includes a controller configured to control movement of the vehicle and operation of the sensors and the application system. The controller is configured to cause the application system to apply one or more of the treatment agents to the plant in response to one or more signals from one or more of the sensors.

[0010] In some embodiments, the mobile crop monitoring and treatment system further includes an on-board computer processor, and the controller is configured to cause the application system to apply the one or more treatment agents to the plant at a dosage and a concentration determined by the on-board computer processor in response to the one or more signals from the one or more sensors.

[0011] In some embodiments, the application system includes at least one robotic arm and at least one applicator.

[0012] In some embodiments, the storage system includes at least one chemical pesticide container configured to house the at least one chemical pesticide, at least one biological control agent container configured to house the at least one biological control agent, and at least one carrier container configured to house at least one solvent or carrier.

[0013] In some embodiments, the controller is configured to cause the mobile crop monitoring and treatment system to draw the at least one chemical pesticide from the at least one chemical pesticide container, draw the at least one solvent or carrier from the at least one carrier container, and combine the at least one chemical pesticide and the at least one solvent or carrier upstream of the at least one applicator.

[0014] In some embodiments, the at least one chemical pesticide container includes a multi-compartment container and a pump, each compartment of the multi-compartment

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container is configured to house a different pesticide or pesticide component material, and the controller is configured to cause the pump to selectively draw multiple pesticides or pesticide component materials from the multi-compartment container and mix the multiple pesticides or pesticide component materials in a mixing region.

[0015] In some embodiments, the mixing region is upstream of the at least one applicator.

[0016] In some embodiments, the mixing region is downstream of the at least one applicator.

[0017] In some embodiments, the at least one biological control agent container includes an aerator or agitator.

[0018] In some embodiments, the mobile crop monitoring and treatment system further includes at least one ultraviolet light positioned on the at least one robotic arm.

[0019] In some embodiments, the mobile crop monitoring and treatment system is a ground-based system.

[0020] In some embodiments, the mobile crop monitoring and treatment system is an air-borne system.

[0021] In some embodiments, the mobile crop monitoring and treatment system forms part of a robotic scout.

[0022] In some embodiments, the mobile crop monitoring and treatment system forms part of a cart that is configured to be driven by an operator.

[0023] In a second embodiment, a method for treating a plant in a crop includes assessing a health of the plant in the crop by gathering sensor data using an automated vehicle equipped with multiple sensors. The method also includes processing the sensor data to determine a treatment to be applied to the plant in the crop. The method further includes dispensing the treatment from a storage system carried on-board the automated vehicle, where the storage system houses at least one chemical pesticide and at least one biological control agent. In addition, the method includes delivering the treatment to the plant in the crop via a robotic arm and an applicator carried on-board the automated vehicle. A concentration and a dosage of the treatment applied to the plant in the crop are controllable and adjustable by a controller on-board the automated vehicle.

[0024] In some embodiments, the sensor data is processed on-board the automated vehicle to determine the treatment to be applied to the plant in the crop.

[0025] In some embodiments, dispensing the treatment from the storage system

includes mixing multiple chemical pesticides or pesticide component materials drawn from the storage system with at least one carrier to provide a desired formulation.

[0026] In some embodiments, dispensing the treatment from the storage system includes mixing multiple chemical pesticides or pesticide component materials drawn from the storage system with at least one carrier and with at least one adjuvant to provide a desired formulation.

[0027] In some embodiments, the at least one biological control agent is housed in a container in the storage system, and the method further includes agitating or aerating the at least one biological control agent so that the at least one biological control agent is more uniformly dispersed within the container.

[0028] In a third embodiment, a mobile crop monitoring and treatment system includes a vehicle with a propulsion system and multiple sensors mounted on the vehicle. Each sensor is configured to capture data pertaining to at least one plant-related parameter when the sensor is positioned proximate to a plant in a crop. The mobile crop monitoring and treatment system also includes a storage system configured to house chemical pesticides and biological control agents on-board the vehicle. The storage system includes multiple containers, and at least one of the containers includes multiple compartments. The compartments of the containers are collectively configured to store multiple materials including the chemical pesticides or pesticide component materials, the biological control agents, one or more solvents, and one or more adjuvants. The mobile crop monitoring and treatment system further includes one or more applicators configured to apply one or more treatments to the plant and one or more robotic arms configured to position at least one of the one or more applicators for application of the one or more treatments to the plant. In addition, the mobile crop monitoring and treatment system includes a controller configured to control movement of the vehicle and operation of the mobile crop monitoring and treatment system. The controller is configured to cause the one or more applicators to apply the one or more treatments to the plant in response to one or more signals from one or more of the sensors. Different treatments are associated with different materials or combinations of materials from the containers.

[0029] Other technical features may be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] For a more complete understanding of this disclosure, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

[0031] FIGURE 1 illustrates an example mobile crop monitoring and treatment system in accordance with this disclosure;

[0032] FIGURE 2 illustrates an example crop treatment system that can be incorporated into a mobile crop monitoring and treatment system in accordance with this disclosure;

[0033] FIGURES 3A and 3B illustrate a specific example implementation of a mobile crop monitoring and treatment system in accordance with this disclosure;

[0034] FIGURES 4A through 6B illustrate example storage containers/dispensers that can be used on-board a mobile crop monitoring and treatment system and from which at least one treatment can be dispensed in accordance with this disclosure; and

[0035] FIGURE 7 illustrates an example crop management system that includes a mobile crop monitoring and treatment system in accordance with this disclosure.

DETAILED DESCRIPTION

[0036] FIGURES 1 through 7, described below, and the various embodiments used to describe the principles of the present invention in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the invention. Those skilled in the art will understand that the principles of the present invention may be implemented in any type of suitably arranged device or system.

[0037] FIGURE 1 illustrates an example mobile crop monitoring and treatment system 100 in accordance with this disclosure. As shown in FIGURE 1, the mobile system 100 includes multiple sensors 110 and at least one data storage device 115 configured to store data captured by the sensors 110. Various types of sensors 110 may be used in the mobile system 100, examples of which are described below. Each sensor 110 includes any suitable structure configured to capture data pertaining to at least one plant-related parameter, such as when the sensor 110 is positioned proximate to each of one or more plants in one or more crops. Various types of data storage devices 115 may also be used in the mobile system 100, such as one or more volatile or non-volatile memories. Example types of data storage devices 115 that may be used in the mobile system 100 include a random access memory, a read only memory, a hard drive, a Flash memory, or an optical disc.

[0038] The mobile system 100 also includes a treatment system 120, which is configured to apply one or more treatment agents (such as at least one chemical pesticide and/or at least one biological control agent) to each of one or more plants in one or more crops. The treatment system 120 includes any suitable structure configured to deliver one or more treatment agents to plants. Details of an example implementation of the treatment system 120 are provided below.

[0039] The mobile system 100 further includes a computer and control system 130 with associated software 135. The computer and control system 130 is configured to control the overall operation of the mobile system 100, such as by controlling movement of the mobile system 100 and operation of the sensors 110 and treatment system 120. The computer and control system 130 can execute the software 135 in order to perform its functions. The computer and control system 130 includes at least one processor, such as at least one of a central processing unit (CPU), a graphics processing unit (GPU), a data processing unit (DPU), and a Tensor processing unit (TPU). An on-board DPU or other processor(s) of the computer and control system 130 can be used, for example, to process sensor data and determine one or more suitable treatments to be applied to one or more plants in one or more crops. Note that

while the software 135 here is shown as a separate component, the software 135 may be stored internally within the computer and control system 130, such as in a non-volatile memory of the computer and control system 130.

[0040] The mobile system 100 may optionally include a communication system/interface 140, which may allow the mobile system 100 to communicate information and data to one or more external systems or devices and/or to receive information or commands from one or more external systems or devices. In some embodiments, the communication system/interface 140 may include an external serial connection that is provided to allow a user to connect a personal computer (PC) or other device to the mobile system 100, such as in order to modify the software 135 on-board the mobile system 100. Also, in some embodiments, the communication system/interface 140 may include at least one wireless radio or other wireless transmitter, receiver, or transceiver that allows wireless communications to and/or from the mobile system 100.

[0041] The mobile system 100 also includes a propulsion system 150, which is configured to move the mobile system 100 (such as on the ground or in the air). The propulsion system 150 includes any suitable structure configured to propel or otherwise move the mobile system 100, such as an electric motor, wheels, propellers, etc. The mobile system 100 further includes a power supply 155, which is configured to provide operating power to other components of the mobile system 100. The power supply 155 includes any suitable structure configured to provide operating power to the mobile system 100. In some embodiments, the power supply 155 includes at least one battery or other energy storage device and associated recharging equipment. In particular embodiments, the power supply 155 includes a power management system that is configured to provide for switching between multiple energy sources. The power management system may also incorporate safety and protection devices.

[0042] The mobile system 100 may further include a guidance and positioning system 160, which can be configured to identify a location of the mobile system 100 and to support navigation by the mobile system 100. In some embodiments, the guidance and positioning system 160 produces location tags that can be associated with sensor measurements, where the location tags identify positions at which the sensor measurements are captured. The location tags can be stored in the data storage device 115 and optionally transmitted, along with the sensor data, via the communication system/interface 140. The guidance and positioning system 160 includes any suitable structure configured to identify a location of the mobile system 100, such as a Global Positioning System (GPS) receiver or other satellite-based receiver, an Ultra-

Wideband (UWB) receiver, a Radio Frequency Identification (RFID) device, or other device. Note that the guidance and positioning system 160 may operate by receiving incoming signals to identify its location or by transmitting outgoing signals that allow other components to identify its location.

[0043] In addition, the mobile system 100 may include a display and/or user interface 165, which can be used to provide information to a user or receive information from the user. For example, the display and/or user interface 165 may be used to identify current settings of the mobile system 100, sensor measurements captured by the sensors 110, or treatments to be applied by the treatment system 120. The display and/or user interface 165 may also be used to receive user observations of plant conditions, user confirmations of proposed treatments, or other information. The display and/or user interface 165 includes any suitable structure configured to provide information to or receive information from a user, such as a liquid crystal display (LCD), light-emitting diode (LED) display, or other display device. Depending on the implementation, the display and/or user interface 165 may include physical buttons and/or a touchscreen.

[0044] In some embodiments of the mobile crop monitoring and treatment system 100, the position(s) of one, some, or all of the sensors 110 can be adjustable so that the sensor(s) 110 can be positioned appropriately. Various factors can affect how one or more of the sensors 110 are positioned, such as the size (like height and/or volume) of a plant being inspected and which region of the plant is to be sensed. In particular embodiments, at least some of the sensors 110 can be moved and re-positioned automatically (rather than manually) based on commands from a control system, which can be responsive to inputs indicative of where the sensor(s) 110 should be positioned.

[0045] Note that the mobile crop monitoring and treatment system 100 here can be implemented in a number of ways depending on particular needs. For example, in some embodiments, the mobile system 100 is implemented as a ground-based platform, such as when the mobile system 100 is implemented using a robotic ground-based scout or other ground-based device. In other embodiments, the mobile system 100 is implemented as an air-borne platform, such as when the mobile system 100 is implemented using a robotic air-borne scout or other air-based device (like a drone). Combinations of approaches may also be used, such as when the mobile crop monitoring and treatment system 100 includes a robotic ground-based scout or other ground-based device that operates in conjunction with a robotic air-borne scout or other air-based device. As particular examples, ECOATION INNOVATIVE SOLUTIONS

INC. offers various products that can be used in greenhouses or other locations, such as the OKO manually-driven cart (which includes an interactive display that can be used by an operator) and the IRIS SCOUTROBOT robotic scout. The mobile system 100 may be incorporated into either of these products and used manually or autonomously. For instance, in the case of the OKO cart, an operator may drive the cart to specific locations and use an interactive display to distribute one or more chemical pesticides or biological control agents. In the case of the IRIS robotic scout, one or more chemical pesticides or biological control agents may be distributed in an autonomous manner. In general, this disclosure is not limited to any particular manual, partially automated, or fully automated manner of distributing chemical pesticides or biological control agents.

[0046] Although FIGURE 1 illustrates one example of a mobile crop monitoring and treatment system 100, various changes may be made to FIGURE 1. For example, various components shown in FIGURE 1 may be combined, further subdivided, replicated, rearranged, or omitted and additional components may be added according to particular needs.

[0047] FIGURE 2 illustrates an example crop treatment system 200 that can be incorporated into a mobile crop monitoring and treatment system in accordance with this disclosure. For example, the crop treatment system 200 may be used to at least partially implement the treatment system 120 of the mobile crop monitoring and treatment system 100 in FIGURE 1. Note, however, that the crop treatment system 200 may be used in any other suitable mobile system.

[0048] As shown in FIGURE 2, the crop treatment system 200 includes at least one chemical pesticide storage container/dispenser 210, which is configured to receive, hold, and dispense at least one chemical pesticide. For example, each chemical pesticide storage container/dispenser 210 can include one or more containers that receive and hold one or more pesticides or pesticide component materials. Each chemical pesticide storage container/dispenser 210 can also include one or more devices used to draw the chemical pesticide(s) or component material(s) from the container(s) for use. In this example, the chemical pesticide storage container/dispenser 210 includes a mixer 215, which may be configured to mix pesticide formulations as needed or desired. For instance, the mixer 215 may be configured to receive different combinations of stored chemical pesticides or component materials and to mix the combinations of stored chemical pesticides or component materials. Each chemical pesticide storage container/dispenser 210 includes any suitable structure configured to retain and dispense at least one pesticide or component material. Each mixer 215 includes any suitable

structure configured to mix materials.

[0049] The crop treatment system 200 also includes at least one solvent and adjuvant storage container/dispenser 220, which is configured to receive, hold, and provide one or more solvents and/or one or more adjuvants. A solvent refers to a liquid or other material into which at least one chemical pesticide can be dissolved or mixed, and an adjuvant refers to a liquid or other material that helps to enhance the effectiveness of one or more pesticides. The solvent(s) and/or adjuvant(s) can be drawn from the solvent and adjuvant storage container/dispenser 220 and combined with one or more pesticides from the chemical pesticide storage container/dispenser 210. Each solvent and adjuvant storage container/dispenser 220 includes any suitable structure configured to retain and dispense at least one solvent and/or at least one adjuvant.

[0050] The crop treatment system 200 further includes at least one biological control agent storage container/dispenser 230, which is configured to receive, hold, and dispense at least one biological control agent. A biological control agent refers to one or more living organisms or natural products that can be used to reduce or eliminate a pest, disease, or other problem with a plant. For example, each biological control agent storage container/dispenser 230 can include one or more containers that receive and hold one or more biological control agents. Each biological control agent storage container/dispenser 230 can also include one or more devices used to distribute the biological control agent(s) from the container(s) for use. In this example, the biological control agent storage container/dispenser 230 includes an agitator and/or aerator 240. An agitator can be used to distribute one or more biological control agents more evenly within the container/dispenser 230. An aerator can be used to provide air to one or more biological control agents within the container/dispenser 230. While not shown here, the biological control agent storage container/dispenser 230 can include a mixer, which may be configured to mix different combinations of biological control agents as needed or desired. For instance, the mixer may be configured to receive different combinations of stored biological control agents and to mix the combinations of stored biological control agents. Each biological control agent storage container/dispenser 230 includes any suitable structure configured to retain and dispense at least one biological control agent.

[0051] Note that one, some, or all of the containers/dispensers 210, 220, and 230 can be divided into multiple compartments for use in storing different materials or agents. Also, one, some, or all of the containers/dispensers 210, 220, and 230 may include one or more pumps (not shown), where each pump is configured to dispense one or more materials from one or more containers. Different example implementations of the containers/dispensers 210, 220,

230 are discussed below, although these implementations are for illustration only.

[0052] The crop treatment system 200 also includes a controller 250, which can be used to determine the treatment or treatments to be administered to each of various plants in at least one crop and to control the dispensing, formulation, dilution, dosage, and application of such treatments. The controller 250 includes at least one processor or other processing device configured to perform control operations. In some embodiments, the controller 250 may form part of a computer and control system used for a broader system of which the crop treatment system 200 is a part, such as when the controller 250 forms a part of the computer and control system 130 in the system 100 of FIGURE 1. In other embodiments, the controller 250 may represent a separate computer-based controller or other stand-alone controller. If the controller 250 is used in conjunction with another device (such as an on-board computer processor in the computer and control system 130), the described functionality of the controller 250 may be distributed. As a particular example, the on-board computer processor may determine a dosage and a concentration for a treatment to be applied to a plant in response to one or more signals from one or more sensors 110, and the controller 250 may initiate the treatment to the plant based on the identified dosage and concentration.

[0053] In addition, the crop treatment system 200 includes at least one robotic arm 260 and interchangeable applicators 265, which are configured to apply one or more treatments to various plants in at least one crop under the control of the controller 250. For example, the at least one robotic arm 260 can be used to selectively position one or more applicators 265 at one or more desired positions at or near each plant being treated, and the one or more applicators 265 can be used to dispense one or more treatments for the plants. Each robotic arm 260 includes any suitable structure configured to be moved in order to selectively position one or more applicators 265. Each applicator 265 includes any suitable structure configured to apply one or more treatments. For instance, the applicators 265 can include different nozzles, hoses, sprayers, rollers, misters, foggers, dusters, atomizers, and/or any other suitable applicators. While not shown here, the applicators 265 and/or robotic arm 260 may include one or more valves or other flow control devices configured to start, stop, and adjust the flow of material(s), such as one or more chemical pesticides and/or one or more biological control agents. Also while not shown here, the applicators 265 and/or robotic arm 260 may include one or more grippers or other structures designed to grasp or otherwise physically manipulate plants during inspection or treatment. The type(s) of applicator(s) 265 and/or grippers used can vary based on various factors, such as the type(s) of plant(s) to be treated and inspected. In addition,

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the robotic arm 260 may be used to carry other components that are not used to dispense chemical pesticides and biological control agents but that may be used to treat plant problems in other ways. For instance, the robotic arm 260 may carry at least one ultraviolet (UV) light 270, such as one that produces UV-c light, since ultraviolet light can be used to treat plant diseases like powdery mildew.

[0054] Note that the crop treatment system 200 or a similar system can be incorporated into a mobile sensory platform for crop health monitoring. Example platforms in which the crop treatment system 200 may be used can include the one described above with respect to FIGURE 1, as well as the ones described in U.S. Patent No. 10,241,097 and U.S. Patent Application Publication No. 2017/0032258 (both of which are hereby incorporated by reference in their entirety). Other example platforms in which the crop treatment system 200 may be used can include the OKO cart and IRIS SCOUTROBOT robotic scout from ECOATION INNOVATIVE SOLUTIONS INC.

[0055] Although FIGURE 2 illustrates one example of a crop treatment system 200 that can be incorporated into a mobile crop monitoring and treatment system, various changes may be made to FIGURE 2. For example, various components shown in FIGURE 2 may be combined, further subdivided, replicated, rearranged, or omitted and additional components may be added according to particular needs. Also, certain chemical pesticides and biological control agents may be delivered in other ways and need not be stored in containers and sprayed through applicators. For instance, a chemical pesticide or biological control agent may be placed on a tray, and a gripper or other portion of a robotic arm 260 may be used to grasp and deliver the chemical pesticide or biological control agent.

[0056] FIGURES 3A and 3B illustrate a specific example implementation of a mobile crop monitoring and treatment system 300 in accordance with this disclosure. The mobile crop monitoring and treatment system 300 here can include various components shown in FIGURES 1 and 2 that are described above. As shown in FIGURE 3A, the mobile system 300 includes a cart 305 having four wheels 308 (two of which are visible) and a frame 310 mounted to a platform 312. The platform 312 is, in turn, mounted to a scissor lift 315. The scissor lift 315 allows the platform 312, the frame 310, and components mounted to the platform 312 or the frame 310 to be raised and lowered. This may be done, for instance, depending on the heights of plants in a crop being inspected or treated.

[0057] A power supply, which in this example includes a battery 320, is carried on-board the cart 305. The power supply can provide electrical power to various on-board systems

and electrical power used for propulsion of the mobile system 300. In some embodiments, the mobile system 300 can represent an adaption of a typical pipe rail trolley that is often used in horticulture and greenhouse applications and that is designed to maneuver through small pathways and to be adjustable to desired heights. A pipe rail mounting wheel 322 and a pipe rail detection sensor 325 can be used to guide the mobile system 100 through crops in situations where there are pipe rails.

[0058] In some instances, the mobile system 300 may be configured to operate in an autonomous manner (without an on-board operator or driver). In other instances, a human (such as a farmer or grower) can optionally ride aboard the mobile system 300 on the platform 312, such as while acting as an observer or to drive or otherwise operate one or more aspects of the mobile system 300 manually. A steering device 330 can be used to steer the mobile system 300 manually, and a mobility controller 332 can be used to manually control propulsion of the mobile system 300, such as when the mobile system 300 is not under automated control.

[0059] The mobile system 300 also includes an on-board crop monitoring system that includes various sensors and sensor modules mounted to the frame 310. In some embodiments, the position(s) of one, some, or all of the sensors/sensor modules can be adjustable during operation of the mobile system 300, and a control system can control the position(s) of the sensor(s)/sensor module(s). In this example of the mobile system 300, the mobile system 300 includes a crop health monitoring sensor module 340 and imaging sensors 342 and 345. In some embodiments, the crop health monitoring sensor module 340 represents a multi-sensor module that can include various types of sensors contained in a housing. The imaging sensors 342 and 345 can be used to capture images of different portions of plants. For example, the imaging sensor 342 can be used to image a crop head, and the imaging sensor 345 (the height of which can be adjusted by moving it up and down on mounting rods 348 automatically or manually) can be used for fruit imaging.

[0060] The mobile system 300 may include any other or additional sensors. Other sensors on-board the mobile system 300 can include, for example, physiological sensors, surface analysis sensors, chemical sensors, microclimate sensors, and/or canopy screening sensors. In some embodiments, the mobile system 300 includes at least one physiological sensor that includes at least one configurable optical probe and at least one tunable detector, at least one surface analysis sensor that includes at least one full spectrum light source and at least one spectroscopic detector, and at least one chemical analysis sensor (which may include at least one photo-ionization detector, at least one surface acoustic wave sensor, and/or at least

one quartz crystal microbalance sensor). In particular embodiments, the mobile system 300 includes a multispectral or hyperspectral imaging device, a leaf temperature sensor, an evapotranspiration sensor, a surface electrical charge sensor, a terahertz sensor, a spore detection sensor, and/or a tunable microphone.

[0061] The mobile system 300 further includes an on-board crop treatment system that includes multiple material storage containers and associated dispensers from which chemical pesticides or pesticide component materials (possibly with appropriate solvents and/or adjuvants) and biological control agents are drawn and administered to plants in a crop. In this example embodiment, the mobile system 300 includes three storage containers/dispensers 350a, 350b, and 350c, each of which can have one or more compartments and can include one or more mixers, aerators, agitators, and/or smart pumps. Example implementations of storage containers and dispensers are described in more detail in reference to FIGURES 4A through 6B below. However, other containers and dispensers and other numbers of containers and dispensers may be used.

[0062] The material storage containers/dispensers 350a, 350b, and 350c can be selectively fluidly connected to deliver chemical pesticides, suitable solvents and/or adjuvants, and biological control agents to at least one robotic arm 360 via which they are selectively applied to plants in a crop in a targeted, localized manner. Each robotic arm 360 can have multiple degrees of freedom, such as when the robotic arm 360 can swivel, pivot, extend, etc., so that treatment can be selectively applied to a desired location on each individual plant. The robotic arm 360 may include an interchangeable applicator (such as a spray nozzle or other applicator 265) or gripper 365 that can be changed automatically or on demand and may be adjustable. Alternative applicators or grippers (not shown) can be carried on-board the mobile system 300 and connected to the robotic arm 360 as needed. Some applicators 365 can have UV lights at the end, and the robotic arm 360 can point the UV light attachment to specific areas of the plants or crop to treat diseases.

[0063] In some embodiments, the mobile crop monitoring and treatment system 300 (or the mobile system 100 described above) can be controlled and operated from a remote location (such as via wireless communications) and/or can be equipped with one or more on-board computers and controllers for controlling propulsion of the mobile system and operation of the sensor-based on-board crop monitoring system and on-board crop treatment system. In this example, the mobile system 300 includes two on-board computer-based control systems 370 and 375, and the mobile system 300 can be operated and controlled autonomously

using these on-board computer-based control systems 370 and 375. For example, these systems 370 and 375 can be used to analyze the results from the on-board crop monitoring system, such as based on the outputs of the various sensors, and determine in real-time what treatments will be applied to a crop using the on-board crop treatment system. The system 300 also includes an interactive display 380 that can provide information to a human who is on-board the mobile system 300. Any suitable information can be displayed, such as information about the findings of the on-board crop monitoring system and treatment being applied by the on-board crop treatment system.

[0064] FIGURE 3B illustrates a portion 390 of the mobile crop monitoring and treatment system 300 of FIGURE 3A and, in particular, shows the three material storage containers/dispensers 350a, 350b, and 350c in close-up view. These three material storage containers/dispensers 350a, 350b, and 350c can be the same as one another or different from one another. This can depend on a number of factors, such as the materials to be dispensed. In some embodiments, the material storage containers/dispensers 350a, 350b, and 350c can be formed of one or more materials that are inert and that will not contaminate or be degraded by the materials that are to be stored in them.

[0065] Although FIGURES 3A and 3B illustrate a specific example implementation of a mobile crop monitoring and treatment system 300, various changes may be made to FIGURES 3A and 3B. For example, various components shown in FIGURES 3A and 3B may be combined, further subdivided, replicated, rearranged, or omitted and additional components may be added according to particular needs. Also, the form of the cart and other physical components of the mobile system 300 can easily vary as needed or desired.

[0066] FIGURES 4A through 6B illustrate example storage containers/dispensers that can be used on-board a mobile crop monitoring and treatment system and from which at least one treatment can be dispensed in accordance with this disclosure. In particular, FIGURES 4A and 4B illustrate a first example storage container/dispenser 350a, FIGURES 5A and 5B illustrate a second example storage container/dispenser 350b, and FIGURES 6A and 6B illustrate a third example storage container/dispenser 350c. Note that these associations of different structures with different storage containers/dispensers 350a, 350b, and 350c are for illustration only and that each storage container/dispenser 350a, 350b, and 350c of the mobile system 300 may have any suitable structure.

[0067] As shown in FIGURE 4A, the storage container/dispenser 350a includes a cylindrical storage area 410 that is divided vertically into eight compartments. As shown in

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FIGURE 4B, a cross-sectional view of the storage area 410 shows the eight compartments 420a-420h, each of which can contain a different chemical pesticide or active ingredient thereof. Note that while the compartments 420a-420h here are shown as being generally equal in size, this need not be the case. Each compartment 420a-420h is connected to a smart pump 430 via a separate hose 425 or other connector. An on-board computer-based control system or other system can cause an appropriate pesticide or mix of pesticides or pesticide components to be drawn from one, some, or all of the compartments 420a-420h by the smart pump 430 and, if needed, to be mixed in a mixing area 440. The pesticide or mix of pesticides or pesticide components that is selected can be based on the specific problem that needs to be treated, which may be identified by the on-board sensor-based crop monitoring system. The pesticide or mix of pesticides or pesticide components is supplied from the mixing area 440 to an applicator, such as an applicator 265 on a robotic arm 260 or an applicator 365 on a robotic arm 360, via a supply line 450.

[0068] As shown in FIGURE 5A, the storage container/dispenser 350b includes a cylindrical storage area 510 that is divided vertically into two compartments. As shown in FIGURE 5B, a cross-sectional view of the storage area 510 shows the two compartments 520a-520b. Note that while the compartments 520-520b here are shown as being unequal in size, this need not be the case. The larger compartment 520a can contain at least one carrier (such as water or another suitable solvent or carrier) for one or more chemical pesticides in another container. The smaller compartment 520b can contain at least one adjuvant. Adjuvants can include, for example, wetter-spreaders, stickers or adherents, penetrants, compatibility agents, and/or ionic or non-ionic surfactants. In some embodiments, materials are given an electronic charge to enhance their adherence to the foliage of plants. Each compartment 520a and 520b is connected to a smart pump 530 via a separate hose 525 or other connector. An on-board computer-based control system or other system can cause an appropriate quantity of carrier and adjuvant to be drawn respectively from the compartments 520a and 520b by the smart pump 530, mixed in a mixing area 540, and supplied to an applicator, such as an applicator 265 on a robotic arm 260 or an applicator 365 on a robotic arm 360, via a supply line 550. In some cases, an appropriate dose of pesticide or a desired pesticide mixture can be drawn from the container/dispenser 350a and diluted to the desired concentration with the carrier/adjuvant mixture, and the desired dose can be delivered to at least one desired location on a plant or crop via the applicator. The pesticide(s) and carrier/adjuvant can be combined at the applicator, upstream of the applicator, or downstream of the applicator.

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[0069] As shown in FIGURE 6A, the storage container/dispenser 350c includes a cylindrical storage area 610 that is divided vertically into four compartments. As shown in FIGURE 6B, a cross-sectional view of the storage area 610 shows the four compartments 620a-620d, each of which can contain a different biological control agent. Note that while the compartments 620a-620d here are shown as being generally equal in size, this need not be the case. The biological control agents may be in a liquid or solid formulation. In some cases, the biological control agents are stored and delivered along with a solid particulate carrier, such as a fibrous material, powder, or other particulate (like one derived from natural products such as leaves, husks, wood, or minerals). The carrier may help protect fragile living organisms and aid in dispersing the organisms during delivery to a plant. Each compartment 620a-620d is connected to a smart pump, blower, or fan 630 via a separate hose or tube 625 or other connector. An on-board computer-based control system or other system can cause one or more appropriate biological control agents to be drawn from the compartments 620a-620d by the smart pump, blower, or fan 630 and, if needed, mixed in a mixing area 640. The biological control agent or mix of agents that is selected can be based on the specific problem that needs to be treated, which may be identified by the on-board sensor-based crop monitoring system. The biological control agent or agents are supplied from the mixing area 640 to an applicator, such as an applicator 265 on a robotic arm 260 or an applicator 365 on a robotic arm 360, via a supply line 650. The dosage of the biological control agent(s) can be controlled by the computer-based control system depending on the nature and severity of the problem.

[0070] Some biological control agents will have a tendency to settle or congregate in specific regions of the compartments 620a-620d. Aeration hoses 660 can be used to blow air into the compartments 620a-620d from time to time or as needed to distribute the biological control agents (along with a carrier material if present) more evenly within the compartments 620a-620d prior to dispensing them. In some embodiments, air is supplied to the aeration hoses 660 by the smart pump, blower, or fan 630. Other suitable devices or techniques may also be used to distribute biological control agents more evenly within compartments prior to dispensing them, such as where propellers or other agitation devices may be used.

[0071] Although FIGURES 4A through 6B illustrate examples of storage containers/dispensers that can be used on-board a mobile crop monitoring and treatment system and from which at least one treatment can be dispensed, various changes may be made to FIGURES 4A through 6B. For example, the cylindrical shapes and the use of specific numbers of compartments are examples only and can vary as needed or desired. Each storage container/

dispenser may have any suitable size and shape and may include any suitable number of compartments.

[0072] Returning to FIGURES 3A and 3B, in some embodiments, the robotic arm 360 and gripper 365 may pick up and apply other treatments that are stored on-board the mobile crop monitoring and treatment system 300. For example, the other treatments may be located on a tray or in a storage container. This may occur in response to commands from the computer-based control system.

[0073] Moreover, the embodiment of the mobile crop monitoring and treatment system 300 illustrated in FIGURE 3A includes three multi-compartment material storage containers/dispensers and has a single robotic arm 360 and an interchangeable applicator or gripper 365. However, other embodiments of such systems can include different numbers and/or types and styles of storage containers/dispensers, applicators, and/or grippers. In some cases, at least one carrier and at least one adjuvant may be drawn from the same container as the active agent(s). Also, other embodiments of such systems may include more than one robotic arm and associated applicators or grippers, such as for applying treatments to different plants at the same time or for applying different treatments to the same plant at the same time. Each arm-applicator/gripper can be independently supplied with pesticides and/or biological control agents from an on-board storage system as described above. Other embodiments of such systems may include a robotic arm that has multiple applicators and/or grippers on it, or an individual applicator may have multiple outlets or nozzles.

[0074] In some embodiments, the pumps that are used to dispense materials from the on-board material storage system are multi-channel pumps suitable for precise, simultaneous metering or dosing of multiple materials (such as multiple chemical pesticides or components, carriers, and adjuvants) in desired and variable ratios. Also, in some embodiments, component materials of a particular treatment formulation can be mixed in a mixing region or container downstream of the pump(s) and upstream of the applicator(s) from which the treatment is delivered to a plant. In other embodiments, the desired quantities or ratios of the component materials are individually supplied to separate applicators (or to separate outlets or nozzles on a single applicator), and they mix as they exit the applicator outlets before they reach the plant. In other words, in these embodiments, the mixing region for at least some of the components of a particular treatment formulation can be downstream of the applicator outlets. This approach can offer some advantages. For example, if separate and dedicated supply lines are used to supply different materials or components of a treatment formulation to different

applicator outlets, contamination of a treatment with materials from a previous treatments is reduced. In some cases, a chemical pesticide may have an adverse effect on other pesticides or biological control agents, and it is preferred that the latter materials do not come into contact with trace or residual amounts of the potentially-detrimental pesticide that could remain in a shared supply line. By having separate supply lines, this risk can be mitigated. Another approach if shared supply lines are used between the material storage system and the applicator(s) is to flush the shared supply lines with water or another solvent (pumped from the storage system) in between administering different treatments from the mobile system.

[0075] In some implementations, the mobile crop monitoring and treatment system 300 is deployed to autonomously scan a row of plants in order to identify one or more locations of pests or diseases as it moves in one direction along the row. The mobile system 300 can then rapidly or immediately determine appropriate treatment(s) to be administered via the on-board treatment system as the mobile system 300 moves back along the row of plants. The treatment and dosage that is applied can be specific for each plant or for a specific region of an individual plant and can be varied as the mobile system 300 moves among the plants. This can be repeated for any number of rows. The mobile system 300 can be configured so that the position of the plant, the cart, the robotic arm, and the applicator are known, allowing the appropriate treatment to be applied precisely where it is needed. This approach allows the treatment to be performed immediately after detection of a problem with the health of a plant, such as a pest or disease. Early detection and remediation of issues can greatly enhance crop yields.

[0076] Conventionally, entire crops are often treated with pesticide(s) and/or biological control agent(s) as a matter of course, even in the absence of an identified disease or pest. However, it is generally desirable to reduce the amount of chemical pesticides and biological control agents used for treating a crop, such as due to their costs and other potentially-adverse factors, especially those associated with the use of pesticides. Also, pesticides are conventionally applied to crops and then, only after a waiting period of several days, are biological control agents subsequently applied. In most cases, the delivery of biological control agents is done manually and prophylactically.

[0077] The systems and methods described in this disclosure allow for highly-tailored and targeted application of appropriate dosages of chemical pesticides and biological control agents at the precise locations where they are needed. This can substantially reduce the amount of these materials that are used. Furthermore, such localized or targeted application can allow biological control agents to be used simultaneously with chemical pesticides (or directly before

or after treatment with chemical pesticides) to treat the same plant. For example, biological control agents can be applied to an area of a plant that is close to an area of infestation or disease that is being treated with a pesticide. In addition, the ability of the systems and methods described here to formulate on-demand and select appropriate dosages based on need, in response to information received from a sensor-based crop monitoring system, means that treatments can be applied effectively and efficiently in a timely manner.

[0078] In some embodiments, compartments in the storage containers are equipped with sensors to indicate the quantity of material(s) remaining in each compartment. The mobile system 300 can communicate information from these sensors to alert the user or operator if the material in a compartment needs to be replenished.

[0079] Crop treatment systems as described here can be mounted on other semi-automated or autonomous crop health monitoring vehicles, robots, or other mobile devices. For example, the mobile platform may be configured to move autonomously among plants or in response to commands from a controller, which in some embodiments is on-board the mobile system and in other embodiments is a component of an external data processing unit or other device or system. Thus, in some embodiments of the mobile crop monitoring and treatment systems described here, functions such as data collection, processing, and analysis and control of the system (including operation of the treatment system) is performed on-board the mobile system by one or more computer processors and control systems. In other embodiments, the mobile system is controlled entirely, or at least to some extent, remotely. One example of the latter is shown in FIGURE 7.

[0080] FIGURE 7 illustrates an example crop management system 700 that includes a mobile crop monitoring and treatment system in accordance with this disclosure. In the crop management system 700, at least some processing and analysis of sensor data and control of a mobile system is performed remotely. As shown in FIGURE 7, the crop management system 700 includes a mobile crop monitoring and treatment system 710, which includes multiple sensors and one or more robotic arms for applying treatments to plants. The sensors and robotic arms can be mounted on, for example, a vehicle, cart, or drone. In some embodiments, the mobile system 710 may be the same as or similar to the mobile system 100 or 300 described above.

[0081] In the crop management system 700, the mobile crop monitoring and treatment system 710 captures sensor data related to plants in a crop. Some or all of the data can be transmitted to a data processing unit (DPU) 720 via a network 730. In some embodiments, the

mobile system 710 represents one of multiple vehicles or robots, and these vehicles or robots may communicate and exchange information with one another as well as with the DPU 720. The DPU 720 analyzes the sensor data and sends information regarding the crop to an individual 760, such as a grower and/or other parties, via one or more end-user devices, such as a smartphone 740 and/or a computer 750. The DPU 720 may also send commands to the mobile crop monitoring and treatment system 710. The grower or other individuals 760 may also send information to the DPU 720 and/or send commands to the mobile system 710 via the network 730.

[0082] In FIGURE 7, arrows are used to indicate transmission of sensor data and/or other information. In some embodiments, the crop management system 700 includes or supports a web-based and/or cloud-based system, where communications between the mobile system 710, the DPU 720, and the grower or other individuals 760 or devices is primarily or entirely through wireless communications.

[0083] Although FIGURE 7 illustrates one example of a crop management system 700 that includes a mobile crop monitoring and treatment system, various changes may be made to FIGURE 7. For example, various components shown in FIGURE 7 may be combined, further subdivided, replicated, rearranged, or omitted and additional components may be added according to particular needs.

[0084] Note that, in some embodiments, the mobile crop monitoring and treatment systems described here are designed to operate in the dark, such as at night. This can be beneficial as it can reduce interference with other greenhouse or field operations. Also, in some cases, the sensor-based monitoring systems may operate with greater sensitivity at night, as plants tend to be dormant during periods of darkness. During the daytime, normal practices of staff tending to a crop might temporarily stress the plants, such as due to moving plant heads, removing shoots, picking fruits, and the like.

[0085] Also note that embodiments of the systems and methods described here may rely primarily on the detection (through sensors) and interpretation (through data analysis) of plant-based signals to provide information about crop health and to determine appropriate remediative treatments to be administered. In some embodiments, the sensors on the mobile sensory platforms are proximate to the plants during sensing and data capture but do not touch the plants or soil. Such non-contact monitoring can help to reduce the spread of pests and diseases.

[0086] Further, note that the systems and methods described here for monitoring and

assessing crop health can provide rapid and sensitive screening of individual plant health and treatment of plants with reduced human labor and at a far greater speed than can be accomplished by humans manually. The systems and methods described here can be deployed outdoors (such as in a field or orchard) or indoors (such as in a greenhouse). The systems and methods have automated components but are flexible and can be modified to enhance the crop monitoring and treatment that they perform.

[0087] In addition, note that embodiments of the technology, devices, systems, and methods described here can be used separately or can be used in various combinations as desired. For example, any desired combination of features of the mobile systems 100, 300, 710 described above may be used in a specific implementation of a mobile system.

[0088] In some embodiments, various functions described in this patent document are implemented or supported by a computer program that is formed from computer readable program code and that is embodied in a computer readable medium. The phrase “computer readable program code” includes any type of computer code, including source code, object code, and executable code. The phrase “computer readable medium” includes any type of medium capable of being accessed by a computer, such as read only memory (ROM), random access memory (RAM), a hard disk drive (HDD), a compact disc (CD), a digital video disc (DVD), or any other type of memory. A “non-transitory” computer readable medium excludes wired, wireless, optical, or other communication links that transport transitory electrical or other signals. A non-transitory computer readable medium includes media where data can be permanently stored and media where data can be stored and later overwritten, such as a rewritable optical disc or an erasable storage device.

[0089] It may be advantageous to set forth definitions of certain words and phrases used throughout this patent document. The terms “application” and “program” refer to one or more computer programs, software components, sets of instructions, procedures, functions, objects, classes, instances, related data, or a portion thereof adapted for implementation in a suitable computer code (including source code, object code, or executable code). The term “communicate,” as well as derivatives thereof, encompasses both direct and indirect communication. The terms “include” and “comprise,” as well as derivatives thereof, mean inclusion without limitation. The term “or” is inclusive, meaning and/or. The phrase “associated with,” as well as derivatives thereof, may mean to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or

with, have, have a property of, have a relationship to or with, or the like. The phrase “at least one of,” when used with a list of items, means that different combinations of one or more of the listed items may be used, and only one item in the list may be needed. For example, “at least one of: A, B, and C” includes any of the following combinations: A, B, C, A and B, A and C, B and C, and A and B and C.

[0090] The description in the present application should not be read as implying that any particular element, step, or function is an essential or critical element that must be included in the claim scope. The scope of patented subject matter is defined only by the allowed claims. Moreover, none of the claims invokes 35 U.S.C. § 112(f) with respect to any of the appended claims or claim elements unless the exact words “means for” or “step for” are explicitly used in the particular claim, followed by a participle phrase identifying a function. Use of terms such as (but not limited to) “mechanism,” “module,” “device,” “unit,” “component,” “element,” “member,” “apparatus,” “machine,” “system,” “processor,” or “controller” within a claim is understood and intended to refer to structures known to those skilled in the relevant art, as further modified or enhanced by the features of the claims themselves, and is not intended to invoke 35 U.S.C. § 112(f).

[0091] While this disclosure has described certain embodiments and generally associated methods, alterations and permutations of these embodiments and methods will be apparent to those skilled in the art. Accordingly, the above description of example embodiments does not define or constrain this disclosure. Other changes, substitutions, and alterations are also possible without departing from the spirit and scope of this disclosure, as defined by the following claims.

WHAT IS CLAIMED IS:

1. A mobile crop monitoring and treatment system comprising:
 - a vehicle with a propulsion system;
 - multiple sensors mounted on the vehicle, each sensor configured to capture data pertaining to at least one plant-related parameter when the sensor is positioned proximate to a plant in a crop;
 - a storage system configured to house multiple treatment agents comprising at least one chemical pesticide and at least one biological control agent on-board the vehicle;
 - an application system configured to apply one or more of the treatment agents to the plant; and
 - a controller configured to control movement of the vehicle and operation of the sensors and the application system, the controller configured to cause the application system to apply one or more of the treatment agents to the plant in response to one or more signals from one or more of the sensors.

2. The mobile crop monitoring and treatment system of Claim 1, wherein:
 - the mobile crop monitoring and treatment system further comprises an on-board computer processor; and
 - the controller is configured to cause the application system to apply the one or more treatment agents to the plant at a dosage and a concentration determined by the on-board computer processor in response to the one or more signals from the one or more sensors.

3. The mobile crop monitoring and treatment system of Claim 1, wherein the application system comprises at least one robotic arm and at least one applicator.

4. The mobile crop monitoring and treatment system of Claim 3, wherein the storage system comprises:
 - at least one chemical pesticide container configured to house the at least one chemical pesticide;
 - at least one biological control agent container configured to house the at least one biological control agent; and
 - at least one carrier container configured to house at least one solvent or carrier.

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5. The mobile crop monitoring and treatment system of Claim 4, wherein the controller is configured to cause the mobile crop monitoring and treatment system to:

draw the at least one chemical pesticide from the at least one chemical pesticide container;

draw the at least one solvent or carrier from the at least one carrier container; and

combine the at least one chemical pesticide and the at least one solvent or carrier upstream of the at least one applicator.

6. The mobile crop monitoring and treatment system of Claim 4, wherein:

the at least one chemical pesticide container comprises a multi-compartment container and a pump;

each compartment of the multi-compartment container is configured to house a different pesticide or pesticide component material; and

the controller is configured to cause the pump to selectively draw multiple pesticides or pesticide component materials from the multi-compartment container and mix the multiple pesticides or pesticide component materials in a mixing region.

7. The mobile crop monitoring and treatment system of Claim 6, wherein the mixing region is upstream of the at least one applicator.

8. The mobile crop monitoring and treatment system of Claim 6, wherein the mixing region is downstream of the at least one applicator.

9. The mobile crop monitoring and treatment system of Claim 4, wherein the at least one biological control agent container comprises an aerator or agitator.

10. The mobile crop monitoring and treatment system of Claim 3, further comprising:

at least one ultraviolet light positioned on the at least one robotic arm.

11. The mobile crop monitoring and treatment system of Claim 1, wherein the mobile crop monitoring and treatment system is a ground-based system.

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12. The mobile crop monitoring and treatment system of Claim 1, wherein the mobile crop monitoring and treatment system is an air-borne system.

13. The mobile crop monitoring and treatment system of Claim 1, wherein the mobile crop monitoring and treatment system forms part of a robotic scout.

14. The mobile crop monitoring and treatment system of Claim 1, wherein the mobile crop monitoring and treatment system forms part of a cart that is configured to be driven by an operator.

15. A method for treating a plant in a crop, the method comprising:
assessing a health of the plant in the crop by gathering sensor data using an automated vehicle equipped with multiple sensors;
processing the sensor data to determine a treatment to be applied to the plant in the crop;
dispensing the treatment from a storage system carried on-board the automated vehicle, the storage system housing at least one chemical pesticide and at least one biological control agent; and
delivering the treatment to the plant in the crop via a robotic arm and an applicator carried on-board the automated vehicle;
wherein a concentration and a dosage of the treatment applied to the plant in the crop are controllable and adjustable by a controller on-board the automated vehicle.

16. The method of Claim 15, wherein the sensor data is processed on-board the automated vehicle to determine the treatment to be applied to the plant in the crop.

17. The method of Claim 15, wherein dispensing the treatment from the storage system comprises:
mixing multiple chemical pesticides or pesticide component materials drawn from the storage system with at least one carrier to provide a desired formulation.

18. The method of Claim 15, wherein dispensing the treatment from the storage system comprises:

mixing multiple chemical pesticides or pesticide component materials drawn from the storage system with at least one carrier and with at least one adjuvant to provide a desired formulation.

19. The method of Claim 15, wherein:

the at least one biological control agent is housed in a container in the storage system;
and

the method further comprises agitating or aerating the at least one biological control agent so that the at least one biological control agent is more uniformly dispersed within the container.

20. A mobile crop monitoring and treatment system comprising:

a vehicle with a propulsion system;

multiple sensors mounted on the vehicle, each sensor configured to capture data pertaining to at least one plant-related parameter when the sensor is positioned proximate to a plant in a crop;

a storage system configured to house chemical pesticides and biological control agents on-board the vehicle, the storage system comprising multiple containers, at least one of the containers comprising multiple compartments, the compartments of the containers collectively configured to store multiple materials including the chemical pesticides or pesticide component materials, the biological control agents, one or more solvents, and one or more adjuvants;

one or more applicators configured to apply one or more treatments to the plant;

one or more robotic arms configured to position at least one of the one or more applicators for application of the one or more treatments to the plant; and

a controller configured to control movement of the vehicle and operation of the mobile crop monitoring and treatment system, the controller configured to cause the one or more applicators to apply the one or more treatments to the plant in response to one or more signals from one or more of the sensors, wherein different treatments are associated with different materials or combinations of materials from the containers.

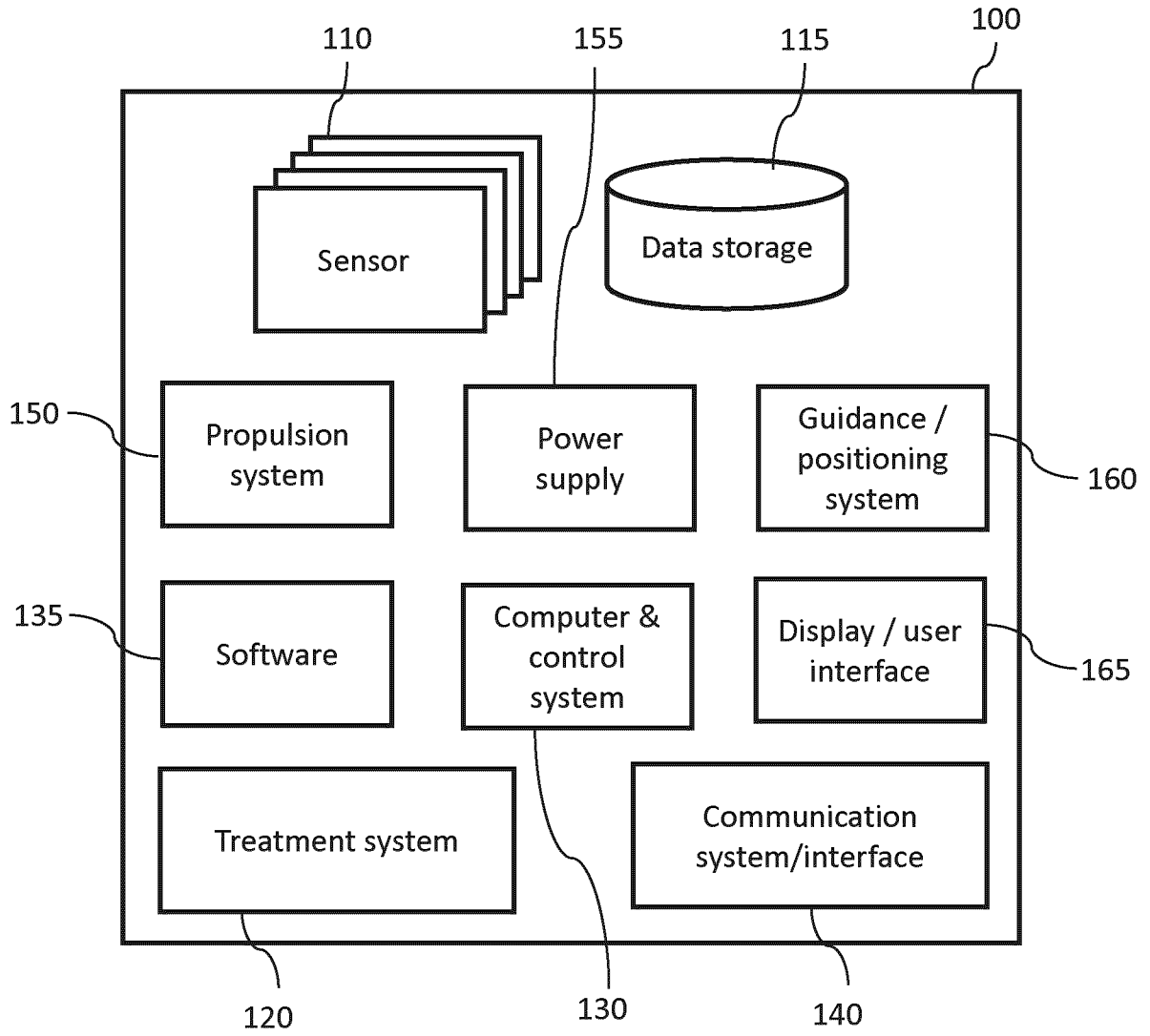


FIG. 1

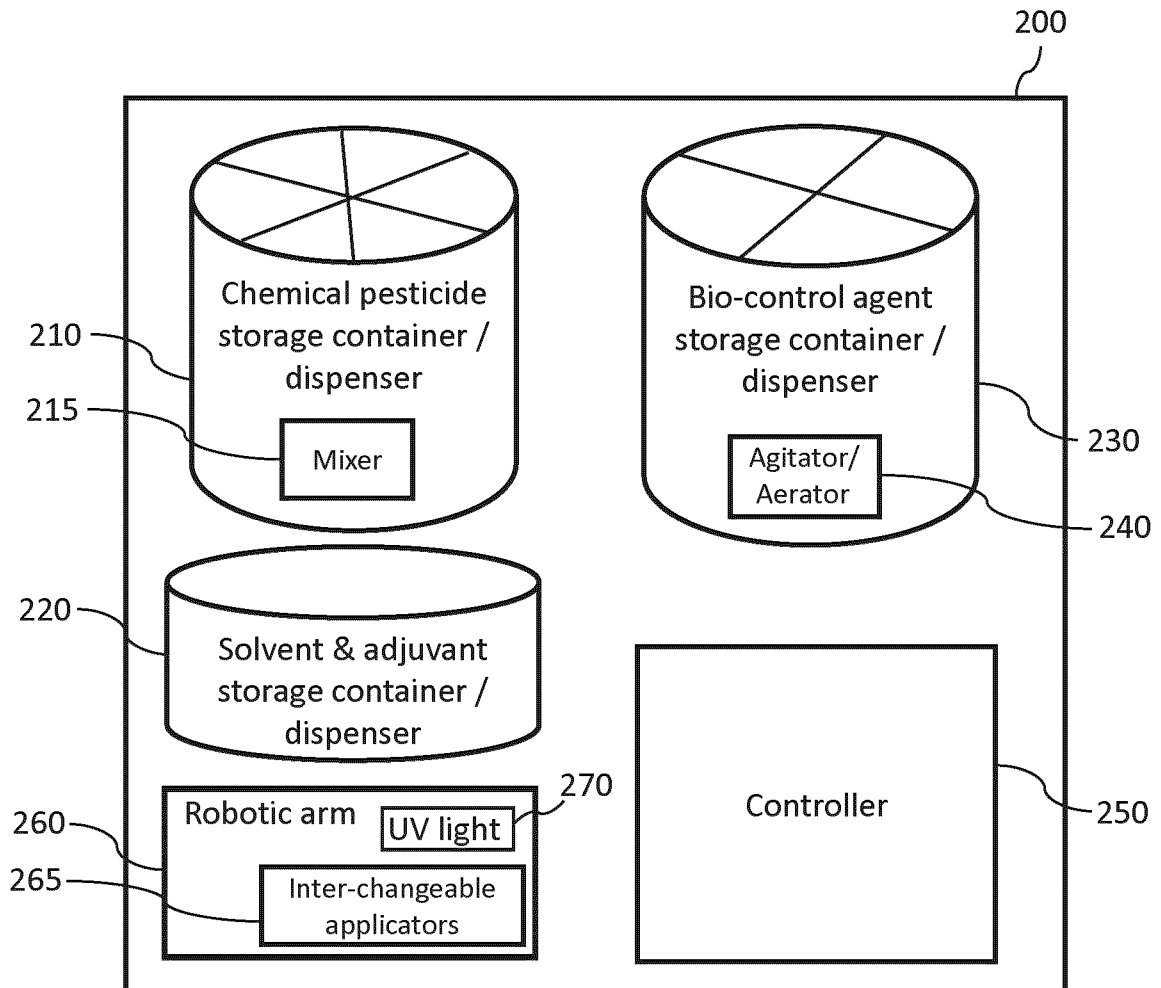


FIG. 2

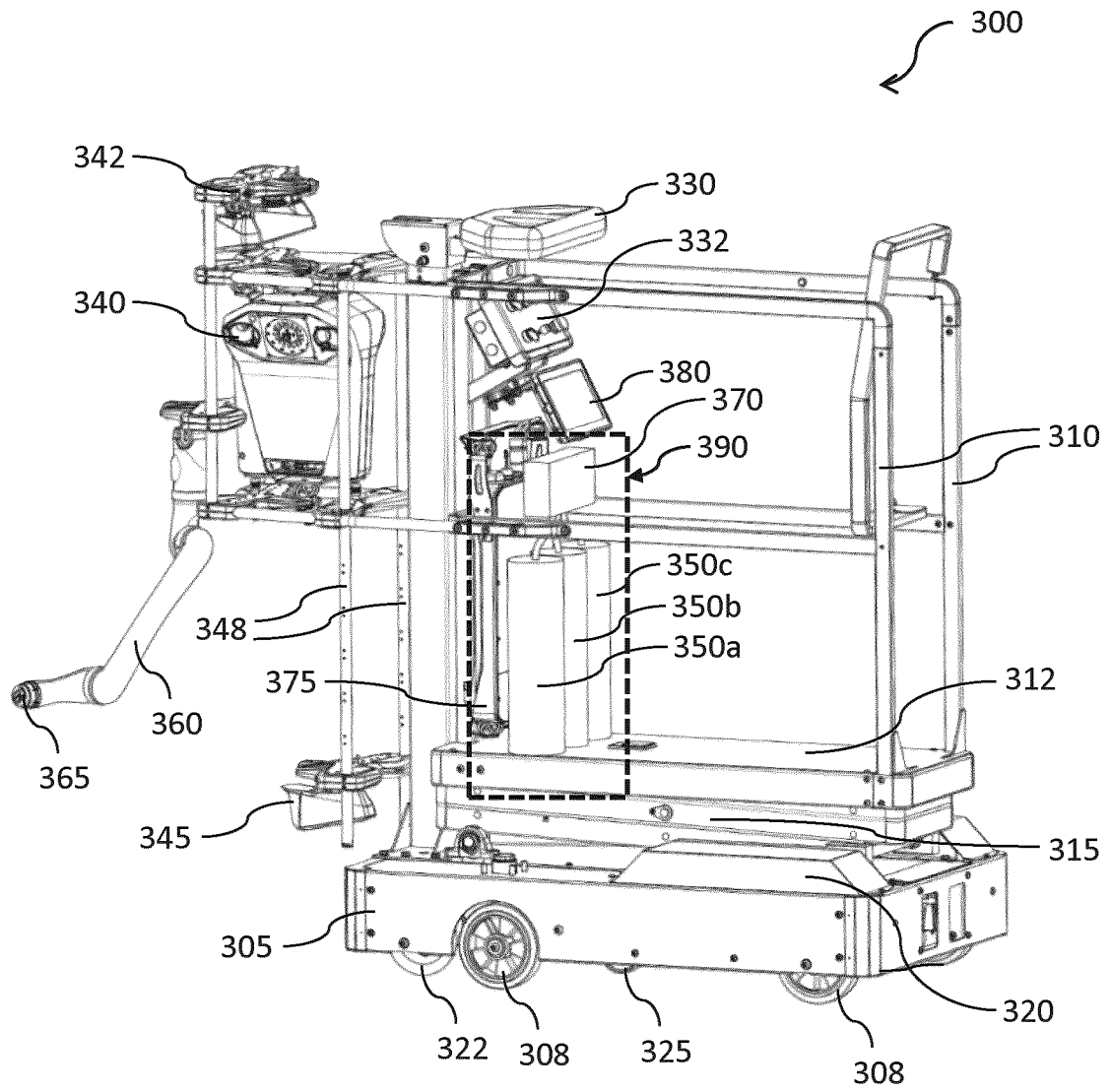


FIG. 3A

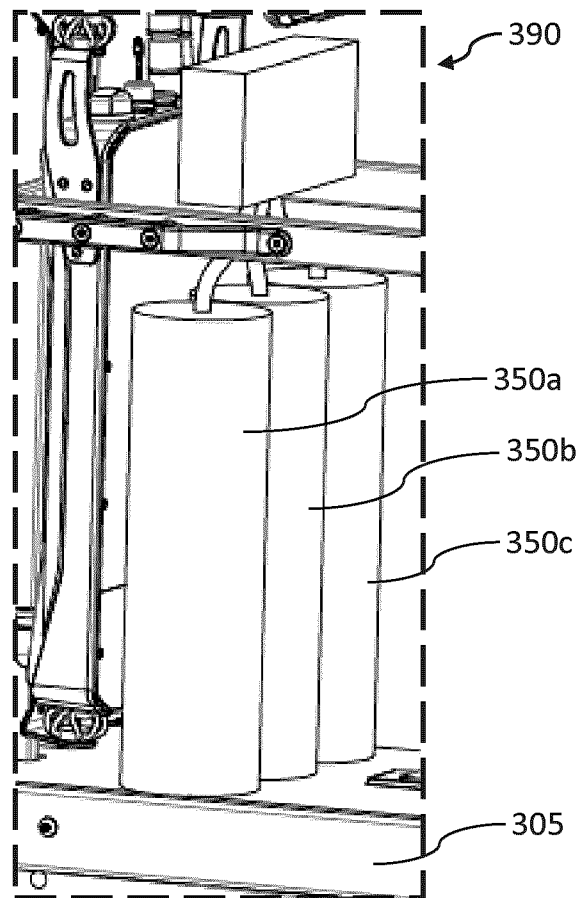


FIG. 3B

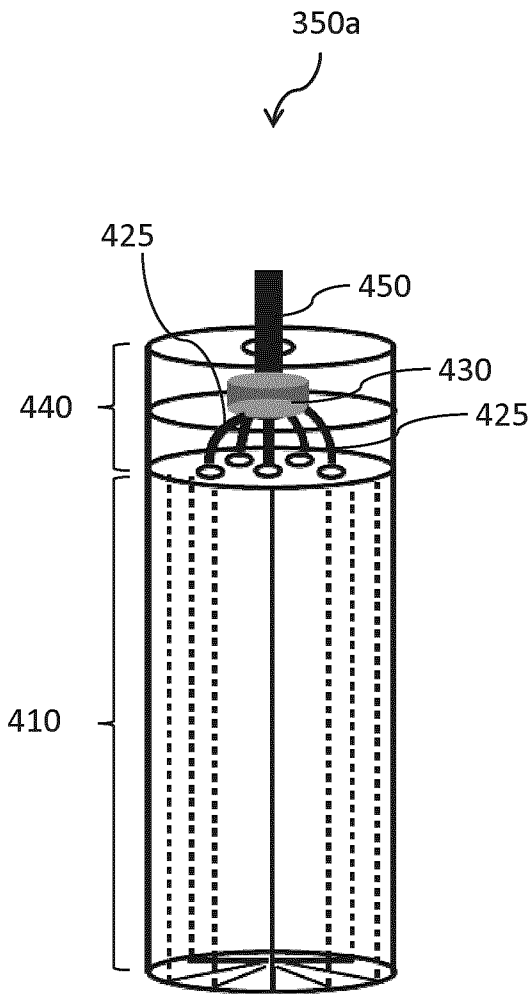


FIG. 4A

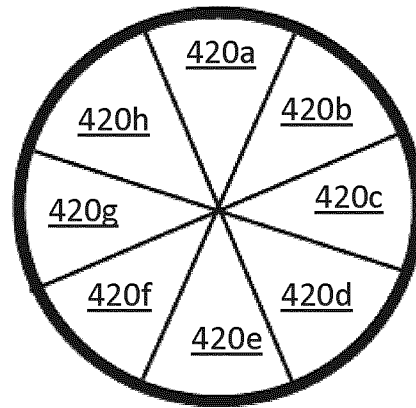


FIG. 4B

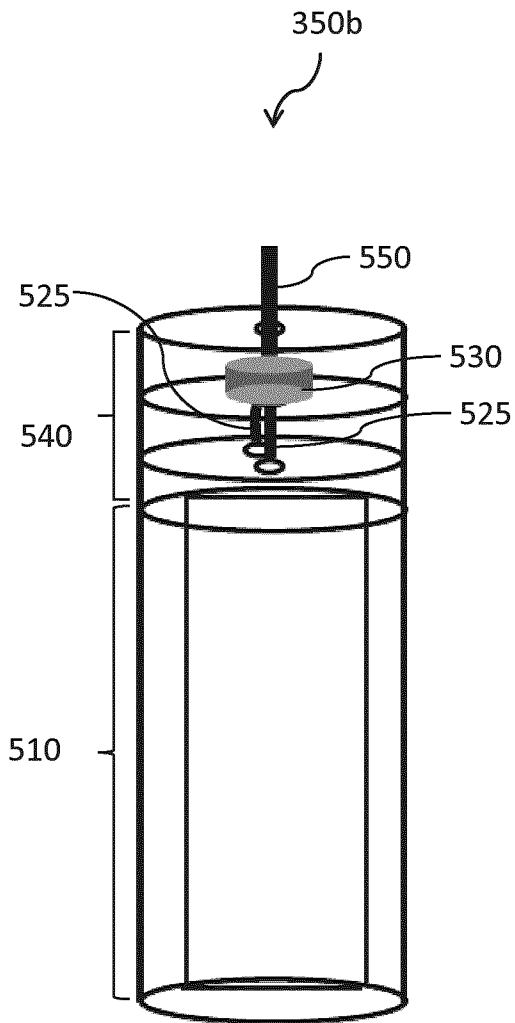


FIG. 5A

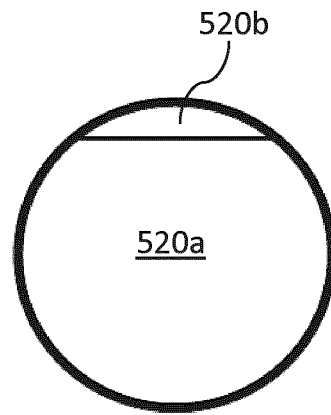


FIG. 5B

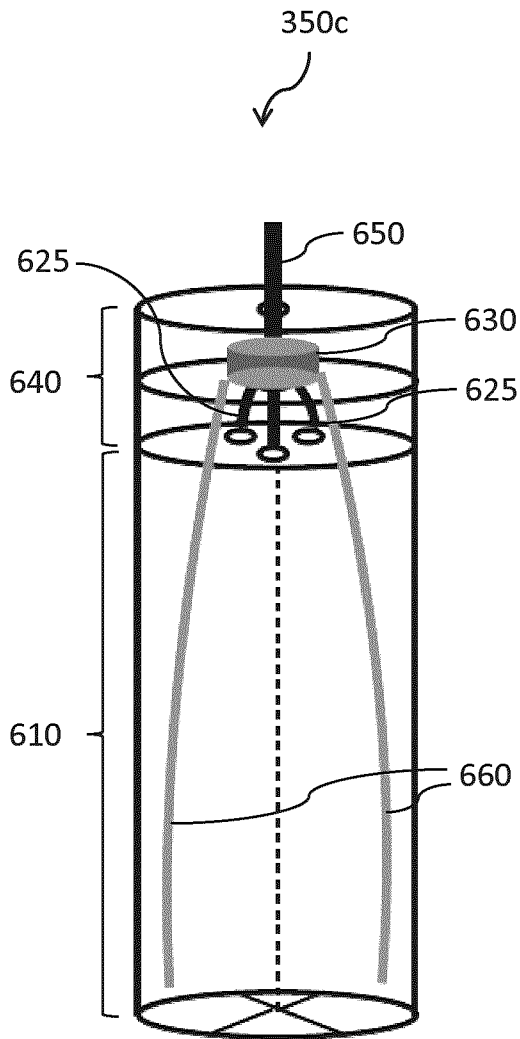


FIG. 6A

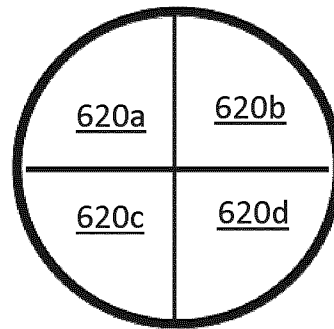


FIG. 6B

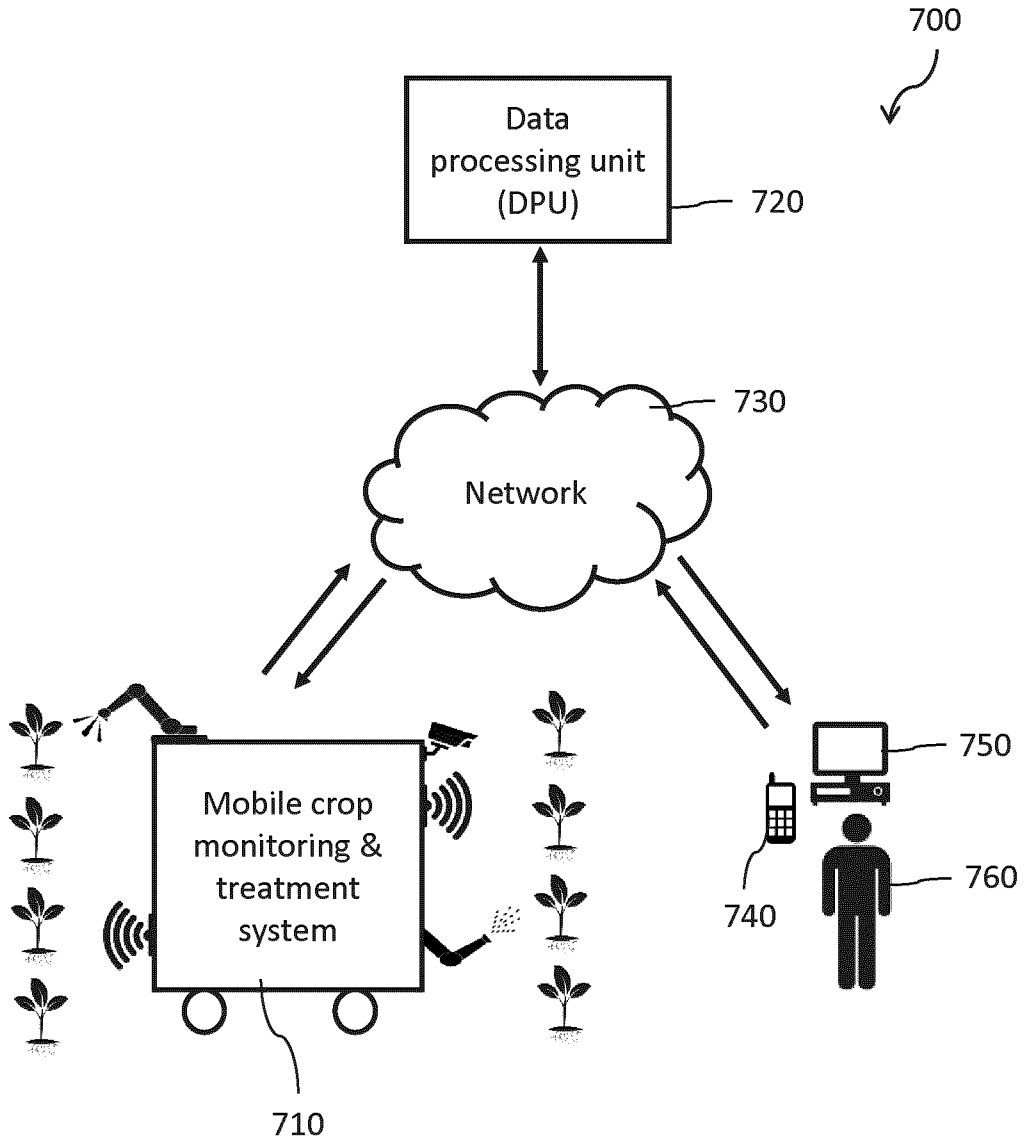


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2020/051099

A. CLASSIFICATION OF SUBJECT MATTER IPC: <i>A01G 7/00</i> (2006.01), <i>A01G 23/00</i> (2006.01), <i>G06Q 50/02</i> (2012.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) IPC: <i>A01G 7/00</i> (2006.01), <i>A01G 23/00</i> (2006.01), <i>G06Q 50/02</i> (2012.01), <i>A01M-021/04</i> (2006.01) CPC: <i>A01M-021/043</i>		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used) Questel Orbit (FAMPAT), Google Patent Keywords: sensor?, pesticide?, pollen, bacteria, hormone, nozzle?, applicator? Google keywords: crop sensor treatment applicator pesticides controller		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO2018203337A1 (GELTNER, IDDO), 08 November 2018 (08-11-2018) *Fig. 4c, 10; p. 5, lines 7-17; p. 19, line 24 to p. 20, line 2; p. 27, line 28; p. 28, line 4*	1 to 11, 13 to 20 12
X Y	US2015027040A1 (REDDEN LEE, K.), 29 January 2015 (29-01-2015) *Fig. 2B and 7; par. 0043, 0046, 0053, 0073, 0146 and 0164*	1, 2, 4 to 8, 11, 13 to 18, 20 12
Y	US2017030877A1 (MIRESMALLI, S. et al.), 02 February 2017 (02-02-2017) *par. 0059*	12
Y	US2017359943A1 (CALLEIJA, M. et al.), 21 December 2017 (21-12-2017) *Fig. 5*	12
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* "A" "D" "E" "L" "O" "P"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance document cited by the applicant in the international application earlier application or patent but published on or after the international filing date document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) document referring to an oral disclosure, use, exhibition or other means document published prior to the international filing date but later than the priority date claimed	"T" "X" "Y" "&"
Date of the actual completion of the international search 06 November 2020 (06-11-2020)		later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art document member of the same patent family
Date of mailing of the international search report 06 November 2020 (06-11-2020)		
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476		Authorized officer Christine Lord (819) 639-7867

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2020/051099

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US2014180549A1 (SIEMENS, M. et al.), 26 June 2014 (26-06-2014) *Whole document*	1 to 20
A	US2019098842A1 (BARBER III, A. et al.), 04 April 2019 (04-04-2019) *Whole document*	1 to 20
A	US9992991B2 (CINK, J. et al.), 12 June 2018 (12-06-2018) *Whole document*	1 to 20
A	US10701852B2 (CALLEIJA, M. et al.), 07 July 2020 (07-07-2020) *Whole document*	1 to 20
A	WO2019144231A1 (VAN ESSEN, Y. et al.), 01 August 2019 (01-08-2019) *Whole document*	1 to 20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2020/051099

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
WO2018203337A1	08 November 2018 (08-11-2018)	AU2018262566A1 CA3060517A1 EP3618609A1 EP3618609A4 JP2020518272A KR20200003877A US2020120886A1	14 November 2019 (14-11-2019) 08 November 2018 (08-11-2018) 11 March 2020 (11-03-2020) 06 May 2020 (06-05-2020) 25 June 2020 (25-06-2020) 10 January 2020 (10-01-2020) 23 April 2020 (23-04-2020)
US2015027040A1	29 January 2015 (29-01-2015)	US10537071B2 EP2822380A1 EP2822380A4 EP3032946A2 EP3032946A4 EP3107367A1 EP3107367A4 EP3264892A1 EP3264892A4 US2013235183A1 US9030549B2 US2013238201A1 US9064173B2 US2015015697A1 US9658201B2 US2015237790A1 US9717171B2 US2015245554A1 US9756771B2 US2017290260A1 US10098273B2 US2017219711A1 US10175362B2 US2015027043A1 US10219449B2 US2016255778A1 US10327393B2 US2015027044A1 US10390497B2 US2018116094A1 US10524402B2 US2019261581A1 US10617071B2 US2019064363A1 US10761211B2 US2015027041A1 US2019090408A1 US2019335684A1 US2020187406A1 US2020187433A1 WO2013134480A1 WO2015006675A2 WO2015006675A3 WO2015013723A2 WO2015013723A3 WO2015127397A1 WO2015127397A8 WO2016144795A1	21 January 2020 (21-01-2020) 14 January 2015 (14-01-2015) 06 April 2016 (06-04-2016) 22 June 2016 (22-06-2016) 10 May 2017 (10-05-2017) 28 December 2016 (28-12-2016) 01 November 2017 (01-11-2017) 10 January 2018 (10-01-2018) 12 September 2018 (12-09-2018) 12 September 2013 (12-09-2013) 12 May 2015 (12-05-2015) 12 September 2013 (12-09-2013) 23 June 2015 (23-06-2015) 15 January 2015 (15-01-2015) 23 May 2017 (23-05-2017) 27 August 2015 (27-08-2015) 01 August 2017 (01-08-2017) 03 September 2015 (03-09-2015) 12 September 2017 (12-09-2017) 12 October 2017 (12-10-2017) 16 October 2018 (16-10-2018) 03 August 2017 (03-08-2017) 08 January 2019 (08-01-2019) 29 January 2015 (29-01-2015) 05 March 2019 (05-03-2019) 08 September 2016 (08-09-2016) 25 June 2019 (25-06-2019) 29 January 2015 (29-01-2015) 27 August 2019 (27-08-2019) 03 May 2018 (03-05-2018) 07 January 2020 (07-01-2020) 29 August 2019 (29-08-2019) 14 April 2020 (14-04-2020) 28 February 2019 (28-02-2019) 01 September 2020 (01-09-2020) 29 January 2015 (29-01-2015) 28 March 2019 (28-03-2019) 07 November 2019 (07-11-2019) 18 June 2020 (18-06-2020) 18 June 2020 (18-06-2020) 12 September 2013 (12-09-2013) 15 January 2015 (15-01-2015) 12 March 2015 (12-03-2015) 29 January 2015 (29-01-2015) 26 March 2015 (26-03-2015) 27 August 2015 (27-08-2015) 12 November 2015 (12-11-2015) 15 September 2016 (15-09-2016)
US2017030877A1	02 February 2017 (02-02-2017)	US10241097B2	26 March 2019 (26-03-2019)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2020/051099

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
		CA2937571A1 CA2937574A1 US2017032258A1 US2019170718A1	30 January 2017 (30-01-2017) 30 January 2017 (30-01-2017) 02 February 2017 (02-02-2017) 06 June 2019 (06-06-2019)
US2017359943A1	21 December 2017 (21-12-2017)	AU2015362069A1 AU2015362069B2 AU2019246795A1 EP3229577A1 EP3229577A4 WO2016090414A1	13 July 2017 (13-07-2017) 11 July 2019 (11-07-2019) 31 October 2019 (31-10-2019) 18 October 2017 (18-10-2017) 31 October 2018 (31-10-2018) 16 June 2016 (16-06-2016)
US2014180549A1	26 June 2014 (26-06-2014)	WO2012094116A1	12 July 2012 (12-07-2012)
US2019098842A1	04 April 2019 (04-04-2019)	EP3490364A2 EP3490364A4 JP2019524112A US2018028700A1 US10624978B2 WO2018022724A2 WO2018022724A3	05 June 2019 (05-06-2019) 11 March 2020 (11-03-2020) 05 September 2019 (05-09-2019) 01 February 2018 (01-02-2018) 21 April 2020 (21-04-2020) 01 February 2018 (01-02-2018) 01 March 2018 (01-03-2018)
US9992991B2	12 June 2018 (12-06-2018)	US2016198695A1 AR097416A1 AU2014310308A1 AU2014310308B2 CN105578877A EP3035797A1 JP2016527915A JP6552496B2 JP2019107032A KR20160071370A MX2016002248A TW201521568A US2018255760A1 US10420332B2 WO2015025252A1	14 July 2016 (14-07-2016) 16 March 2016 (16-03-2016) 10 March 2016 (10-03-2016) 29 March 2018 (29-03-2018) 11 May 2016 (11-05-2016) 29 June 2016 (29-06-2016) 15 September 2016 (15-09-2016) 31 July 2019 (31-07-2019) 04 July 2019 (04-07-2019) 21 June 2016 (21-06-2016) 18 November 2016 (18-11-2016) 16 June 2015 (16-06-2015) 13 September 2018 (13-09-2018) 24 September 2019 (24-09-2019) 26 February 2015 (26-02-2015)
US10701852B2	07 July 2020 (07-07-2020)	US2018153084A1 AU2016269849A1 AU2016269849B2 AU2018372564A1 AU2019246911A1 AU2019246911B2 CA3083265A1 CN108135122A CN111386032A EP3307047A1 EP3307047A4 WO2016191825A1 WO2019100118A1	07 June 2018 (07-06-2018) 18 January 2018 (18-01-2018) 15 August 2019 (15-08-2019) 18 June 2020 (18-06-2020) 31 October 2019 (31-10-2019) 12 March 2020 (12-03-2020) 31 May 2019 (31-05-2019) 08 June 2018 (08-06-2018) 07 July 2020 (07-07-2020) 18 April 2018 (18-04-2018) 14 November 2018 (14-11-2018) 08 December 2016 (08-12-2016) 31 May 2019 (31-05-2019)
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(74) 专利代理机构 中国专利代理(香港)有限公司 72001

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W02021/026648 EN 2021.02.18

(71) 申请人 伊库森创新解决方案公司

地址 加拿大不列颠哥伦比亚省

(72) 发明人 S·米雷斯马伊

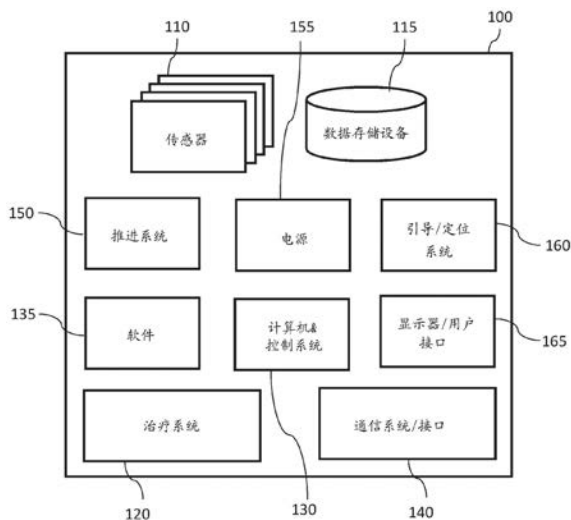
权利要求书3页 说明书14页 附图8页

(54) 发明名称

用于作物监测和治疗的移动平台

(57) 摘要

一种移动作物监测和治疗系统(100, 300, 710)包括具有推进系统(150)的载具(305)和安装在载具上的多个传感器(110, 340, 342, 345)。每个传感器被配置为当传感器靠近作物中的植物定位时捕获与至少一个植物相关参数有关的数据。该系统还包括存储系统(210, 220, 230, 350a-350c),其被配置为在载具上容纳包括至少一种化学农药和至少一种生物控制剂的多种治疗剂。该系统进一步包括施加系统(120, 260, 265, 360, 365),其被配置为向植物施加一种或多种治疗剂。此外,该系统包括控制器(130, 250, 370, 375),其被配置为控制载具的移动以及传感器和施加系统的操作。控制器被配置为使得施加系统响应于来自一个或多个传感器的一个或多个信号而向植物施加一种或多种治疗剂。



1. 一种移动作物监测和治疗系统,包括:
 - 具有推进系统的载具;
 - 安装在载具上的多个传感器,每个传感器被配置为当传感器靠近作物中的植物定位时捕获与至少一个植物相关参数有关的数据;
 - 存储系统,其被配置为在载具上容纳包括至少一种化学农药和至少一种生物控制剂的多种治疗剂;
 - 施加系统,其被配置为向植物施加一种或多种治疗剂;以及
 - 控制器,其被配置为控制载具的移动以及传感器和施加系统的操作,所述控制器被配置为使得施加系统响应于来自一个或多个传感器的一个或多个信号而向植物施加一种或多种治疗剂。
2. 根据权利要求1所述的移动作物监测和治疗系统,其中:
 - 所述移动作物监测和治疗系统进一步包括机载计算机处理器;并且
 - 控制器被配置为使得施加系统响应于来自所述一个或多个传感器的所述一个或多个信号,以机载计算机处理器确定的剂量和浓度向植物施加所述一种或多种治疗剂。
3. 根据权利要求1所述的移动作物监测和治疗系统,其中施加系统包括至少一个机器人臂和至少一个施加器。
4. 根据权利要求3所述的移动作物监测和治疗系统,其中存储系统包括:
 - 至少一个化学农药容器,其被配置为容纳所述至少一种化学农药;
 - 至少一个生物控制剂容器,其被配置为容纳所述至少一种生物控制剂;以及
 - 至少一个载体容器,其被配置为容纳至少一种溶剂或载体。
5. 根据权利要求4所述的移动作物监测和治疗系统,其中控制器被配置为使得所述移动作物监测和治疗系统:
 - 从所述至少一个化学农药容器中抽取所述至少一种化学农药;
 - 从所述至少一个载体容器中抽取所述至少一种溶剂或载体;以及
 - 在所述至少一个施加器的上游将所述至少一种化学农药和所述至少一种溶剂或载体组合。
6. 根据权利要求4所述的移动作物监测和治疗系统,其中:
 - 所述至少一个化学农药容器包括多隔室容器和泵;
 - 多隔室容器的每个隔室被配置为容纳不同的农药或农药组分材料;以及
 - 控制器被配置为使得泵选择性地从多隔室容器中抽取多种农药或农药组分材料,并在混合区域中混合多种农药或农药组分材料。
7. 根据权利要求6所述的移动作物监测和治疗系统,其中混合区域在所述至少一个施加器的上游。
8. 根据权利要求6所述的移动作物监测和治疗系统,其中混合区域在所述至少一个施加器的下游。
9. 根据权利要求4所述的移动作物监测和治疗系统,其中所述至少一个生物控制剂容器包括充气器或搅拌器。
10. 根据权利要求3所述的移动作物监测和治疗系统,进一步包括:
 - 位于所述至少一个机器人臂上的至少一个紫外线灯。

11. 根据权利要求1所述的移动作物监测和治疗系统,其中所述移动作物监测和治疗系统是基于地面的系统。

12. 根据权利要求1所述的移动作物监测和治疗系统,其中所述移动作物监测和治疗系统是空运系统。

13. 根据权利要求1所述的移动作物监测和治疗系统,其中所述移动作物监测和治疗系统形成机器人侦察的部分。

14. 根据权利要求1所述的移动作物监测和治疗系统,其中所述移动作物监测和治疗系统形成被配置为由操作员驱动的推车的部分。

15. 一种用于治疗作物中的植物的方法,所述方法包括:
通过使用配备有多个传感器的自动化载具收集传感器数据来评估作物中的植物的健康;

处理传感器数据以确定要施加到作物中的植物的治疗;

从自动化载具上携带的存储系统分发所述治疗,存储系统容纳至少一种化学农药和至少一种生物控制剂;以及

经由自动化载具上携带的机器人臂和施加器将所述治疗输送给作物中的植物;

其中施加到作物中植物的治疗的浓度和剂量可由自动化载具上的控制器控制和调整。

16. 根据权利要求15所述的方法,其中传感器数据在自动化载具上被处理,以确定要施加到作物中的植物的治疗。

17. 根据权利要求15所述的方法,其中从存储系统分发所述治疗包括:

将从存储系统中抽取的多种化学农药或农药组分材料与至少一种载体混合,以提供所期望的配制。

18. 根据权利要求15所述的方法,其中从存储系统分发所述治疗包括:

将从存储系统中抽取的多种化学农药或农药组分材料与至少一种载体和与至少一种助剂混合,以提供所期望的配制。

19. 根据权利要求15所述的方法,其中:

所述至少一种生物控制剂被容纳在存储系统中的容器中;并且

所述方法进一步包括对所述至少一种生物控制剂进行搅拌或充气,使得所述至少一种生物控制剂更均匀地分散在容器内。

20. 一种移动作物监测和治疗系统,包括:

具有推进系统的载具;

安装在载具上的多个传感器,每个传感器被配置为当传感器靠近作物中的植物定位时捕获与至少一个植物相关参数有关的数据;

存储系统,其被配置为在载具上容纳化学农药和生物控制剂,所述存储系统包括多个容器,至少一个容器包括多个隔室,容器的隔室共同地被配置为存储多种材料,包括化学农药或农药组分材料、生物控制剂、一种或多种溶剂以及一种或多种助剂;

一个或多个施加器,其被配置为向植物施加一种或多种治疗;

一个或多个机器人臂,其被配置为定位所述一个或多个施加器中的至少一个用于向植物施加一种或多种治疗;以及

控制器,其被配置为控制载具的移动和所述移动作物监测和治疗系统的操作,控制器

被配置为使得所述一个或多个施加器响应于来自一个或多个传感器的一个或多个信号而向植物施加所述一种或多种治疗,其中不同的治疗与来自容器的不同材料或材料组合相关联。

用于作物监测和治疗的移动平台

[0001] 相关申请和优先权要求的交叉引用

本申请在35 U.S.C. § 119(e)下要求于2019年8月12日提交的美国临时专利申请No. 62/885,448和于2020年8月11日提交的美国专利申请No. 16/990,212的优先权,特此将上述专利申请通过引用以其整体并入。

技术领域

[0002] 本公开涉及用于作物监测和治疗的移动平台以及用于操作所述移动平台的方法。本公开的一些实施例涉及用于同时靶向施用生物和化学试剂两者的移动平台。

背景技术

[0003] 当食物和其他作物大规模种植时——无论是在保护地栽培(诸如温室中)还是在室外,种植者都面临着若干挑战。例如,对于种植者而言可能难以知道作物是否、在何处以及何时有问题(诸如与害虫、疾病、水、其他非生物胁迫或营养缺乏有关的问题)以及问题的程度,直到它对于经常被雇佣来视觉检查作物的人类侦察者而言容易可见为止。到那个阶段,问题可能经常需要昂贵且广泛的干预。在一些情况下,尽管作物很少是统一的且问题趋于是局部化的,但却跨整个作物预防性地采用一些作物管理做法和治疗,而不是让人类侦察者标识有问题的单个植物或作物区域并且然后治疗它们。

[0004] 最近,已经开发了各种基于传感器的系统用于作物监测。例如,一些系统使用悬挂在作物上方或位于作物中植物之间的传感器静态网格。这种传感网格可以用于在粗粒度范围内监测环境条件或来自植物的一般反应。一些传感设备夹住植物或以其他方式接触植物。一些系统依赖于使用运动检测或视觉模式识别对因果因素(诸如害虫或疾病)的视觉检测。一些传感设备和系统是针对特定的指标。一些传感系统可以收集非常一般的信息(诸如温度和湿度),但不能准确地指出单个植物层面的问题,也不能实时传达信息以促成及时的动作或反应。用于作物健康监测、评估和诊断的移动系统也是已知的,其包括移动传感平台或装备有传感器阵列的载具,并且存在朝着这种系统自动化越来越强的趋势。

[0005] 农药被广泛用于作物栽培中并且可以是极其有效的。然而,关于农药对环境和对其他生物体、包括对人类和动物健康的影响存在越来越多的关注。使用农药控制害虫的另一个问题是,在一些情况下,随着时间的推移,害虫可能对农药产生抗性。

[0006] 使用生物控制剂用于害虫和疾病控制涉及使用另一种活的生物体或天然产品而不是化学品来减少或消除害虫或疾病。传统的生物控制一般涉及将害虫的天敌、寄生虫或病原体引入一个区域,以保护或治疗作物。生物控制剂的一些优点是它们不会引起环境污染,并且害虫不会对生物控制剂变得有抗性。然而,在大多数情况下,活的生物控制剂不能与化学农药同时使用来治疗同一植物或作物,这是因为农药对活的生物控制剂可能是致命的,或者至少对它们有不利影响。一些化学农药也会对生物控制剂有残留效应,并且因此,在施加农药之后,在可以引入生物控制剂之前一般存在等待时段。

[0007] 由于成本和其他因素,一般而言合期望的是通过仅在需要农药和生物控制剂的地

方和时候施加它们来减少使用的农药和生物控制剂的量,而不是治疗整个作物或者即使在没有问题的情况下也理所当然地治疗作物。早期且快速标识作物中的问题、继之以集中于需要的地方进行及时且精确的干预可以允许种植者高效利用化学农药和生物控制剂,并且实现其更高的作物产量。

发明内容

[0008] 本公开涉及用于作物监测和治疗的移动平台以及用于操作所述移动平台的方法。

[0009] 在第一实施例中,一种移动作物监测和治疗系统包括具有推进系统的载具和安装在载具上的多个传感器。每个传感器被配置为当传感器靠近作物中的植物定位时捕获与至少一个植物相关参数有关的数据。所述移动作物监测和治疗系统还包括存储系统,其被配置为在载具上容纳包括至少一种化学农药和至少一种生物控制剂的多种治疗剂。所述移动作物监测和治疗系统进一步包括施加系统,所述施加系统被配置为向植物施加一种或多种治疗剂。此外,所述移动作物监测和治疗系统包括控制器,所述控制器被配置为控制载具的移动以及传感器和施加系统的操作。控制器被配置为使得施加系统响应于来自一个或多个传感器的一个或多个信号而向植物施加一种或多种治疗剂。

[0010] 在一些实施例中,所述移动作物监测和治疗系统进一步包括机载计算机处理器,并且控制器被配置为使得施加系统响应于来自所述一个或多个传感器的所述一个或多个信号,以机载计算机处理器确定的剂量和浓度向植物施加所述一种或多种治疗剂。

[0011] 在一些实施例中,所述施加系统包括至少一个机器人臂和至少一个施加器。

[0012] 在一些实施例中,存储系统包括被配置为容纳所述至少一种化学农药的至少一个化学农药容器、被配置为容纳所述至少一种生物控制剂的至少一个生物控制剂容器、以及被配置为容纳至少一种溶剂或载体的至少一个载体容器。

[0013] 在一些实施例中,控制器被配置为使得移动作物监测和治疗系统从所述至少一个化学农药容器中抽取所述至少一种化学农药,从所述至少一个载体容器中抽取所述至少一种溶剂或载体,并且在所述至少一个施加器的上游将所述至少一种化学农药和所述至少一种溶剂或载体组合。

[0014] 在一些实施例中,所述至少一个化学农药容器包括多隔室容器和泵,多隔室容器的每个隔室被配置为容纳不同的农药或农药组分材料,并且控制器被配置为使得泵选择性地从多隔室容器中抽取多种农药或农药组分材料,并且在混合区域中混合多种农药或农药组分材料。

[0015] 在一些实施例中,混合区域在所述至少一个施加器的上游。

[0016] 在一些实施例中,混合区域在所述至少一个施加器的下游。

[0017] 在一些实施例中,所述至少一个生物控制剂容器包括充气器或搅拌器。

[0018] 在一些实施例中,所述移动作物监测和治疗系统进一步包括位于所述至少一个机器人臂上的至少一个紫外线灯。

[0019] 在一些实施例中,所述移动作物监测和治疗系统是基于地面的系统。

[0020] 在一些实施例中,所述移动作物监测和治疗系统是空运系统。

[0021] 在一些实施例中,所述移动作物监测和治疗系统形成机器人侦察的部分。

[0022] 在一些实施例中,所述移动作物监测和治疗系统形成被配置为由操作员驱动的推

车的部分。

[0023] 在第二实施例中,一种用于治疗作物中的植物的方法包括通过使用配备有多个传感器的自动化载具收集传感器数据来评估作物中的植物的健康。所述方法还包括处理传感器数据以确定要施加到作物中的植物的治疗。所述方法进一步包括从自动化载具上携带的存储系统分发所述治疗,其中存储系统容纳至少一种化学农药和至少一种生物控制剂。此外,所述方法包括经由自动化载具上携带的机器人臂和施加器将所述治疗输送给作物中的植物。施加到作物中植物的治疗的浓度和剂量可由自动化载具上的控制器控制和调整。

[0024] 在一些实施例中,传感器数据在自动化载具上被处理,以确定要施加到作物中的植物的治疗。

[0025] 在一些实施例中,从存储系统分发所述治疗包括将从存储系统中抽取的多种化学农药或农药组分材料与至少一种载体混合,以提供所期望的配制。

[0026] 在一些实施例中,从存储系统分发所述治疗包括将从存储系统中抽取的多种化学农药或农药组分材料与至少一种载体和与至少一种助剂混合,以提供所期望的配制。

[0027] 在一些实施例中,所述至少一种生物控制剂被容纳在存储系统中的容器中,并且所述方法进一步包括对所述至少一种生物控制剂进行搅拌或充气,使得所述至少一种生物控制剂更均匀地分散在容器内。

[0028] 在第三实施例中,所述移动作物监测和治疗系统包括具有推进系统的载具和安装在载具上的多个传感器。每个传感器被配置为当传感器靠近作物中的植物定位时捕获与至少一个植物相关参数有关的数据。移动作物监测和治疗系统还包括存储系统,其被配置为在载具上容纳化学农药和生物控制剂。存储系统包括多个容器,并且至少一个容器包括多个隔室。容器的隔室共同地被配置为存储多种材料,包括化学农药或农药组分材料、生物控制剂、一种或多种溶剂以及一种或多种助剂。所述移动作物监测和治疗系统进一步包括被配置为向植物施加一种或多种治疗的一个或多个施加器,以及被配置为定位所述一个或多个施加器中的至少一个用于向植物施加一种或多种治疗的一个或多个机器人臂。此外,所述移动作物监测和治疗系统包括控制器,所述控制器被配置为控制载具的移动和移动作物监测和治疗系统的操作。控制器被配置为使得所述一个或多个施加器响应于来自一个或多个传感器的一个或多个信号而向植物施加所述一种或多种治疗。不同的治疗与来自容器的不同材料或材料组合相关联。

[0029] 根据以下各图、描述和权利要求,其他技术特征对于本领域技术人员来说可能是容易清楚的。

附图说明

[0030] 为了更完整地理解本公开,现在结合附图参考以下描述,附图中:

图1图示了根据本公开的示例移动作物监测和治疗系统;

图2图示了根据本公开的可以并入到移动作物监测和治疗系统中的示例作物治疗系统;

图3A和3B图示了根据本公开的移动作物监测和治疗系统的具体示例实现;

图4A至6B图示了根据本公开的示例存储容器/分发器,其可以用在移动作物监测和治疗系统上并且可以从其分发至少一种治疗;以及

图7图示了根据本公开的包括移动作物监测和治疗系统的示例作物管理系统。

具体实施方式

[0031] 下面描述的图1至7以及在本专利文件中用于描述本发明原理的各种实施例仅仅作为说明,并且不应当以任何方式解释为限制本发明的范围。本领域技术人员将理解,本发明的原理可以在任何类型的适当布置的设备或系统中实现。

[0032] 图1图示了根据本公开的示例移动作物监测和治疗系统100。如图1中所示,移动系统100包括多个传感器110和至少一个数据存储设备115,该数据存储设备115被配置为存储由传感器110捕获的数据。各种类型的传感器110可以用在移动系统100中,其示例在下面描述。每个传感器110包括诸如当传感器110靠近一种或多种作物中的一个或多个植物中的每一个定位时,被配置为捕获与至少一个植物相关参数有关的数据的任何合适的结构。各种类型的数据存储设备115也可以用在移动系统100中,诸如一个或多个易失性或非易失性存储器。可以在移动系统100中使用的数据存储设备115的示例类型包括随机存取存储器、只读存储器、硬盘驱动器、闪速存储器或光盘。

[0033] 移动系统100还包括治疗系统120,其被配置为将一种或多种治疗剂(诸如至少一种化学农药和/或至少一种生物控制剂)施加到一种或多种作物中的一个或多个植物中的每一个。治疗系统120包括被配置为向植物输送一种或多种治疗剂的任何合适的结构。下面提供了治疗系统120的示例实现的细节。

[0034] 移动系统100进一步包括具有相关联软件135的计算机和控制系统130。计算机和控制系统130被配置为控制移动系统100的整体操作,诸如通过控制移动系统100的移动以及传感器110和治疗系统120的操作。计算机和控制系统130可以执行软件135,以便执行其功能。计算机和控制系统130包括至少一个处理器,诸如中央处理单元(CPU)、图形处理单元(GPU)、数据处理单元(DPU)和张量处理单元(TPU)中的至少一个。计算机和控制系统130的机载DPU或(一个或多个)其他处理器可以用于例如处理传感器数据,并确定要施加到一种或多种作物中的一个或多个植物的一种或多种合适的治疗。注意到,虽然软件135在这里被示为单独的组件,但是软件135可以内部地存储在计算机和控制系统130内,诸如在计算机和控制系统130的非易失性存储器中。

[0035] 移动系统100可以可选地包括通信系统/接口140,其可以允许移动系统100向一个或多个外部系统或设备传送信息和数据和/或从一个或多个外部系统或设备接收信息或命令。在一些实施例中,通信系统/接口140可以包括外部串行连接,其被提供来允许用户将个人计算机(PC)或其他设备连接到移动系统100,诸如以便修改移动系统100上的软件135。此外,在一些实施例中,通信系统/接口140可以包括至少一个无线无线电或其他无线发射器、接收器或收发器,其允许去往和/或来自移动系统100的无线通信。

[0036] 移动系统100还包括推进系统150,其被配置为(诸如在地面上或空中)使移动系统100移动。推进系统150包括被配置为推动或以其他方式使移动系统100移动的任何合适的结构,诸如电动机、轮、螺旋桨等。移动系统100进一步包括电源155,其被配置为向移动系统100的其他组件提供操作电力。电源155包括被配置为向移动系统100提供操作电力的任何合适的结构。在一些实施例中,电源155包括至少一个电池或其他能量存储设备以及相关再充电装备。在特定实施例中,电源155包括被配置为在多个能量源之间提供切换的电力

管理系统。电力管理系统还可以并入安全和保护设备。

[0037] 移动系统100可以进一步包括引导和定位系统160,其可以被配置为标识移动系统100的位置并支持移动系统100的导航。在一些实施例中,引导和定位系统160产生可以与传感器测量相关联的位置标签,其中位置标签标识传感器测量被捕获所处的位置。位置标签可以存储在数据存储设备115中,并且可选地经由通信系统/接口140与传感器数据一起传输。引导和定位系统160包括被配置为标识移动系统100的位置的任何合适的结构,诸如全球定位系统(GPS)接收器或其他基于卫星的接收器、超宽带(UWB)接收器、射频标识(RFID)设备或其他设备。注意到,引导和定位系统160可以通过接收传入信号以标识其位置或者通过传输允许其他组件标识其位置的传出信号来进行操作。

[0038] 此外,移动系统100可以包括显示器和/或用户接口165,其可以用于向用户提供信息或从用户接收信息。例如,显示器和/或用户接口165可以用于标识移动系统100的当前设置、由传感器110捕获的传感器测量或者要由治疗系统120施加的治疗。显示器和/或用户接口165还可以用于接收对植物状况的用户观察、对建议治疗的用户确认或其他信息。显示器和/或用户接口165包括被配置为向用户提供信息或从用户接收信息的任何合适的结构,诸如液晶显示器(LCD)、发光二极管(LED)显示器或其他显示器设备。取决于实现,显示器和/或用户接口165可以包括物理按钮和/或触摸屏。

[0039] 在移动作物监测和治疗系统100的一些实施例中,一个、一些或所有传感器110的(一个或多个)位置可以是可调整的,使得(一个或多个)传感器110可以被适当地定位。各种因素可能影响一个或多个传感器110如何定位,诸如被检查的植物的大小(如高度和/或体积)以及植物的哪个区域将被感测。在特定实施例中,可以基于来自控制系统的命令自动地(而不是手动地)移动和重新定位至少一些传感器110,所述命令可以响应于指示(一个或多个)传感器110应当定位在何处的输入。

[0040] 注意到,这里的移动作物监测和治疗系统100可以取决于特定需求以多种方式实现。例如,在一些实施例中,诸如当移动系统100使用机器人基于地面的侦察或其他基于地面的设备来实现时,移动系统100被实现为基于地面的平台。在其他实施例中,诸如当移动系统100使用机器人空运侦察或其他基于空中的设备(如无人机)来实现时,移动系统100被实现为空运平台。诸如当移动作物监测和治疗系统100包括与机器人空运侦察或其他基于空中的设备结合操作的机器人基于地面的侦察或其他基于地面的设备时,也可以使用方法的组合。作为特定示例,Ecoation Innovative Solutions Inc提供可以用在温室或其他位置中的各种产品,诸如OKO手动驱动的推车(其包括可以由操作员使用的交互式显示器)和IRIS SCOUTROBOT机器人侦察。移动系统100可以并入到这些产品中的任一个中,并且手动或自主使用。例如,在OKO推车的情况下,操作员可以将推车驱动到特定位置,并使用交互式显示器来分配一种或多种化学农药或生物控制剂。在IRIS机器人侦察的情况下,一种或多种化学农药或生物控制剂可以以自主方式进行分配。一般而言,本公开不限于任何特定的手动、部分自动化或完全自动化的化学农药或生物控制剂分配方式。

[0041] 尽管图1图示了移动作物监测和治疗系统100的一个示例,但是可以对图1进行各种改变。例如,图1中所示的各种组件可以被组合、进一步细分、复制、重新布置或省略,并且可以根据特定需求添加附加组件。

[0042] 图2图示了示例作物治疗系统200,其可以并入到根据本公开的移动作物监测和治

疗系统中。例如，作物治疗系统200可以用于至少部分实现图1中的移动作物监测和治疗系统100的治疗系统120。然而，注意到，作物治疗系统200可以用在任何其他合适的移动系统中。

[0043] 如图2中所示，作物治疗系统200包括至少一个化学农药存储容器/分发器210，其被配置为接收、保持和分发至少一种化学农药。例如，每个化学农药存储容器/分发器210可以包括一个或多个容器，其接收和保持一种或多种农药或农药组分材料。每个化学农药存储容器/分发器210还可以包括用于从一个或多个容器中抽取（一种或多种）化学农药或（一种或多种）组分材料以供使用的一个或多个设备。在该示例中，化学农药存储容器/分发器210包括混合器215，该混合器215可以被配置为根据需要或期望混合农药配制。例如，混合器215可以被配置为接收存储的化学农药或组分材料的不同组合，并且混合存储的化学农药或组分材料的组合。每个化学农药存储容器/分发器210包括被配置为保持和分发至少一种农药或组分材料的任何合适的结构。每个混合器215包括被配置为混合材料的任何合适的结构。

[0044] 作物治疗系统200还包括至少一个溶剂和助剂存储容器/分发器220，其被配置为接收、保持和提供一种或多种溶剂和/或一种或多种助剂。溶剂指代至少一种化学农药可以溶解或混合到其中的液体或其他材料，并且助剂指代有助于提高一种或多种农药效力的液体或其他材料。（一种或多种）溶剂和/或（一种或多种）助剂可以从溶剂和助剂存储容器/分发器220中抽取，并与来自化学农药存储容器/分发器210的一种或多种农药组合。每个溶剂和助剂存储容器/分发器220包括被配置为保持和分发至少一种溶剂和/或至少一种助剂的任何合适的结构。

[0045] 作物治疗系统200进一步包括至少一个生物控制剂存储容器/分发器230，其被配置为接收、保持和分发至少一种生物控制剂。生物控制剂指代一种或多种活的生物体或天然产品，其可以用于减少或消除植物的害虫、疾病或其他问题。例如，每个生物控制剂存储容器/分发器230可以包括接收和保持一种或多种生物控制剂的一个或多个容器。每个生物控制剂存储容器/分发器230还可以包括用于从一个或多个容器中分发（一种或多种）生物控制剂以供使用的一个或多个设备。在该示例中，生物控制剂存储容器/分发器230包括搅拌器和/或充气器240。搅拌器可以用于在容器/分发器230内更均匀地分发一种或多种生物控制剂。充气器可以用于向容器/分发器230内的一种或多种生物控制剂提供空气。虽然这里未示出，但是生物控制剂存储容器/分发器230可以包括混合器，该混合器可以被配置为根据需要或期望混合生物控制剂的不同组合。例如，混合器可以被配置为接收存储的生物控制剂的不同组合，并混合存储的生物控制剂的组合。每个生物控制剂存储容器/分发器230包括被配置为保持和分发至少一种生物控制剂的任何合适的结构。

[0046] 注意到，容器/分发器210、220和230中的一个、一些或所有可以被分成多个隔室，用于存储不同的材料或试剂。此外，容器/分发器210、220和230中的一个、一些或所有可以包括一个或多个泵（未示出），其中每个泵被配置为从一个或多个容器分发一种或多种材料。下面讨论了容器/分发器210、220、230的不同示例实现，尽管这些实现仅用于说明。

[0047] 作物治疗系统200还包括控制器250，控制器250可以用于确定要对至少一种作物中的各个植物中的每个施用的一种或多种治疗，并控制这种治疗的分发、配制、稀释、剂量和施加。控制器250包括被配置为执行控制操作的至少一个处理器或其他处理设备。在一些

实施例中,控制器250可以形成用于更广泛系统的计算机和控制系统的部分,作物治疗系统200是该更广泛系统的一部分,诸如当控制器250形成图1的系统100中的计算机和控制系统130的一部分时。在其他实施例中,控制器250可以表示单独的基于计算机的控制器或其他独立控制器。如果控制器250与另一设备(诸如计算机和控制系统130中的机载计算机处理器)结合使用,则控制器250的所描述功能性可以是分布式的。作为特定示例,机载计算机处理器可以响应于来自一个或多个传感器110的一个或多个信号来确定要施加到植物的治疗的剂量和浓度,并且控制器250可以基于所标识的剂量和浓度来启动对植物的治疗。

[0048] 此外,作物治疗系统200包括至少一个机器人臂260和可互换施加器265,其被配置为在控制器250的控制下对至少一种作物中的各个植物施加一种或多种治疗。例如,至少一个机器人臂260可以用于选择性地将一个或多个施加器265定位在每个被治疗的植物处或附近的一个或多个期望位置处,并且一个或多个施加器265可以用于为植物分发一种或多种治疗。每个机器人臂260包括被配置为移动以便选择性地定位一个或多个施加器265的任何合适的结构。每个施加器265包括被配置为施加一种或多种治疗的任何合适的结构。例如,施加器265可以包括不同的喷嘴、软管、喷洒器、滚筒、喷雾器、烟雾器、除尘器、雾化器和/或任何其他合适的施加器。虽然这里未示出,但是施加器265和/或机器人臂260可以包括一个或多个阀或其他流动控制设备,其被配置为启动、停止和调整(一种或多种)材料、诸如一种或多种化学农药和/或一种或多种生物控制剂的流动。此外,虽然这里未示出,但施加器265和/或机器人臂260可以包括一个或多个夹具或其他结构,其被设计成在检查或治疗期间抓取或以其他方式物理操控植物。所使用的(一个或多个)施加器265和/或夹具的类型可以基于各种因素而变化,诸如待治疗和检查的(一个或多个)植物的(一种或多种)类型。此外,机器人臂260可以用于携带其他组件,这些组件不用于分发化学农药和生物控制剂,但可以用于以其他方式治疗植物问题。例如,机器人臂260可以携带(诸如产生UV-c光的)至少一个紫外线(UV)灯270,这是因为紫外线灯可以用于治疗如白粉病之类的植物疾病。

[0049] 注意到,作物治疗系统200或类似的系统可以并入到用于作物健康监测的移动传感平台中。其中可以使用作物治疗系统200的示例平台可以包括上面参考图1描述的平台,以及在美国专利No. 10,241,097和美国专利申请公开No. 2017/0032258中描述的平台(特此将这两个专利通过引用以其整体并入)。其中可以使用作物治疗系统200的其他示例平台可以包括来自Ecoation Innovative Solutions Inc的OKO推车和IRIS SCOUTROBOT机器人侦察。

[0050] 尽管图2图示了可以并入到移动作物监测和治疗系统中的作物治疗系统200的一个示例,但是可以对图2进行各种改变。例如,图2中所示的各种组件可以被组合、进一步细分、复制、重新布置或省略,并且可以根据特定需求添加附加组件。此外,某些化学农药和生物控制剂可以以其他方式输送,并且不需要存储在容器中并通过施加器喷洒。例如,化学农药或生物控制剂可以放置在托盘上,并且机器人臂260的夹具或其他部分可以用于抓取和输送化学农药或生物控制剂。

[0051] 图3A和3B图示了根据本公开的移动作物监测和治疗系统300的具体示例实现。这里的移动作物监测和治疗系统300可以包括上面所述的图1和2中所示的各种组件。如图3A中所示,移动系统300包括具有四个轮308(其中两个可见)的推车305和安装到平台312的框

架310。平台312又安装到剪式升降机315。剪式升降机315允许平台312、框架310和安装到平台312或框架310的组件被升高和降低。例如,这可以取决于被检查或治疗的作物中的植物的高度来完成。

[0052] 在该示例中包括电池320的电源被携带在推车305上。电源可以向各种机载系统提供电力,并提供用于推进移动系统300的电力。在一些实施例中,移动系统300可以表示典型管轨小车的适配,其通常在园艺和温室应用中使用,并且被设计成通过小路径操控并且可调整到期望的高度。管轨安装轮322和管轨检测传感器325可以用于在有管轨的情况下引导移动系统100穿过作物。

[0053] 在一些情况下,移动系统300可以被配置为以自主方式操作(没有机载操作员或驾驶员)。在其他情况下,人类(诸如农民或种植者)可以可选地乘坐在平台312上的移动系统300上,诸如同时充当观察者或者手动驱动或以其他方式操作移动系统300的一个或多个方面。诸如当移动系统300不在自动化控制下时,转向设备330可以用于手动转向移动系统300,并且移动控制器332可以用于手动控制移动系统300的推进。

[0054] 移动系统300还包括机载作物监测系统,该机载作物监测系统包括安装到框架310的各种传感器和传感器模块。在一些实施例中,在移动系统300的操作期间,一个、一些或所有传感器/传感器模块的(一个或多个)位置可以是可调整的,并且控制系统可以控制(一个或多个)传感器/(一个或多个)传感器模块的(一个或多个)位置。在移动系统300的该示例中,移动系统300包括作物健康监测传感器模块340和成像传感器342和345。在一些实施例中,作物健康监测传感器模块340表示多传感器模块,其可以包括包含在外壳中的各种类型的传感器。成像传感器342和345可以用于捕获植物不同部分的图像。例如,成像传感器342可以用于对作物头部成像,并且成像传感器345(其高度可以通过在安装杆348上自动或手动上下移动它来调整)可以用于水果成像。

[0055] 移动系统300可以包括任何其他或附加的传感器。移动系统300上的其他传感器可以包括例如生理传感器、表面分析传感器、化学传感器、小气候传感器和/或遮篷筛选传感器。在一些实施例中,移动系统300包括:至少一个生理传感器,其包括至少一个可配置的光学探针和至少一个可调检测器;至少一个表面分析传感器,其包括至少一个全光谱光源和至少一个光谱检测器;以及至少一个化学分析传感器(其可以包括至少一个光电离检测器、至少一个表面声波传感器和/或至少一个石英晶体微量天平传感器)。在特定实施例中,移动系统300包括多光谱或超光谱成像设备、叶片温度传感器、蒸散传感器、表面电荷传感器、太赫兹传感器、孢子检测传感器和/或可调麦克风。

[0056] 移动系统300进一步包括机载作物治疗系统,其包括多个材料存储容器和相关联的分发器,化学农药或农药组分材料(可能具有适当的溶剂和/或助剂)和生物控制剂从所述多个材料存储容器和相关联的分发器中抽取并施用到作物中的植物。在该示例实施例中,移动系统300包括三个存储容器/分发器350a、350b和350c,其中每个可以具有一个或多个隔室,并且可以包括一个或多个混合器、充气器、搅拌器和/或智能泵。下面参考图4A至6B更详细地描述存储容器和分发器的示例实现。然而,可以使用其他容器和分发器以及其他数量的容器和分发器。

[0057] 材料存储容器/分发器350a、350b和350c可以选择性地流体连接,以将化学农药、合适的溶剂和/或助剂以及生物控制剂输送到至少一个机器人臂360,经由该机器人臂360,

它们以靶向、局部化的方式选择性地施加到作物中的植物。每个机器人臂360可以具有多个自由度,诸如当机器人臂360可以旋转、枢转、延伸等时,使得治疗可以选择性地施加到每个单个植物上的期望位置。机器人臂360可以包括可互换的施加器(诸如喷嘴或其他施加器265)或夹具365,其可以自动或按需改变并且可以是可调整的。替代施加器或夹具(未示出)可以根据需要被携带在移动系统300上并连接到机器人臂360。一些施加器365可以在末端处具有UV灯,并且机器人臂360可以将UV灯附接体指向植物或作物的特定区域以治疗疾病。

[0058] 在一些实施例中,移动作物监测和治疗系统300(或上述移动系统100)可以从远程位置(诸如经由无线通信)被控制和操作,和/或可以配备有一个或多个机载计算机和控制器,用于控制移动系统的推进以及基于传感器的机载作物监测系统和机载作物治疗系统的操作。在该示例中,移动系统300包括两个机载的基于计算机的控制系统370和375,并且移动系统300可以使用这些机载的基于计算机的控制系统370和375自主地操作和控制。例如,这些系统370和375可以用于诸如基于各种传感器的输出而分析来自机载作物监测系统的结果,并且使用机载作物治疗系统实时确定将对作物施加什么治疗。系统300还包括交互式显示器380,其可以向移动系统300上的人类提供信息。可以显示任何合适的信息,诸如关于机载作物监测系统的发现和由机载作物治疗系统正在施加的治疗的信息。

[0059] 图3B图示了图3A的移动作物监测和治疗系统300的一部分390,并且以特写视图特别示出了三个材料存储容器/分发器350a、350b和350c。这三个材料存储容器/分发器350a、350b和350c可以彼此相同或彼此不同。这可以取决于许多因素,诸如要分发的材料。在一些实施例中,材料存储容器/分发器350a、350b和350c可以由一种或多种材料形成,所述材料是惰性的并且将不会被要存储在其中的材料污染或降解。

[0060] 尽管图3A和3B图示了移动作物监测和治疗系统300的具体示例实现,但是可以对图3A和3B进行各种改变。例如,图3A和3B中所示的各种组件可以被组合、进一步细分、复制、重新布置或省略,并且可以根据特定需求添加附加组件。此外,移动系统300的推车和其他物理组件的形式可以根据需要或期望容易地变化。

[0061] 图4A至6B图示了根据本公开的示例存储容器/分发器,其可以用在移动作物监测和治疗系统上并且可以从其分发至少一种治疗。特别地,图4A和4B图示了第一示例存储容器/分发器350a,图5A和5B图示了第二示例存储容器/分发器350b,并且图6A和6B图示了第三示例存储容器/分发器350c。注意到,不同结构与不同存储容器/分发器350a、350b和350c的这些关联仅用于说明,并且移动系统300的每个存储容器/分发器350a、350b和350c可以具有任何合适的结构。

[0062] 如图4A中所示,存储容器/分发器350a包括垂直分成八个隔室的圆柱形存储区域410。如图4B中所示,存储区域410的截面视图示出了八个隔室420a-420h,每个隔室可以包含不同的化学农药或其活性成分。注意到,虽然这里的隔室420a-420h示为大小大致相等,但情况无需如此。每个隔室420a-420h经由单独的软管425或其他连接器连接到智能泵430。机载的基于计算机的控制系统或其他系统可以使得适当的农药或者农药或农药组分的混合物通过智能泵430从隔室420a-420h中的一个、一些或所有中被抽取,并且如果需要则在混合区域440中被混合。所选择的农药或者农药或农药组分的混合物可以基于需要治疗的特定问题,所述特定问题可以通过机载的基于传感器的作物监测系统来标识。农药或者农药或农药组分的混合物从混合区域440经由供应管线450供应到施加器,诸如机器人臂260

上的施加器265或机器人臂360上的施加器365。

[0063] 如图5A中所示,存储容器/分发器350b包括垂直分成两个隔室的圆柱形存储区域510。如图5B中所示,存储区域510的截面视图示出了两个隔室520a-520b。注意到,虽然这里的隔室520-520b示为大小不相等,但情况无需如此。较大的隔室520a可以在另一个容器中包含用于一种或多种化学农药的至少一种载体(诸如水或另一种合适的溶剂或载体)。较小的隔室520b可以包含至少一种助剂。助剂可以包括例如润湿剂、粘附剂或粘合剂、渗透剂、相容剂和/或离子或非离子表面活性剂。在一些实施例中,材料被赋予电荷以增强它们对植物叶子的粘合。每个隔室520a和520b经由单独的软管525或其他连接器连接到智能泵530。机载的基于计算机的控制系统或其他系统可以使得适当量的载体和助剂分别由智能泵530从隔室520a和520b中抽取,在混合区域540中混合,并经由供应管线550供应到施加器,诸如机器人臂260上的施加器265或机器人臂360上的施加器365。在一些情况下,可以从容器/分发器350a中抽取适当剂量的农药或期望的农药混合物,并用载体/助剂混合物稀释至期望浓度,并且可以经由施加器将期望剂量输送至植物或作物上的至少一个期望位置。(一种或多种)农药和载体/助剂可以在施加器处、施加器上游或施加器下游组合。

[0064] 如图6A中所示,存储容器/分发器350c包括垂直分成四个隔室的圆柱形存储区域610。如图6B中所示,存储区域610的截面视图示出了四个隔室620a-620d,每个隔室可以包含不同的生物控制剂。注意到,虽然这里的隔室620a-620d示为大小大致相等,但情况无需如此。生物控制剂可以是在液体或固体配制中。在一些情况下,生物控制剂与固体颗粒载体一起被存储和输送,所述固体颗粒载体诸如纤维材料、粉末或其他颗粒(如得自诸如叶子、外皮、木头或矿物之类天然产品的颗粒)。该载体可以帮助保护脆弱的活生物体,并且在输送到植物期间帮助分散生物体。每个隔室620a-620d经由单独的软管或管625或其他连接器连接到智能泵、鼓风机或风扇630。机载的基于计算机的控制系统或其他系统可以使得智能泵、鼓风机或风扇630从隔室620a-620d中抽取一种或多种适当的生物控制剂,并且如果需要,在混合区域640中进行混合。所选择的生物控制剂或试剂混合物可以基于需要治疗的特定问题,这可以通过机载的基于传感器的作物监测系统来标识。一种或多种生物控制剂从混合区域640经由供应管线650供应到施加器,诸如机器人臂260上的施加器265或机器人臂360上的施加器365。(一种或多种)生物控制剂的剂量可以由基于计算机的控制系统取决于问题的性质和严重性进行控制。

[0065] 一些生物控制剂将具有在隔室620a-620d的特定区域中沉淀或聚集的趋势。充气软管660可以用于不时地或根据需要将空气吹入隔室620a-620d中,以在分发生物控制剂(以及载体材料,如果存在的话)之前使它们在隔室620a-620d内更均匀地分布。在一些实施例中,空气由智能泵、鼓风机或风扇630供应到充气软管660。在分发生物控制剂之前,也可以使用其他合适的设备或技术来使它们在隔室内更均匀地分布,诸如在可以使用螺旋桨或其他搅拌设备的地方。

[0066] 尽管图4A至6B图示了可以在移动作物监测和治疗系统上使用并且可以从其中分发至少一种治疗的存储容器/分发器的示例,但是可以对图4A至6B进行各种改变。例如,圆柱形形状和特定数量隔室的使用仅仅是示例,并且可以根据需要或期望而变化。每个存储容器/分发器可以具有任何合适的大小和形状,并且可以包括任何合适数量的隔室。

[0067] 回到图3A和3B,在一些实施例中,机器人臂360和夹具365可以拾取和施加存储在

移动作物监测和治疗系统300上的其他治疗。例如,其他治疗可以位于托盘上或存储容器中。这可以响应于来自基于计算机的控制系统的命令而发生。

[0068] 此外,图3A中所图示的移动作物监测和治疗系统300的实施例包括三个多隔室材料存储容器/分发器,并且具有单个机器人臂360和可互换的施加器或夹具365。然而,这种系统的其他实施例可以包括不同数量和/或类型和样式的存储容器/分发器、施加器和/或夹具。在一些情况下,至少一种载体和至少一种助剂可以从与(一种或多种)活性剂相同的容器中抽取。此外,这种系统的其他实施例可以包括一个以上的机器人臂和相关联的施加器或抓具,诸如用于同时对不同的植物施加治疗或者用于同时对同一植物施加不同的治疗。如上所述,每个臂式施加器/夹具可以从机载存储系统独立地被供应有农药和/或生物控制剂。这种系统的其他实施例可以包括其上具有多个施加器和/或夹具的机器人臂,或者单个施加器可以具有多个出口或喷嘴。

[0069] 在一些实施例中,用于从机载材料存储系统分发材料的泵是多通道泵,适于以期望的和可变的比率精确地、同时计量或定量多种材料(诸如多种化学农药或组分、载体和助剂)。此外,在一些实施例中,特定治疗配制的组分材料可以在(一个或多个)泵下游和(一个或多个)施加器上游的混合区域或容器中混合,治疗从所述施加器输送到植物。在其他实施例中,期望的量或比率的组分材料被单独供应到单独的施加器(或单个施加器上的单独出口或喷嘴),并且在它们到达植物之前在它们离开施加器出口时它们混合。换句话说,在这些实施例中,用于特定治疗配制的至少一些组分的混合区域可以是施加器出口的下游。该方法可以提供一些优势。例如,如果使用单独且专用的供应管线向不同的施加器出口供应治疗配制的不同材料或组分,则减少来自先前治疗的材料对治疗的污染。在一些情况下,化学农药可能对其他农药或生物控制剂有不利影响,并且优选的是后者材料不与可能剩余在共享供应管线中的微量或残余量的潜在有害农药接触。通过具有单独的供应管线,可以缓解该风险。如果在材料存储系统和(一个或多个)施加器之间使用共享供应管线,则另一种方法是在从移动系统施用不同治疗之间用水或另一种溶剂(从存储系统泵出)冲洗共享供应管线。

[0070] 在一些实现中,移动作物监测和治疗系统300被部署来自主地扫描一行植物,以便当其沿着行在一个方向上移动时标识害虫或疾病的一个或多个位置。然后,当移动系统300沿着植物的行向后移动时,移动系统300可以快速或及时确定要经由机载治疗系统施用的(一种或多种)适当治疗。所施加的治疗和剂量可以对每个植物或单个植物的特定区域是特定的,并且可以随着移动系统300在植物之间移动而变化。这可以对任何数量的行进行重复。移动系统300可以被配置为使得植物、推车、机器人臂和施加器的位置是已知的,从而允许在需要的地方精确地施加适当的治疗。这种方法允许在检测到植物健康问题(诸如虫害或疾病)之后及时执行治疗。问题的早期检测和补救可以大幅提高作物产量。

[0071] 常规地,整个作物通常理所当然地用(一种或多种)农药和/或(一种或多种)生物控制剂治疗,即使没有所标识的疾病或害虫亦如此。然而,诸如由于化学农药和生物控制剂的成本和其他潜在的不利因素、尤其是那些与使用农药相关联的不利因素,一般合期望的是减少用于治疗作物的化学农药和生物控制剂的量。此外,农药常规被施加到作物,并且然后仅在几天的等待时段之后随后施加生物控制剂。在大多数情况下,生物控制剂的输送是手动和预防性完成的。

[0072] 本公开中描述的系统和方法允许在需要化学农药和生物控制剂的精确位置处高度定制和靶向施加适当剂量的化学农药和生物控制剂。这可以显著减少这些材料的用量。此外,这种局部化或靶向施加可以允许生物控制剂与化学农药同时使用(或直接在用化学农药治疗之前或之后使用)来治疗同一植物。例如,生物控制剂可以施加到接近正在用农药治疗的感染或疾病区域的植物区域。此外,这里描述的系统和方法响应于从基于传感器的作物监测系统接收到的信息而按需求配制并基于需要选择适当剂量的能力意味着可以以及时的方式有效且高效地施加治疗。

[0073] 在一些实施例中,存储容器中的隔室配备有传感器,以指示在每个隔室中剩余的(一种或多种)材料的量。移动系统300可以传送来自这些传感器的信息,以警告用户或操作员是否需要补充隔室中的材料。

[0074] 如这里描述的作物治疗系统可以安装在其他半自动化或自主作物健康监测载具、机器人或其他移动设备上。例如,移动平台可以被配置为在植物之间自主移动或者响应于来自控制器的命令而移动,所述控制器在一些实施例中在移动系统上,并且在其他实施例中是外部数据处理单元或其他设备或系统的组件。因此,在这里描述的移动作物监测和治疗系统的一些实施例中,诸如系统的数据收集、处理、以及分析和控制(包括治疗系统的操作)的功能由一个或多个计算机处理器和控制系统在移动系统上执行。在其他实施例中,移动系统完全地或至少在某种程度上被远程控制。在图7中示出了后者的一个示例。

[0075] 图7图示了根据本公开的示例作物管理系统700,其包括移动作物监测和治疗系统。在作物管理系统700中,传感器数据的至少一些处理和分析以及移动系统的控制是远程执行的。如图7中所示,作物管理系统700包括移动作物监测和治疗系统710,其包括多个传感器和一个或多个用于向植物施加治疗的机器人臂。传感器和机器人臂可以安装在例如载具、推车或无人机上。在一些实施例中,移动系统710可以与上述移动系统100或300相同或相似。

[0076] 在作物管理系统700中,移动作物监测和治疗系统710捕获与作物中的植物相关的传感器数据。一些或所有数据可以经由网络730传输到数据处理单元(DPU)720。在一些实施例中,移动系统710表示多个载具或机器人中的一个,并且这些载具或机器人可以彼此以及与DPU 720通信和交换信息。DPU 720分析传感器数据,并且经由一个或多个终端用户设备,诸如智能电话740和/或计算机750,将关于作物的信息发送给个人760,诸如种植者和/或其他方。DPU 720还可以向移动作物监测和治疗系统710发送命令。种植者或其他个人760也可以经由网络730向DPU 720发送信息和/或向移动系统710发送命令。

[0077] 在图7中,箭头用于指示传感器数据和/或其他信息的传输。在一些实施例中,作物管理系统700包括或支持基于web和/或基于云的系统,其中移动系统710、DPU 720和种植者或其他个人760或设备之间的通信主要或完全通过无线通信。

[0078] 尽管图7图示了包括移动作物监测和治疗系统的作物管理系统700的一个示例,但是可以对图7进行各种改变。例如,图7中所示的各种组件可以被组合、进一步细分、复制、重新布置或省略,并且可以根据特定需求添加附加组件。

[0079] 注意到,在一些实施例中,这里描述的移动作物监测和治疗系统被设计成在黑暗中(诸如在夜间)操作。这可能是有益的,因为它可以减少对其他温室或田野操作的干扰。此外,在一些情况下,基于传感器的监测系统在夜间可以以更高的灵敏度操作,这是因为植物

在黑暗时段期间趋向于休眠。在白天期间,工作人员照料作物的正常做法可能暂时给植物压力,诸如由于移动植物头部、移除嫩枝、采摘果实等。

[0080] 还注意到,这里描述的系统和方法的实施例可以主要依赖于基于植物的信号的检测(通过传感器)和解释(通过数据分析)来提供关于作物健康的信息,并确定要施用的适当补救治疗。在一些实施例中,在感测和数据捕获期间,移动感测平台上的传感器靠近植物,但是不接触植物或土壤。这种非接触式监测可以有助于减少害虫和疾病的传播。

[0081] 此外,注意到,这里描述的用于监测和评估作物健康的系统和方法可以减少的人类劳动并且以比人类可以手动完成快得多的速度提供对单个植物健康的快速且灵敏的筛选以及对植物的治疗。这里描述的系统和方法可以部署在室外(诸如田野或果园中)或室内(诸如温室中)。所述系统和方法具有自动化组件,但是是灵活的,并且可以被修改以增强它们执行的作物监测和治疗。

[0082] 此外,注意到,这里描述的技术、设备、系统和方法的实施例可以单独使用,或者可以根据期望以各种组合使用。例如,上述移动系统100、300、710的特征的任何期望组合可以用于移动系统的特定实现中。

[0083] 在一些实施例中,本专利文件中描述的各种功能由计算机程序实现或支持,该计算机程序由计算机可读程序代码形成并体现在计算机可读介质中。短语“计算机可读程序代码”包括任何类型的计算机代码,包括源代码、目标代码和可执行代码。短语“计算机可读介质”包括能够被计算机访问的任何类型的介质,诸如只读存储器(ROM)、随机存取存储器(RAM)、硬盘驱动器(HDD)、光盘(CD)、数字视频盘(DVD)或任何其他类型的存储器。“非暂时性”计算机可读介质不包括传输暂时性电信号或其他信号的有线、无线、光学或其他通信链路。非暂时性计算机可读介质包括其中可以永久存储数据的介质和其中数据可以存储并稍后覆写的介质,诸如可重写光盘或可擦除存储设备。

[0084] 阐述贯穿本专利文件使用的某些单词和短语的定义可能是有利的。术语“应用”和“程序”指代一个或多个计算机程序、软件组件、指令集、过程、函数、对象、类、实例、相关数据或其适于在合适的计算机代码(包括源代码、目标代码或可执行代码)中实现的部分。术语“通信”及其派生词涵盖直接和间接通信两者。术语“包括”和“包含”及其派生词意味着没有限制地包括。术语“或”是包含性的,意味着和/或。短语“与……相关联”及其派生词可以意味着包括、被包括在……内、与……互连、包含、被包含在……内、连接到……或与……连接、耦合到……或与……耦合、与……通信、与……协作、交错、并置、靠近……、绑定到……或者带有、具有、具有属性、对或具有……具有关系等等。短语“……中的至少一个”当与项目列表一起使用时意味着可以使用一个或多个所列项目的不同组合,并且列表中可能仅需要一个项目。例如,“A、B和C中的至少一个”包括以下组合中的任何一个:A、B、C、A和B、A和C、B和C以及A和B和C。

[0085] 本申请中的描述不应当被理解为暗示任何特定的元素、步骤或功能是必须包括在权利要求范围内的必要或关键的元素。专利主题的范围仅由授权的权利要求限定。此外,除非在特定权利要求中明确使用确切的词语“用于……的手段”或“用于……的步骤”、继之以标识功能的分词短语,否则没有一项权利要求关于任何所附权利要求或权利要求元素援引 35 U.S.C. § 112(f)。权利要求中诸如(但不限于)“机构”、“模块”、“设备”、“单元”、“组件”、“元件”、“构件”、“装置”、“机器”、“系统”、“处理器”或“控制器”之类术语的使用被理解

并旨在指代相关领域技术人员已知的结构,如权利要求本身的特征所进一步修改或增强的,而不是旨在援引35 U.S.C. § 112(f)。

[0086] 虽然本公开已经描述了某些实施例和一般相关联的方法,但是这些实施例和方法的变更和置换对于本领域技术人员来说将是清楚的。因此,示例实施例的上述描述并无限定或限制本公开。在不脱离由所附权利要求限定的本公开的精神和范围的情况下,其他改变、替换和变更也是可能的。

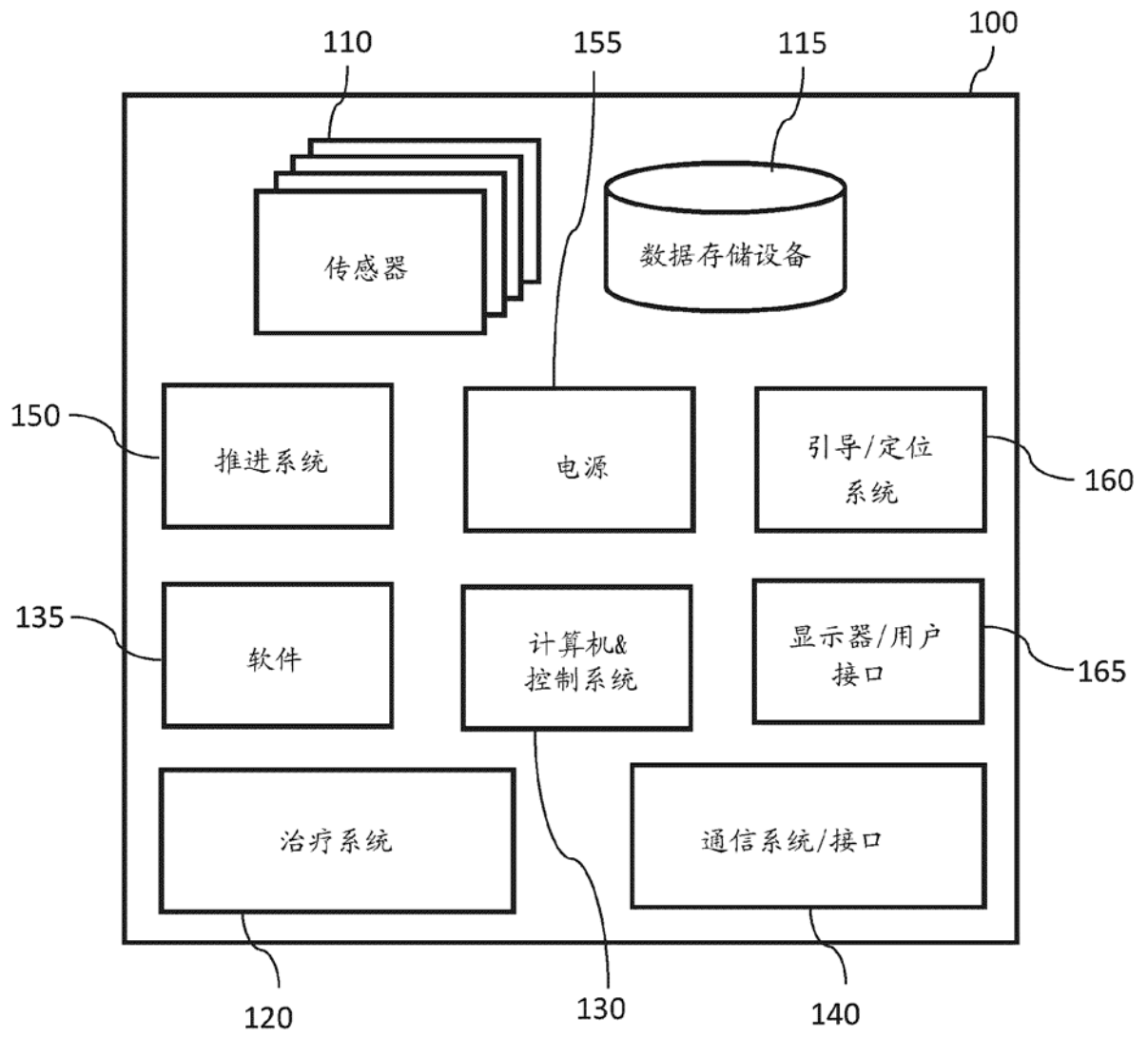


图 1

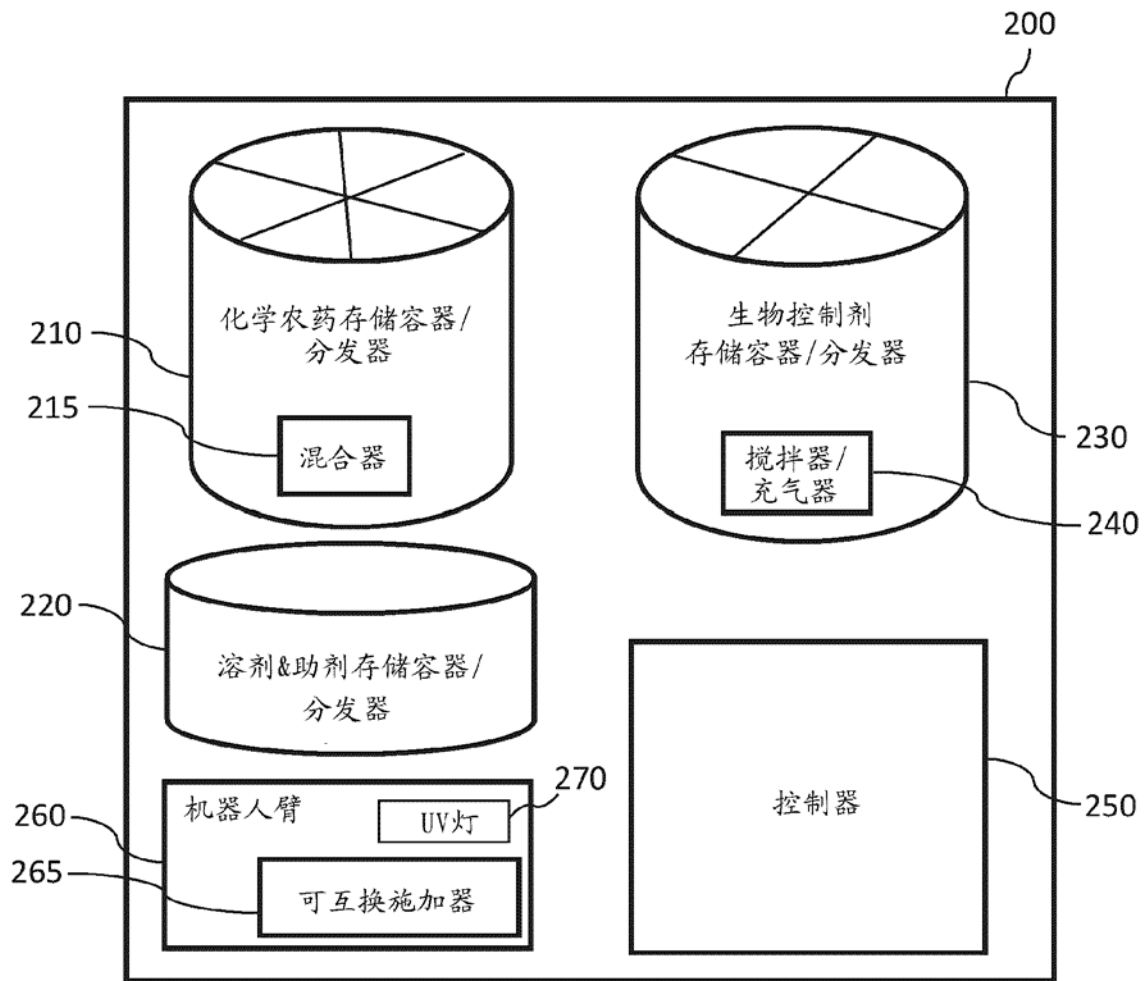


图 2

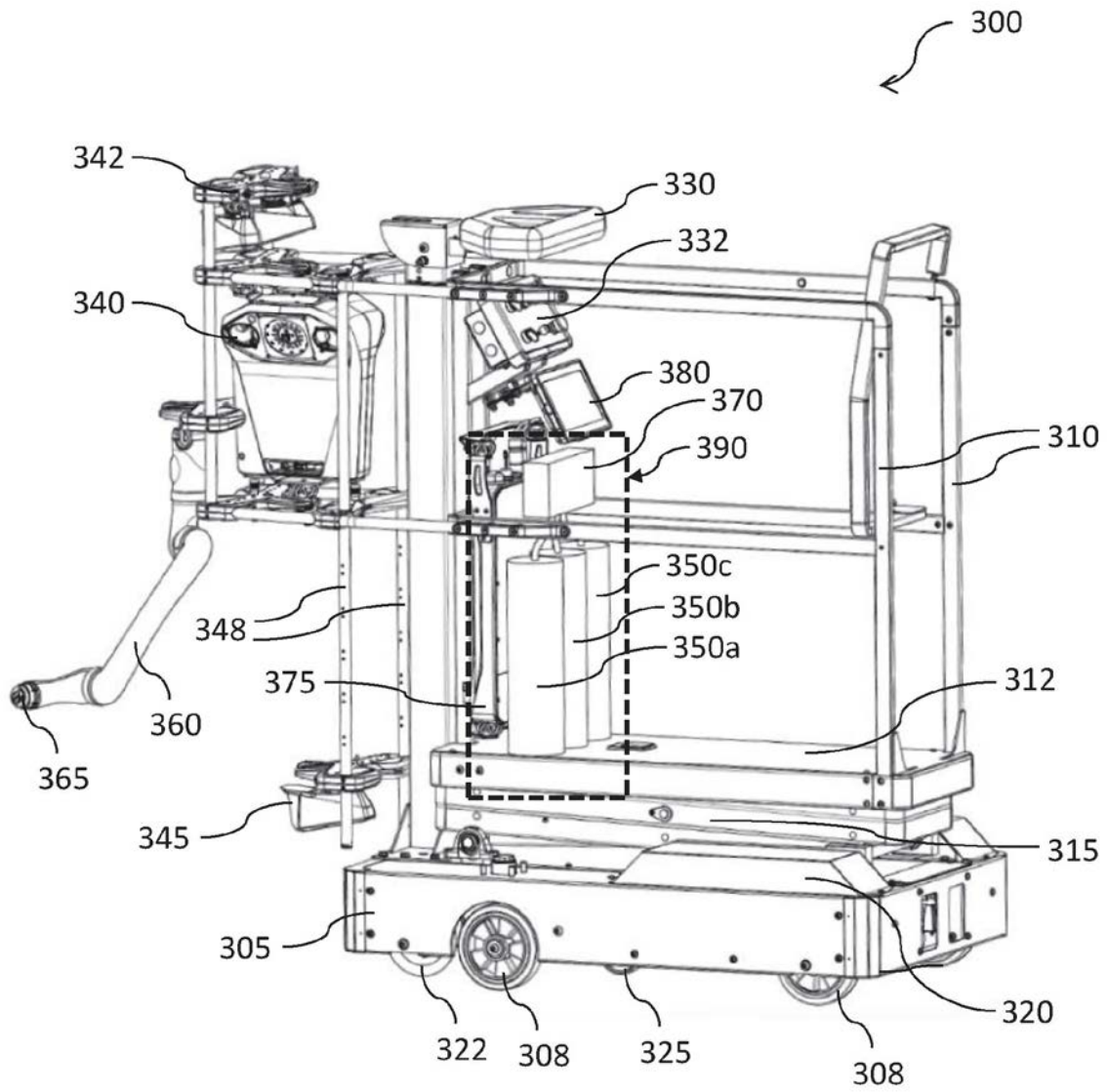


图 3A

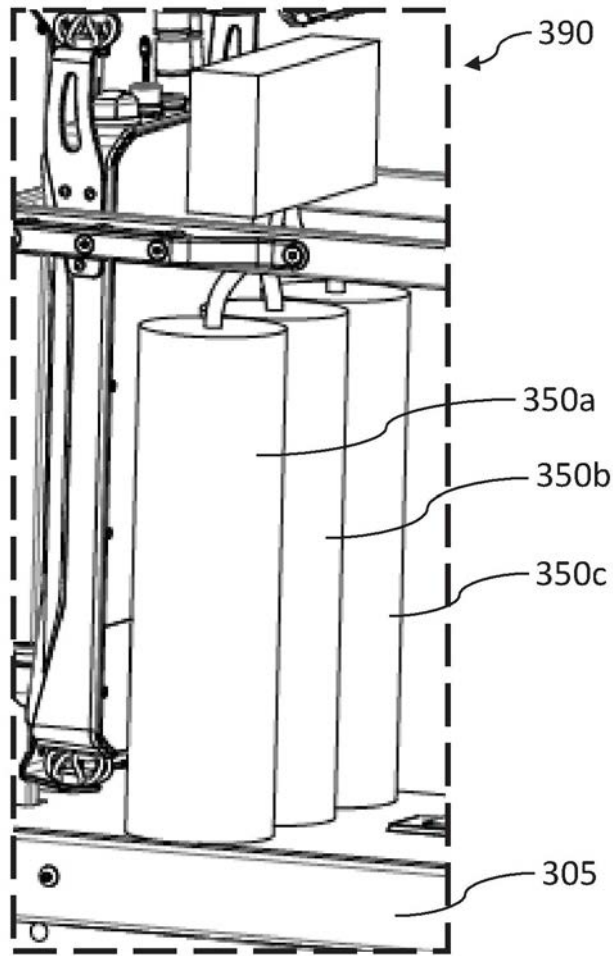


图 3B

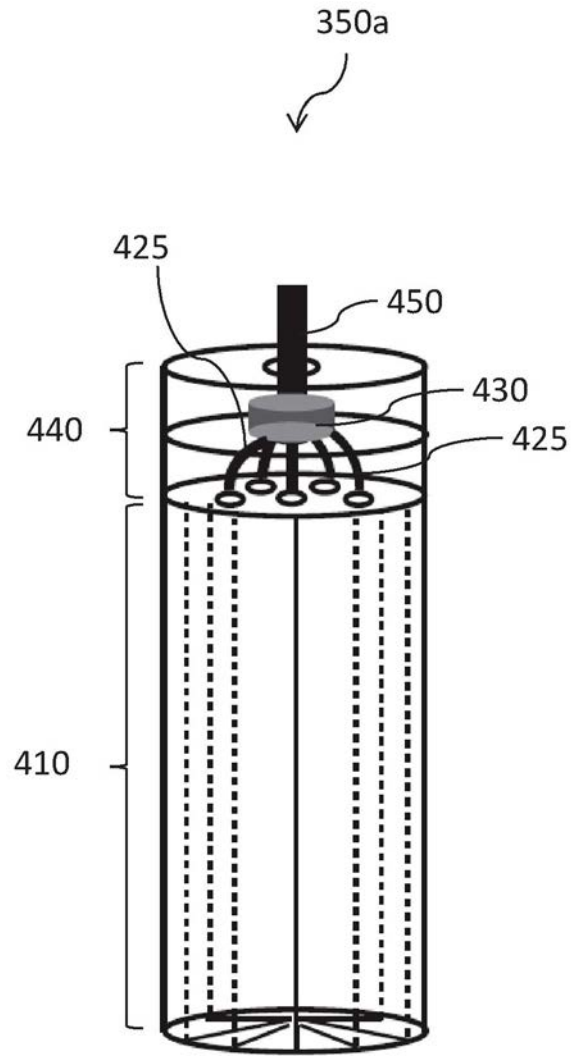


图 4A

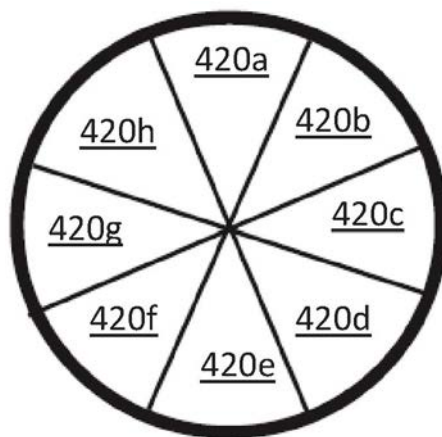


图 4B

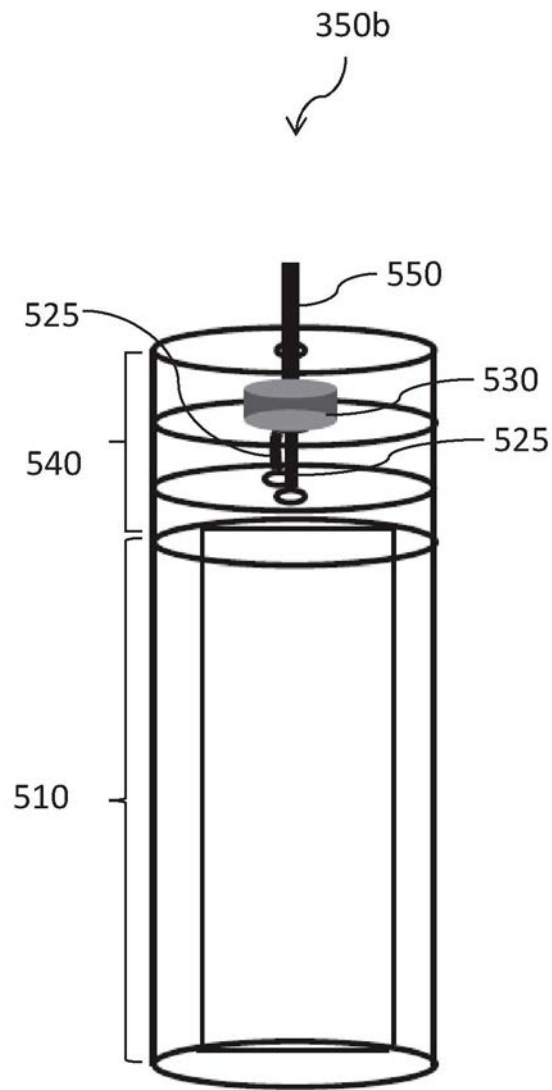


图 5A

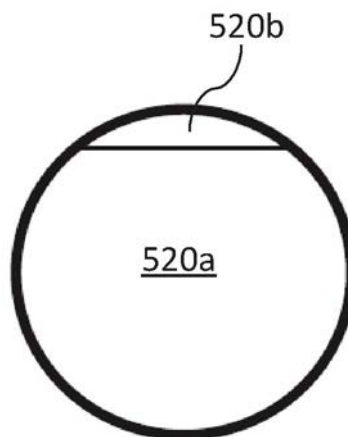


图 5B

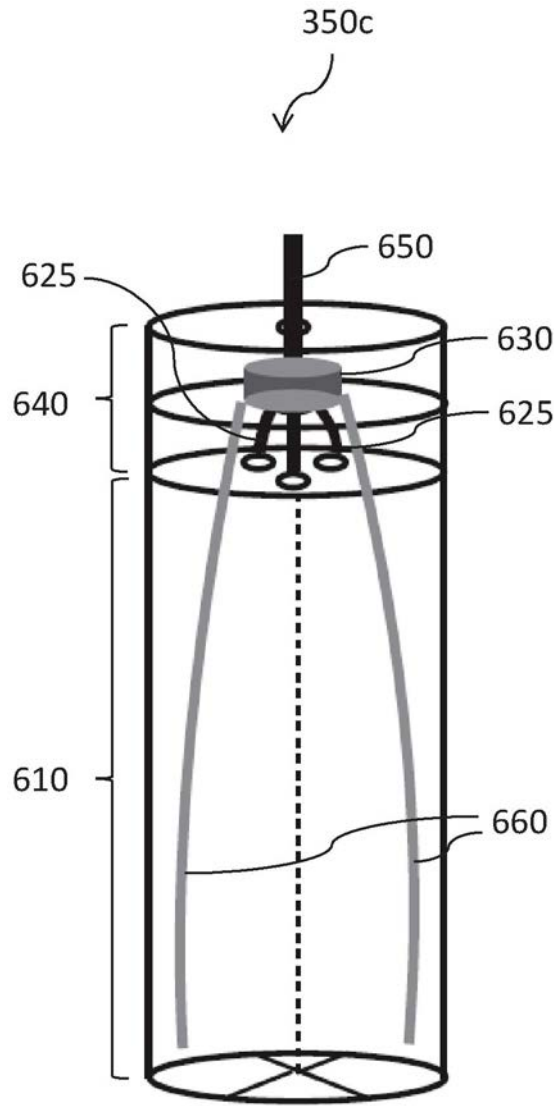


图 6A

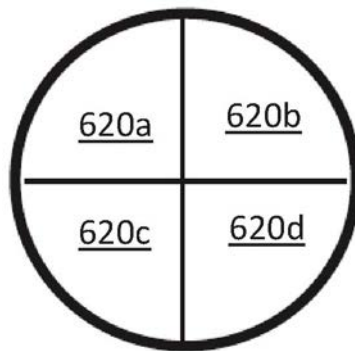


图 6B

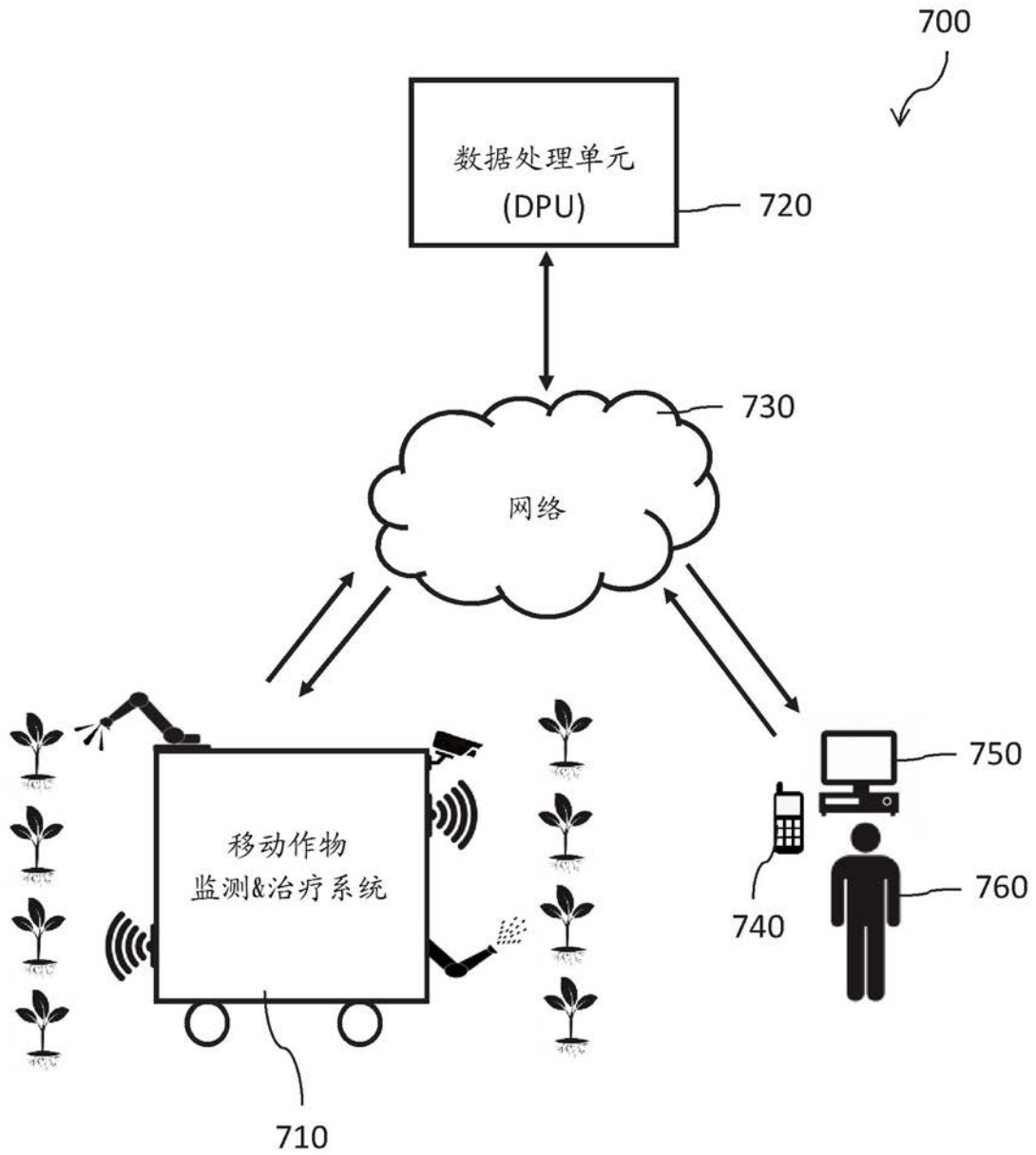


图 7