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Inventor(s) Anderson; Kent Michael et al.

Automated nozzle adjustments for plant treatment application

Abstract

A treatment mechanism for dispensing treatment fluid onto one or more plants in a field is described. The treatment mechanism includes a valve for regulating the dispensing of treatment fluid and a nozzle holder comprising a plurality of nozzles. Each nozzle is configured to dispense treatment fluid and to couple to the valve. The treatment mechanism further includes a control system configured to receive a plant treatment instruction for treating the plants. The plant treatment instruction includes a treatment position for the nozzle holder. The control system is further configured to determine a current position of the nozzle holder and adjust the current position of the nozzle holder to the treatment position for the nozzle holder. The control system is further configured to actuate the treatment mechanism such that the plants are treated via a nozzle of the plurality of nozzles.

Inventors: **Anderson; Kent Michael (Signal Mountain, TN), Chostner; Benjamin Ray (San Francisco, CA), Majusiak; Bryon William (Incline Village, NV)**

Applicant: **Deere & Company** (Moline, IL)

Family ID: **1000008764331**

Assignee: **Deere & Company (Moline, IL)**

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
6193166	12/2000	Miller	239/574	A01M 7/006
6325302	12/2000	Guzowski	239/128	B05B 1/14
6444090	12/2001	Wolf	118/325	D21G 7/00
6596996	12/2002	Stone	250/341.1	G01N 21/4738
6675988	12/2003	Cline	222/639	B29B 7/325
10192185	12/2018	Tomii	N/A	G06Q 50/02
2014/0138456	12/2013	Lev	239/11	H04N 1/00472
2015/0367358	12/2014	Funseth	239/562	A01G 25/16

Primary Examiner: Lee; Chee-Chong

Attorney, Agent or Firm: Fenwick & West LLP

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) This application claims the benefit of priority to U.S. Provisional Patent Application No. 63/146,433, filed on Feb. 5, 2021, which is incorporated by reference in its entirety.

BACKGROUND
Field of Disclosure
(1) This disclosure relates to a system for applying treatment fluid to plants in a field, and more specifically to automatically adjusting nozzles for dispensing treatment fluid.
Description of the Related Art
(2) Current methods for spraying plant treatment (e.g., herbicide treatment, fungicide treatment, etc.) on plants in a field utilize high-density spray nozzles. Each spray nozzle in the spray system is uniform. Over time nozzles wear-out and need to be replaced. Additionally, nozzles must be replaced for different types of application of plant treatment (e.g., broadcast application, spot spraying, etc.). Typically, swapping and/or replacing the nozzles is a large manual burden and can suffer from human error.

SUMMARY
(3) A farming machine is configured to move through a field and treat one or more plants in the field using various treatment mechanisms. A treatment mechanism may include a plurality of nozzle holders with each nozzle holder of the plurality of nozzle holders including a plurality of nozzles. Each nozzle is configured to couple to a valve and to dispense treatment fluid. The valve is configured to regulate the dispensing of treatment fluid. One or more nozzle holders may be automatically adjusted (e.g., the positioning of one or more nozzle holders may be adjusted) based on plant treatment instructions. In some embodiments, the plant treatment instructions include a treatment position for a nozzle holder. The treatment mechanism determines a current position of the nozzle holder and adjusts the position of the nozzle holder from the current position to the treatment position. In some embodiments, the treatment mechanism may determine one or more nozzles of the plurality of nozzles are unable to dispense treatment fluid (e.g., are blocked, clogged, or worn out). Based on this determination, the treatment mechanism may adjust the position of one or more nozzle holders such that operable nozzles are coupled to the valve.
(4) In some embodiments, a farming machine is described for treating one or more plants in a field. The farming machine comprises a treatment mechanism configured to dispense treatment fluid to one or more plants as the farming machine travels past the plants in a field. The treatment mechanism comprises a valve for regulating the dispensing of treatment fluid, a nozzle holder comprising a plurality of nozzles, and a control system. Each nozzle is configured to dispense treatment fluid and to couple to the valve. The control system is configured to receive a plant treatment instruction for treating the plants. The plant treatment instruction comprises a treatment position for a nozzle holder. The treatment position for a nozzle holder is a position of the nozzle holder which enables the farming machine to provide the treatment corresponding to the treatment instruction. That is, in the treatment position the nozzle holder couples a nozzle that will apply the desired treatment to the valve. Additionally, each nozzle in a nozzle holder corresponds to a position of the nozzle holder that couples it to the valve. Each position may be a treatment position when the treatment instruction is for its corresponding nozzle.
(5) The control system is further configured to determine a current position of the nozzle holder in the treatment mechanism. The control system determines the current position of the nozzle holder by receiving a magnetic field measurement produced by one or more magnets positioned in the nozzle holder and identifying the current position of the nozzle holder based on the measurement of the magnetic field. The control system is further configured to automatically adjust the current position of the nozzle holder to the treatment position for the nozzle holder. The control system is further configured to actuate, based on the plant treatment instruction, the treatment mechanism such that the plants are treated via a nozzle while the nozzle holder is in the treatment position as the farming machine moves past the plants in the field.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1**A illustrates an isometric view of a farming machine, in accordance with an example embodiment.
(2) FIG. **1**B illustrates a top view of the farming machine, in accordance with the example embodiment.
(3) FIG. **1**C illustrates an isometric view of a farming machine, in accordance with a second example embodiment.
(4) FIG. **2** illustrates the fluidic components and couplings of a treatment mechanism, in accordance with an example embodiment.
(5) FIG. **3**A illustrates a front view of a distribution manifold, in accordance with an example

embodiment.
(6) FIG. **3**B illustrates an isometric view of the distribution manifold, in accordance with the example embodiment.
(7) FIG. **4**A illustrates a side view of a distribution manifold, in accordance with a second example embodiment.
(8) FIG. **4**B illustrates a top view of the distribution manifold, in accordance with the second example embodiment.
(9) FIG. **5**A illustrates a side view of a distribution manifold, in accordance with a third example embodiment.
(10) FIG. **5**B illustrates a top view of the distribution manifold, in accordance with the third example embodiment.
(11) FIG. **6** illustrate a side view of a distribution manifold with sensors, in accordance with an example embodiment.
(12) FIG. **7** is a block diagram of the system environment for the farming machine, in accordance with one or more example embodiments.
(13) FIG. **8** is a flow chart illustrating a method of treating a plant, in accordance with an example embodiment.
(14) FIG. **9** is a block diagram illustrating components of an example machine for reading and executing instructions from a machine-readable medium, in accordance with one or more example embodiments.
(15) The figures depict various embodiments for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein.

DETAILED DESCRIPTION

I. Farming Machine

(16) A farming machine that identifies and treats plants may have a variety of configurations, some of which are described in greater detail below. For example, FIG. **1**A is an isometric view of a farming machine and FIG. **1**B is a top view of the farming machine of FIG. **1**A. FIG. **1**C is a second embodiment of a farming machine. Other embodiments of a farming machine are also possible. The farming machine **100**, illustrated in FIGS. **1**A-**1**C, includes a detection mechanism **110**, a treatment mechanism **120**, and a control system **130**. The farming machine **100** can additionally include a mounting mechanism **140**, a verification mechanism **150**, a power source, digital memory, communication apparatus, or any other suitable component. The farming machine **100** can include additional or fewer components than described herein. Furthermore, the components of the farming machine **100** can have different or additional functions than described below.
(17) The farming machine **100** functions to apply a treatment to one or more plants **102** within a geographic area **104**. Often, treatments function to regulate plant growth. The treatment is directly applied to a single plant **102** (e.g., hygroscopic material), but can alternatively be directly applied to multiple plants, indirectly applied to one or more plants, applied to the environment associated with the plant (e.g., soil, atmosphere, or other suitable portion of the plant environment adjacent to or connected by an environmental factor, such as wind), or otherwise applied to the plants. Treatments that can be applied include necrosing the plant, necrosing a portion of the plant (e.g., pruning), regulating plant growth, or any other suitable plant treatment. Necrosing the plant can include dislodging the plant from the supporting substrate **106**, incinerating a portion of the plant, applying a treatment concentration of treatment fluid (e.g., fertilizer, hormone, water, etc.) to the plant, or treating the plant in any other suitable manner. Regulating plant growth can include promoting plant growth, promoting growth of a plant portion, hindering (e.g., retarding) plant or plant portion growth, or otherwise controlling plant growth. Examples of regulating plant growth

includes applying growth hormone to the plant, applying fertilizer to the plant or substrate, applying a disease treatment or insect treatment to the plant, electrically stimulating the plant, watering the plant, pruning the plant, or otherwise treating the plant. Plant growth can additionally be regulated by pruning, necrosing, or otherwise treating the plants adjacent to the plant.

(18) The plants **102** can be crops but can alternatively be weeds or any other suitable plant. The crop may be cotton, but can alternatively be lettuce, soybeans, rice, carrots, tomatoes, corn, broccoli, cabbage, potatoes, wheat or any other suitable commercial crop. The plant field in which the system is used is an outdoor plant field, but can alternatively be plants within a greenhouse, a laboratory, a grow house, a set of containers, a machine, or any other suitable environment. The plants are grown in one or more plant rows (e.g., plant beds), wherein the plant rows are parallel, but can alternatively be grown in a set of plant pots, wherein the plant pots can be ordered into rows or matrices or be randomly distributed, or be grown in any other suitable configuration. The crop rows are generally spaced between 2 inches and 45 inches apart (e.g. as determined from the longitudinal row axis), but can alternatively be spaced any suitable distance apart, or have variable spacing between multiple rows.

(19) The plants **102** within each plant field, plant row, or plant field subdivision generally includes the same type of crop (e.g., same genus, same species, etc.), but can alternatively include multiple crops (e.g., a first and a second crop), both of which are to be treated. Each plant **102** can include a stem, arranged superior (e.g., above) the substrate **106**, which supports the branches, leaves, and fruits of the plant. Each plant can additionally include a root system joined to the stem, located inferior to the substrate plane (e.g., below ground), that supports the plant position and absorbs nutrients and water from the substrate **106**. The plant can be a vascular plant, non-vascular plant, ligneous plant, herbaceous plant, or be any suitable type of plant. The plant can have a single stem, multiple stems, or any number of stems. The plant can have a tap root system or a fibrous root system. The substrate **106** is soil but can alternatively be a sponge or any other suitable substrate.

(20) The detection mechanism **110** is configured to identify a plant for treatment. As such, the detection mechanism **110** can include one or more sensors for identifying a plant. For example, the detection mechanism **110** can include a multispectral camera, a stereo camera, a CCD camera, a single lens camera, a CMOS camera, hyperspectral imaging system, LIDAR system (light detection and ranging system), a depth sensing system, dynamometer, IR camera, thermal camera, humidity sensor, light sensor, temperature sensor, or any other suitable sensor. In some example systems, the detection mechanism **110** is mounted to the mounting mechanism **140**, such that the detection mechanism **110** traverses over a geographic location before the treatment mechanism **120** as the farming machine **100** moves through the geographic location. However, in some embodiments, the detection mechanism **110** traverses over a geographic location at substantially the same time as the treatment mechanism **120**. In an embodiment of the farming machine **100**, the detection mechanism **110** is statically mounted to the mounting mechanism **140** proximal the treatment mechanism **120** relative to the direction of travel **115**. In other systems, the detection mechanism **110** can be incorporated into any other component of the farming machine **100**.

(21) The treatment mechanism **120** functions to apply a treatment to one or more plants **102**. The treatment mechanism **120** applies the treatment to the treatment area **122** as the farming machine **100** moves in a direction of travel **115**. The effect of the treatment can include plant necrosis, plant growth stimulation, plant portion necrosis or removal, plant portion growth stimulation, or any other suitable treatment effect as described above. The treatment can include plant **102** dislodgement from the substrate **106**, severing the plant (e.g., cutting), plant incineration, electrical stimulation of the plant, fertilizer or growth hormone application to the plant, watering the plant, light or other radiation application to the plant, injecting one or more treatment fluids into the substrate **106** adjacent the plant (e.g., within a threshold distance from the plant), or otherwise treating the plant. In one embodiment, the treatment mechanisms **120** are an array of spray treatment mechanisms. The treatment mechanisms **120** may be configured to spray one or more

treatment fluids including an herbicide, a fungicide, water, a pesticide, another treatment fluid, or a combination thereof. The treatment mechanism **120** is operable between a standby mode, wherein the treatment mechanism **120** does not apply a treatment, and a treatment mode, wherein the treatment mechanism **120** is controlled by the control system **130** to apply the treatment. However, the treatment mechanism **120** can be operable in any other suitable number of operation modes.
(22) The farming machine **100** may include one or more treatment mechanisms **120**. A treatment mechanism **120** may be fixed (e.g., statically coupled) to the mounting mechanism **140** or attached to the farming machine **100** relative to the detection mechanism **110**. Alternatively, the treatment mechanism **120** can rotate or translate relative to the detection mechanism **110** and/or mounting mechanism **140**. In one variation, the farming machine **100** includes a single treatment mechanism, wherein the treatment mechanism **120** is actuated or the farming machine **100** is moved to align the treatment mechanism **120** with the treatment area **122**. In a second variation, the farming machine **100** includes an assembly of treatment mechanisms, wherein a treatment mechanism **120** (or subcomponent of the treatment mechanism **120**) of the assembly is selected to apply the treatment to the plant **102** or portion of a plant in response to the plant position relative to the assembly. In a third variation, such as shown in FIGS. **1**A-**1**C, the farming machine **100** includes an array of treatment mechanisms **120**, wherein the treatment mechanisms **120** are actuated or the farming machine **100** is moved to align the treatment mechanism **120** with the treatment areas **122** with the targeted plant **102** or plant segment.
(23) The components and operation of the treatment mechanism **120** are described in greater detail below in relation to FIGS. **2-6**.
(24) The farming machine **100** includes a control system **130** for controlling operations of system components. In some embodiments, the control system **130** receives plant treatment instructions that dictate certain operations of system components. The control system **130** can receive information from and/or provide input to the detection mechanism **110**, the verification mechanism **150**, and the treatment mechanism **120**. The control system **130** can be automated or can be operated by a user. In some embodiments, the control system **130** may be configured to control operating parameters of the farming machine **100** (e.g., speed, direction). The control system **130** also controls operating parameters of the detection mechanism **110**. Operating parameters of the detection mechanism **110** may include processing time, location and/or angle of the detection mechanism **110**, image capture intervals, image capture settings, etc. The control system **130** can also control operating parameters of the treatment mechanism **120**. Operating parameters of the treatment mechanism **120** may include positioning of one or more components of the treatment mechanism **120** and actuation of the treatment mechanism **120**. The control system **130** may be a computer, as described in greater detail below in relation to FIG. **9**.
(25) The control system **130** may be coupled to the farming machine **100** such that a user (e.g., a driver) can interact with the control system **130**. In other embodiments, the control system **130** is physically removed from the farming machine **100** and communicates with system components (e.g., detection mechanism **110**, treatment mechanism **120**, etc.) wirelessly. In some embodiments, the control system **130** is an umbrella term that includes multiple networked systems distributed across different locations (e.g., a system on the farming machine **100** and a system at a remote location). In some embodiments, one or more processes are performed by another control system. For example, the control system **130** may receive plant treatment instructions from another control system.
(26) In some configurations, the farming machine **100** includes a mounting mechanism **140** that functions to provide a mounting point for the system components. In one example, the mounting mechanism **140** statically retains and mechanically supports the positions of the detection mechanism **110**, the treatment mechanism **120**, and the verification mechanism **150** relative to a longitudinal axis of the mounting mechanism **140**. The mounting mechanism **140** is a chassis or frame but can alternatively be any other suitable mounting mechanism. In the embodiment of

FIGS. **1**A-**1**C, the mounting mechanism **140** extends outward from a body of the farming machine **100** in the positive and negative y-direction (in the illustrated orientation of FIGS. **1**A-**1**C) such that the mounting mechanism **140** is approximately perpendicular to the direction of travel **115**. The mounting mechanism **140** in FIGS. **1**A-**1**C includes an array of treatment mechanisms **120** positioned laterally along the mounting mechanism **140**. In alternate configurations, there may be no mounting mechanism **140**, the mounting mechanism **140** may be alternatively positioned, or the mounting mechanism **140** may be incorporated into any other component of the farming machine **100**.

(27) The farming machine **100** includes a first set of coaxial wheels and a second set of coaxial wheels, wherein the rotational axis of the second set of wheels is parallel with the rotational axis of the first set of wheels. In some embodiments, each wheel in each set is arranged along an opposing side of the mounting mechanism **140** such that the rotational axes of the wheels are approximately perpendicular to the mounting mechanism **140**. In FIGS. **1**A-**1**C, the rotational axes of the wheels are approximately parallel to the mounting mechanism **140**. In alternative embodiments, the system can include any suitable number of wheels in any suitable configuration. The farming machine **100** may also include a coupling mechanism **142**, such as a hitch, that functions to removably or statically couple to a drive mechanism, such as a tractor, more to the rear of the drive mechanism (such that the farming machine **100** is dragged behind the drive mechanism), but can alternatively be attached to the front of the drive mechanism or to the side of the drive mechanism. Alternatively, the farming machine **100** can include the drive mechanism (e.g., a motor and drive train coupled to the first and/or second set of wheels). In other example systems, the system may have any other means of traversing through the field.

(28) In some configurations, the farming machine **100** additionally includes a verification mechanism **150** that functions to record a measurement of the ambient environment of the farming machine **100**. The farming machine may use the measurement to verify or determine the extent of plant treatment. The verification mechanism **150** records a measurement of the geographic area previously measured by the detection mechanism **110**. The verification mechanism **150** records a measurement of the geographic region encompassing the plant treated by the treatment mechanism **120**. The verification mechanism **150** measurement can additionally be used to empirically determine (e.g., calibrate) treatment mechanism operation parameters to obtain the desired treatment effect. The verification mechanism **150** can be substantially similar (e.g., be the same type of mechanism as) to the detection mechanism **110** or can be different from the detection mechanism **110**. In some embodiments, the verification mechanism **150** is arranged distal the detection mechanism **110** relative the direction of travel, with the treatment mechanism **120** arranged there between, such that the verification mechanism **150** traverses over the geographic location after treatment mechanism **120** traversal. However, the mounting mechanism **140** can retain the relative positions of the system components in any other suitable configuration. In other configurations of the farming machine **100**, the verification mechanism **150** can be included in other components of the system.

(29) In some configurations, the farming machine **100** may additionally include a power source, which functions to power the system components, including the detection mechanism **110**, control system **130**, and treatment mechanism **120**. The power source can be mounted to the mounting mechanism **140**, can be removably coupled to the mounting mechanism **140**, or can be separate from the system (e.g., located on the drive mechanism). The power source can be a rechargeable power source (e.g., a set of rechargeable batteries), an energy harvesting power source (e.g., a solar system), a fuel consuming power source (e.g., a set of fuel cells or an internal combustion system), or any other suitable power source. In other configurations, the power source can be incorporated into any other component of the farming machine **100**.

(30) In some configurations, the farming machine **100** may additionally include a communication apparatus, which functions to communicate (e.g., send and/or receive) data between the control

system **130** and a set of remote devices. The communication apparatus can be a Wi-Fi communication system, a cellular communication system, a short-range communication system (e.g., Bluetooth, NFC, etc.), or any other suitable communication system.

II. Treatment Mechanism

(31) FIG. **2** is an illustration of the fluidic components and couplings of a treatment mechanism, in accordance with an example embodiment. The treatment mechanism **120** includes a distribution manifold **210**, a reservoir **220**, a pump **230**, a bypass valve **240**, a first outtake **250**, a second outtake **260**, and an intake **280**. The treatment mechanism **120** can include additional or fewer components than described herein. For example, the treatment mechanism **120** may include an accumulator **270**. Furthermore, the components of the treatment mechanism **120** can have different or additional functions than described below.

(32) The distribution manifold **210** is configured to apply a plant treatment to the treatment area **122**. The distribution manifold **210** receives operation instructions from the control system **130**. For example, the control system **130** may provide instructions to the distribution manifold **210** that control a mode of operation (e.g., standby mode or treatment mode) of the distribution manifold **210**. In a standby mode, the distribution manifold **210** does not spray treatment fluid and in a treatment mode the distribution manifold **210** does spray treatment fluid. In another example, the control system **130** may provide instructions to the distribution manifold **210** that control which components (e.g., nozzles) to use during the treatment mode as described in greater detail in FIG. **7** and FIG. **8**.

(33) The treatment fluid can be water, fertilizer, growth hormone, herbicide, fungicide, pesticide, or any other suitable fluid. The treatment fluid may be emitted (e.g., sprayed) at a spray pressure of approximately 40-70 psi, within a margin of error (e.g., a 5% margin of error, 2% margin of error, etc.), but alternatively may be emitted at a pressure of 90 psi or at any other suitable pressure. The spray is emitted from the distribution manifold **210** when positioned within several centimeters (e.g., 1 cm, 5 cm, 10 cm, etc.) of the substrate **106** surface, but can alternatively be positioned a meter away from the substrate **106** surface, or positioned any suitable distance away from the substrate **160** surface.

(34) The operation and components of the distribution manifold **210** are described in greater detail below in relation to FIGS. **3-6**.

(35) In the illustrated embodiment of FIG. **2**, the treatment mechanism **120** additionally includes the reservoir **220** and the pump **230**. The reservoir **220** stores a treatment fluid and the pump **230** actuates movement of the treatment fluid through the components of the treatment mechanism **120**. The pump **230** can move fluid from the reservoir **220** using a secondary fluid or a source from the ambient environment (e.g., a fluid source or air), or move the treatment fluid in the reservoir **220** in any other suitable manner.

(36) The bypass valve **240** controls the movement of the treatment fluid throughout the treatment mechanism **120**. The bypass valve **240** is operable between a closed mode wherein the bypass valve **240** fluidly disconnects the distribution manifold **210** from the reservoir **220**, and an open mode, wherein the bypass valve **240** fluidly connects the distribution manifold **210** to the reservoir **220**. In the open mode, the bypass valve **240** fluidly connects the intake **280** to the distribution manifold **210** by disconnecting (e.g., sealing) the intake **280** from the first outtake **250**. For example, the pump **230** moves fluid from the reservoir **220** by pumping the treatment fluid into the intake **280**, through the bypass valve **240**, and through the second outtake **260** to the distribution manifold **210**. In the closed mode, the bypass valve **240** disconnects the intake **280** from the distribution manifold **210** by disconnecting (e.g., sealing) the intake **280** from the second outtake **260**. For example, the pump **230** moves fluid from the reservoir **220** by pumping the treatment fluid into the intake **280**, through the bypass valve **240**, and through the first outtake **250** into the reservoir **220**.

(37) The bypass valve **240** can be passive, wherein the cracking pressure is the same as the desired

spray pressure, or can be active, wherein the bypass valve **240** actuation from the closed to open mode is actively controlled, such as by the control system **130**. The bypass valve **240** opens in response to the intake **280** fluid pressure meeting or exceeding a desired spray pressure, such that the intake **280** is fluidly connected to the distribution manifold **210**. In this variation, the treatment mechanism **120** can additionally include a pressure sensor or flow sensor that measures the fluid pressure or flowrate at the intake **280**, the bypass valve **240**, the first outtake **250**, the second outtake **260**, or the reservoir **220**, where the treatment parameters (e.g., initial spray time or position) can be subsequently adjusted or determined based on the measured treatment fluid parameters.

(38) The treatment mechanism **120** can additionally include an accumulator **270** that is fluidly connected to the reservoir **220** and the distribution manifold **210**, wherein the pump **230** pumps treatment fluid from the reservoir **220** to the accumulator **270**. The accumulator **270** functions to retain a volume of treatment fluid sufficient to dampen pressure changes due to downstream valve actuation. The accumulator **270** can additionally function to pressurize the fluid. In one embodiment, a valve (not shown) may be used to control fluid flow between the accumulator **270** and the distribution manifold **210**. In another embodiment, the bypass valve **240** can control fluid flow between the accumulator **270** and the distribution manifold **210**. When the bypass valve **240** is used, the accumulator **270** is fluidly connected to the intake **280**. The accumulator **270** may be connected in parallel with the distribution manifold **210** but can alternatively be connected in series with the distribution manifold **210**. The accumulator **270** can be additionally fluidly connected to a secondary treatment fluid reservoir (not shown), where metered amounts of a secondary treatment fluid (e.g., fertilizer, growth hormone, etc.) can be provided to the accumulator **270** to mix with the primary treatment fluid (e.g., water) from the reservoir **220** within the accumulator **270** prior to being applied to the treatment area **122** via the distribution manifold **210**.

(39) The treatment mechanism **120** may contain additional, fewer, or different components then those illustrated in FIG. **2**. For example, a treatment mechanism **120** may include a controller that is electronically connected to the control system **130**. The controller may control the operation of the distribution manifold **210**, the pump **230**, the bypass valve **240**, and/or any other component of the treatment mechanism **120**. For example, the controller may enable or disable the distribution manifold **210** to spray or not spray treatment fluid, may turn on or turn off the pump **230**, may open or close the bypass valve, etc.

III. Distribution Manifold Examples

(40) FIG. **3**A and FIG. **3**B, respectively, illustrate a front and isometric view of a distribution manifold of a treatment mechanism, in accordance with an example embodiment. The distribution manifold **210** includes a support structure **310**, a feed tube **320**, a movement mechanism **330**, a plurality of valves **340**, a nozzle holder **350**, a plurality of nozzles **355**, and control connectors **360**. The distribution manifold **260** can include additional or fewer components than described herein. Furthermore, the components of the distribution manifold **260** can have different or additional functions than described below.

(41) The support structure **310** is a structural support apparatus configured to mechanically support and couple other components of the distribution manifold **210**. The support structure **310** may be created from a mechanically rigid material such as steel, plastic, or any other material that can be used to fabricate chemically compatible components for applying treatment fluid in a field. In some embodiments, the support structure **310** contains a hollow cavity that the feed tube **320** sits inside of and treatment fluid flows inside the feed tube **320** within the support structure **310**. In alternative embodiments, the feed tube **320** sits on the outside of the support structure **310**. In the illustrated embodiment, the distribution manifold **210** includes a feed tube **320** mechanically coupled to the left and right side of the support structure **310** but can be coupled in any other position. The feed tube **320** is fluidically connected to the plurality of valves **340** and fluidically connected to the reservoir **220**. For example, the feed tube **320** can be fluidically coupled to the bypass valve **240**

via the second outtake **260**. The feed tube **320** can be constructed from plastic, aluminum, steel, or any other tubing material that can be used to fluidically couple components of the distribution manifold assembly **210**.

(42) The support structure **310** is coupled to the movement mechanism **330**, which, in turn, is coupled to the nozzle holder **350**. The movement mechanism **330** is a device that imparts motion on another object. The motion may be a rotational motion and/or a translational motion. In one example, the movement mechanism **330** may be a motor. The movement mechanism **330** is communicatively coupled to the control system **130** and can receive instructions from the control system **130** to adjust the positioning of the nozzle holder **350**. In one example, the control system **130** may receive plant treatment instructions that specify the nozzle holder treatment position. The control system **130** determines, based on the plant treatment instructions and current positioning of the nozzle holder(s), that the nozzle holder **350** needs to be adjusted (rotated and/or translated) accordingly. This procedure is described in greater detail below in relation to FIG. **7** and FIG. **8**. In another example, the control system **130** may determine one or more nozzles **355** are inoperable (e.g., blocked, clogged, or worn-out) via signals provided by one or more pressure sensors and/or by one or more flow rate sensors. In another example, the control system **130** may determine one or more nozzles **355** are inoperable based on images captured by one or more cameras. The control system **130** determines, based on the one or more nozzles **355** being inoperable, to provide instructions to the movement mechanism **330** to adjust the nozzle holder **350** to align a different set of nozzles **355** below the valves **340**.

(43) The nozzle holder **350** is a structural support apparatus configured to mechanically support a plurality of nozzles **355**. The nozzle holder **350** may support any number of nozzles **355**. In some embodiments, the nozzles **355** may be arranged in a single row or single column on the nozzle holder **350**. In some embodiments, the nozzles **355** may be arranged in a grid pattern on the nozzle holder **350**. In some embodiments, the nozzles **355** may be arranged in a circular pattern. In the illustrated embodiment, the distribution manifold **210** includes one nozzle holder **350**. In alternative embodiments, a distribution manifold **210** may include a plurality of nozzle holders. Each nozzle holder of the plurality may be coupled to a corresponding movement mechanism **330**.

(44) In the illustrated embodiment, the plurality of nozzles **355** are arranged in rows (in the y-direction) and columns (in the x-direction). The movement mechanism **330** may receive instructions to rotate the nozzle holder **350** relative to an axis parallel to the field and perpendicular to the direction of travel across the field (e.g., the nozzle holder **350** can rotate around an axis substantially parallel to the y axis). During the rotation of the nozzle holder **350** by the movement mechanism **330**, a new row of nozzles **355** may be aligned below the valves **340**. In alternative embodiments, the rotation mechanism **330** may translate the nozzle holder **355** relative to an axis parallel to the field and perpendicular to the direction of travel across the field (e.g., the nozzle holder **350** moves in the positive or negative y-direction). In alternative embodiments, the rotation mechanism **330** may translate the nozzle holder **355** relative to an axis parallel to the field and parallel to the direction of travel across the field (e.g., the nozzle holder **350** moves in the positive or negative x-direction). In alternative embodiments, the rotation mechanism **330** may rotate the nozzle holder **355** relative to an axis perpendicular to the field and perpendicular to the direction of travel across the field (e.g., the nozzle holder can rotate around an axis substantially parallel to the z axis). In alternative embodiments, the movement mechanism **330** may both rotate and translate the nozzle holder **350** such that a new row of nozzles **355** are aligned below the valves **340**. In the alternative embodiments, a new row of nozzles **355** may be aligned below the valves **340** following the rotations and/or translations of the nozzle holder **350**.

(45) Each nozzle **355** may affect how the treatment fluid exits the nozzle **355**. For example, each nozzle **355** may affect a set of characteristics including a spray pattern, a droplet size, a flow rate, and an orientation of the treatment fluid exiting the nozzle **355**. The spray pattern is a stream of droplets, but can alternatively be a hollow cone, full cone, wide column, fan, flat spray, mist or any

other suitable spray pattern for applying treatment fluid to plants **102** in a field. A nozzle **355** can be a single-fluid nozzle but can alternatively be a multiple-fluid nozzle. A nozzle **355** may include one or more orifices where the treatment fluid exits the nozzle. The orifices may be of various sizes. The nozzle **355** can be a plain-orifice nozzle, a shaped-orifice nozzle, a surface-impingement single-fluid nozzle, a pressure-swirl single-fluid spray nozzle, a solid-cone single-fluid nozzle, a compound nozzle, an internal mix two-fluid nozzle, external-mix two-fluid nozzle, or any other suitable nozzle. A nozzle **355** can have a fixed exit or an actuatable exit such that the spray pattern and/or droplet size is configurable. Nozzle emission (e.g., nozzle spray) is controlled by the valves **240**, but can alternatively be controlled by any other suitable control mechanism (e.g., the control system **130**).

(46) In the illustrated embodiment, the valves **340** are aligned in a row (in the y-direction) above the nozzles **355** (in the x-direction). In alternative embodiments, the valves **340** may be aligned in rows and columns (in the y-direction and the x-direction). During the treatment mode of the distribution manifold **210** some or all of the valves **340** are coupled to a respective nozzle **355** (e.g., a nozzle **355** aligned directly below a corresponding valve **340**). In an example embodiment, the valves **340** may be solenoid valves which, when electrically energized allow fluid to flow. The valves **340** may be communicatively coupled to the control system **130** via the control connectors **360**. In some embodiments, the valves **340** include a flow rate sensor and/or a pressure sensor. The flow rate sensor may provide a flow rate signal via the control connectors **360** to the control system **130**. The flow rate signal may describe how quickly treatment fluid is moving through the valve **340** during a treatment mode of operation. The pressure sensor may provide a pressure signal via the control connectors **360** to the control system **130**. The pressure signal may describe a pressure level within the valve **340** during a treatment mode of operation. In some embodiments, the control connectors **360** receive machine commands via the control system **130** and actuate the valves **340** in response. The control system **130** provides instructions to the valves **340** that control actuation of the treatment fluid through the valves **340**.

(47) FIG. **4**A and FIG. **4**B, respectively, illustrate a side view and a top view of an example distribution manifold, in accordance with a second example embodiment. The distribution manifold **400** includes a valve **410**, retention slide **420**, a nozzle holder **430**, sealing gaskets **440**, and a plurality of nozzles (e.g., nozzle **451**, nozzle **453**, and nozzle **455**).

(48) The valve **410** may be substantially similar to the valves **340**. The valve **410** is configured to control the flow of treatment fluid. The valve **410** may be fluidically connected to a feed tube (not shown) for receiving treatment fluid from the reservoir **220**. During a treatment mode, the valve **410** may couple to a nozzle (e.g., nozzle **451**, nozzle **453**, or nozzle **455**) that is aligned below the valve **410** (in the positive z-direction). The operation of the valve **410** is controlled by any suitable control mechanism (e.g., the control system **130**). For example, the valve **410** may be communicatively coupled to the control system **130** via one or more control connectors (not shown). The control of the flow of treatment fluid through the valve **410** and in turn through the coupled nozzle **453** by the control system **130** is described in greater detail below in relation to FIG. **7** and FIG. **8**. The coupling of the valve **410** to a nozzle is secured via sealing gaskets **440**. The sealing gaskets **440** fill the space between the valve **410** and the respective nozzle (e.g., nozzle **453**) to prevent leakage from or into the nozzle holder **430** or other components of the distribution manifold **400**.

(49) The nozzle holder **430** houses nozzles **451**, **453**, **455**. The nozzle holder **430** may move in a positive or negative x-direction to align a nozzle (currently nozzle **453**) with the valve **410**. Movement of the nozzle holder **430** relative to the valve **410** is made possible by the retention slide **420** and actuated by the movement mechanism **330** based on instructions received from the control system **130**. The retention slide **420** applies a pressure to maintain the seal provided by the sealing gaskets **440**. The control of the movement of the nozzle holder **430** by the control system **130** is described in greater detail below in relation to FIG. **7** and FIG. **8**.

(50) In some embodiments, each nozzle **451**, **453**, **455** may produce a unique spray pattern. For example, nozzle **451** may be a fan nozzle, nozzle **453** may be a cone nozzle, and nozzle **455** may be a flat fan nozzle. In alternative embodiments, some or all of the nozzles **451**, **453**, **455** may produce a same spray pattern. For example, nozzles **451**, **453** are fan nozzles and nozzle **455** is a cone nozzle.
(51) FIG. **5**A and FIG. **5**B, respectively, illustrate a top view and a side view, respectively, of an example distribution manifold, in accordance with a third example embodiment. The manifold assembly **500** is substantially similar to the manifold assembly **400** as described in FIGS. **4**A and **4**B. The distribution manifold **500** includes a plurality of valves (e.g., valves **510**, **512**, **514**), a nozzle holder **530**, sealing gaskets **540**, and a plurality of nozzles (e.g., nozzle **551**, nozzle **553**, nozzle **561**, nozzle **563**, nozzle **571**, and nozzle **573**).
(52) The valves **510**, **512**, **514** are configured to control the flow of treatment fluid. The valves **510**, **512**, **514** are fluidically connected to a feed tube **520**. The feed tube **520** is substantially similar to the feed tube **320** as described in FIG. **3**A and FIG. **3**B. During a treatment mode, the valves **510**, **512**, **514** may couple to a corresponding nozzle that is aligned below each valve (in the positive z-direction). For example, currently, valve **510** is coupled to nozzle **553**, valve **512** is coupled to nozzle **563**, and valve **514** is coupled to nozzle **573**. The control of the flow of treatment fluid through the valves **510**, **512**, **514** and in turn through the coupled nozzles **553**, **563**, **573** is controlled by the control system **130** and is described in greater detail below in relation to FIG. **7** and FIG. **8**. The coupling between the valves and the nozzles is secured via a sealing gasket. For example, the coupling between the valve **510** and the nozzle **553** is secured via the sealing gasket **540**. The valves **510**, **512**, **514** are aligned in a row (or a column) in the y-direction.
(53) The nozzle holder **530** comprises a plurality of nozzles arranged in rows and in columns. For example, one column may include nozzles **551**, **553** and one row may include nozzles **551**, **561**, **571**. In this illustrated embodiment, the nozzle holder **530** may move in a positive or negative x-direction to align a row that includes multiple nozzles (currently nozzles **553**, **563**, **573**) with the valves **510**, **512**, **514**. Movement of the nozzle holder **530** relative to the valves **510**, **512**, **514** is controlled by the control system **130** and is described in greater detail below in relation to FIG. **7** and FIG. **8**.
(54) In some embodiments of a distribution manifold (not shown), each valve may be associated with a nozzle holder. In some embodiments of a distribution manifold (not shown), a plurality of valves may be associated with a nozzle holder such that by rotating or translating the nozzle holder, the plurality of values may couple to a different nozzle.
(55) In alternative embodiments, the nozzle holder may comprise a plurality of nozzles arranged in a circular configuration. For example, the nozzle holder may rotate around an axis substantially parallel to the z axis to align a nozzle of the plurality of nozzles with a valve. In alternative embodiments, the nozzle holder may move in a positive or negative y direction. Many other embodiments and configurations are also possible.
(56) FIG. **6** illustrates a side view of a distribution manifold with sensors, in accordance with an example embodiment. The distribution manifold **600** is substantially similar to the distribution manifold **400** as described in FIG. **4**A and FIG. **4**B and the distribution manifold **500** as described in FIG. **5**A and FIG. **5**B. The distribution manifold **600** includes a valve **610**, a sensor **620**, a nozzle holder **630**, a plurality of nozzles (e.g., nozzle **640** and nozzle **650**), and a plurality of magnets (e.g., magnet **660** and magnet **670**).
(57) The valve **610** is configured to control the flow of treatment fluid. The valve **610** may be fluidically connected to a feed tube (not shown) for receiving treatment fluid from the reservoir **220**. During a treatment mode, the valve **610** may couple to a corresponding nozzle that is aligned below the valve **610** (in the positive z-direction). For example, currently, valve **610** is coupled to nozzle **650**. The control of the flow of treatment fluid through the valve **610** and in turn through the coupled nozzle **650** is controlled by the control system **130** and is described in greater detail below

in relation to FIG. **7** and FIG. **8**. The coupling between the valve and the nozzle may be secured with a sealing gasket (not shown).
(58) In the illustrated embodiment, the nozzle holder **630** comprises a plurality of nozzles (including nozzles **640**, **650**). The nozzles **640**, **650** are arranged in the nozzle holder **630** in a row (or in a column) in the x-direction. The nozzle holder **630** may additionally include a plurality of magnets (e.g., magnet **660** and magnet **670**). A unique magnet is placed adjacent to each nozzle in the nozzle holder **630**. In the illustrated embodiment, magnet **660** is placed adjacent to nozzle **640** and magnet **670** is placed adjacent to nozzle **650**. The magnets may be positioned either to the right or left of their corresponding nozzle. In alternative embodiments, two or more magnets may be placed adjacent to nozzle **640** and nozzle **650**. Each magnet **660**, **670** produces a unique magnetic field. A stationary sensor **620** measures the unique magnetic fields. In some embodiments, the sensor **620** is Hall-effect sensor. In some embodiments, the sensor **620** is positioned adjacent to the valve **610**. In alternative embodiments, more than one sensor **620** may be used to measure the magnetic fields. The sensor **620** is communicatively coupled to the control system **130** and provides measurements to the control system **130** for further analysis. The control system **130** can determine a current position of the nozzle holder **630** and the nozzles **640**, **650** based on the magnetic field measurement received from the sensor **620** and determine to adjust the nozzle holder **630** based on the determined positions. This process is described in greater detail below in relation to FIG. **7** and FIG. **8**.
(59) In alternative embodiments, magnets may be placed at other known locations on the nozzle holder **630** and/or sensor(s) may be positioned at various known locations on the distribution manifold.
(60) In alternative embodiments of a distribution manifold with sensors, the nozzle holder may comprise a plurality of unique radio frequency identification (RFID) tags. A unique RFID tag may be positioned adjacent to each nozzle. A sensor (e.g., a stationary RFID reader) may read the unique RFID tags. The sensor may be positioned adjacent to the value. The sensor may be communicatively coupled to the control system **130** and provide the unique RFID to the control system **130** for further analysis. The control system **130** can determine a current position of the nozzle holder and the nozzles based on the RFID received from the sensor and determine to adjust the nozzle holder based on the determined position.
(61) In another embodiment of a distribution manifold with sensors, the nozzle holder may comprise color-coded sections. For example, a surface of the nozzle holder adjacent to a nozzle may be color coded a unique color. For example, the surface of the nozzle holder may be colored red adjacent to a first nozzle and colored blue adjacent to a second nozzle. A sensor (e.g., a color sensor) may emit light from a transmitter to the surface of the nozzle holder and detect the light reflected back from the surface with a receiver. The sensor may be positioned adjacent to the valve. The sensor may be communicatively coupled to the control system **130** and provide a light intensity measurement of the reflected light to the control system **130** for further analysis. The control system **130** can determine a current position of the nozzle holder and the nozzles based on the light intensity measurements and determine to adjust the nozzle holder based on the determined position. In another example, a user of the farming machine may inspect the distribution manifold prior to any plants being treated. The user may capture one or more images of the distribution manifold including the color-coded sections using a digital camera and/or a camera on a mobile device (e.g., a smartphone, augmented reality glasses, etc.). The captured images may be provided to the control system **130** and the control system **130** may determine a current position of the nozzle holder and the nozzles based on the captured images.
(62) In alternative embodiments of a distribution manifold with sensors, a sensor (e.g., a camera) may be positioned to capture images of the nozzle holder and/or the nozzles. The sensor provides the captured images to the control system **130** for further analysis. The control system **130** can determine a current position of the nozzle holder and the nozzles based on the captured images and

determine to adjust the nozzle holder based on the determined position.

(63) In alternative embodiments of a distribution manifold with sensors, the nozzle holder may comprise electrically conductive sections. For example, a surface of the nozzle holder adjacent to each nozzle may include a unique pattern of electrically conductive material. A probe (sensor) may be positioned adjacent to the valve such that contact with electrically conductive material closes a circuit. The control system **130** can determine a current position of the nozzle holder and the nozzles based on an evaluation of which circuit is closed. In some embodiments, ferrous materials may be incorporated into the nozzle holder at various known locations (e.g., adjacent to each nozzle) and may be sensed by the probe or another type of electro-magnetic sensor.

(64) In alternative embodiments of a distribution manifold with sensors, the nozzle holder may comprise a unique barcode located at known positions on the nozzle holder. For example, a surface of the nozzle holder adjacent to each nozzle may include a unique barcode. A sensor (e.g., barcode scanner) may be positioned adjacent to the valve such that the sensor can read the barcode(s). The sensor provides the readings to the control system **130** for further analysis. The control system **130** can determine a current position of the nozzle holder and the nozzles based on the readings and determine to adjust the nozzle holder based on the determined position.

IV. System Environment

(65) FIG. **7** is a block diagram of the system environment for the farming machine, in accordance with one or more example embodiments. In this example, the control system **730** is connected to a component array **720** and a user **705** via a network **710** within the system environment **700**.

(66) The component array **720** includes one or more components **722**. Components **722** are elements of the farming machine that can take farming actions. A component **722** may include a movement mechanism (e.g., the movement mechanism **330**) or any other suitable mechanism for rotating and/or translating a nozzle holder (e.g., the nozzle holder **350**, the nozzle holder **430**, the nozzle holder **530**, and the nozzle holder **630**). A component **722** may include a valve (e.g., valve **340**, valve **410**, valves **510**, **512**, **514**, and valve **610**) for controlling the flow of treatment fluid. Each component **722** may have one or more input controllers **724** and one or more sensors **726**, but a component **722** may include only sensors **726** or only input controllers **724**. An input controller **724** controls the function of the component. For example, an input controller **724** may receive machine commands via the network **710** from the control system **730** and actuate the component **722** in response. A sensor **726** generates measurements within the system environment **700**. The measurements may be of the component **722**, the farming machine **100**, or the environment surrounding the farming machine **100**. For example, a sensor **726** may measure a configuration or state of the component **722** (e.g., a positioning of the component **722**, a pressure within the component **722**, etc.), or measure an area surrounding a farming machine **100** (e.g., moisture, temperature, etc.).

(67) The control system **730** receives information from the user **705** and/or the component array **720** and generates farming actions. For example, a user **705** may provide plant treatment instructions to the control system **730**. The plant treatment instructions may include a treatment position for a nozzle holder of the plurality of nozzle holders. The treatment position for the nozzle holder is a position of the nozzle holder which enables the farming machine to provide the treatment corresponding to the treatment instruction. That is, in the treatment position the nozzle holder couples a nozzle that will apply the desired treatment to a valve. Additionally, each nozzle in a nozzle holder corresponds to a position of the nozzle holder that couples it to the valve. Each position may be a treatment position when the treatment instruction is for its corresponding nozzle. For example, a first position is associated with a fan nozzle and a second position is associated with a flat spray nozzle. The treatment position is the position associated with the desired nozzle (e.g., the first position with the fan nozzle).

(68) The plant treatment instructions may further include a type of application of treatment fluid and what treatment fluid to apply. The type of application describes how the treatment fluid is to be

dispensed. For example, the type of application may include an amount, a spray pattern, a pressure, a flow rate, and/or how far the treatment fluid should be dispensed and may include a broadcast application, a spot spraying application, etc. The spray pattern specifies a resolution of spray width (e.g., a 15″ wide spray pattern, a 5″ wide spray pattern, etc.), a droplet size, a droplet distribution profile (e.g., even, tapered, conical, etc.), and an angle of distribution. The pressure specifies a speed with which the treatment fluid is dispensed, and the flow rate specifies how much treatment fluid is to be applied. The treatment fluid to apply describes what type of treatment fluid is to be dispensed on the plants. For example, a treatment fluid may include an herbicide, a pesticide, etc.
(69) In one example embodiment, the control system **730** may employ a plant treatment module **732** to adjust a positioning of one or more nozzle holders of a treatment mechanism **120** and actuate the treatment of one or more plants. The plant treatment module **732** includes a position determination model **734**, a nozzle adjustment model **736**, and a treatment actuation model **738**.
(70) As described herein, the position determination model **734** identifies a current position of one or more nozzle holders of the treatment mechanism **120**. In some embodiments, the position determination model **734** may determine a position of a nozzle holder by receiving a measurement from a sensor **726** (e.g., sensor **620**). For example, the sensor measures a magnetic field produced by a plurality of magnets positioned in the nozzle holder. Each magnet produces a unique magnetic field and each magnet is associated with a particular nozzle on the nozzle holder. For example, the magnet may be associated with a particular position on the nozzle holder (e.g., first position, second position, etc.) or with a particular type of nozzle (e.g., fan nozzle, cone nozzle, etc.). In embodiments, with a sensor **726** (e.g., a Hall effect sensor) located in a known position (e.g., adjacent to a valve) and a unique magnet located adjacent to each nozzle on the nozzle holder, the position determination model **734** can determine a current position of the nozzle holder. In some embodiments, the position determination model **734** determines which nozzle of a plurality of nozzles is currently coupled to the valve based on the received measurements.
(71) The nozzle adjustment model **736** adjusts the positioning of one or more nozzle holders based on the determined current position of the nozzle holders. The nozzle adjustment model **736** provides instructions to one or more movement mechanisms to adjust their corresponding nozzle holders such that the nozzle holder(s) is adjusted from its current position to the treatment position. In some embodiments, the nozzle adjustment model **736** adjusts some but not all nozzle holders. For example, the farming machine may include a plurality of nozzle holders. The plurality of nozzle holders may be divided into two or more groups. The nozzle adjustment model **736** may provide instructions to adjust the positioning of a first group of nozzle holders from the current position to the treatment position and the positioning of a second group of nozzle holders may not be adjusted.
(72) In some embodiments, the nozzle adjustment model **736** determines to adjust the positioning of the nozzle holder based on a nozzle of the plurality of nozzles associated with the nozzle holder being inoperable or unable to dispense treatment fluid (e.g., by being clogged or blocked). For example, the nozzle adjustment model **736** may receive a signal from one or more sensors **726** that measure pressure and/or measure flow rate in certain components **722** of the treatment mechanism (e.g., a valve or a nozzle currently coupled to a valve). The measurements may indicate that a currently coupled nozzle (e.g., a nozzle currently coupled to the valve) is clogged due to a measurement being greater than (or less than) a threshold measurement. As such, the nozzle adjustment model **736** determines to adjust the positioning of the nozzle holder associated with the clogged nozzle from its current position to a different position where a different nozzle is coupled to the valve. In another example, the nozzle adjustment model **736** may receive one or more captured images from one or more sensors **726** (e.g., cameras) that illustrate certain components **722** of the treatment mechanism (e.g., the nozzle currently coupled to the valve). The captured images may indicate that the currently coupled nozzle is clogged (e.g., little to no treatment fluid is dispensed) or worn-out (e.g., amount of dispensed treatment fluid is greater than type of application

specified in plant treatment instructions). As such, the nozzle adjustment model **736** determines to adjust the positioning of the nozzle holder associated with the clogged or worn-out nozzle from its current position to a different position where a different nozzle is then coupled to the valve.

(73) The treatment actuation model **738** provides actuation instructions to the component array **720** to begin treating the plants. In some embodiments, the treatment actuation model **738** provides actuation instructions that instruct certain valves (some but not all) to begin dispensing treatment fluid based on the plant treatment instructions. In some embodiments, the treatment actuation model **738** provides actuation instructions that instruct some or all the valves to continuously dispense treatment fluid for a period of time. For example, the plant treatment instructions include a type of application of treatment fluid to be a broadcast application. The treatment actuation model **738** may provide actuation instructions to the component array **720** for the valves to continuously dispense treatment fluid. In some embodiments, the actuation instructions instruct the valves to briefly dispense treatment fluid. For example, the plant treatment instructions include a type of application of treatment fluid to be spot spraying. The treatment actuation model **738** provides actuation instructions to the component array **720** for the valves to dispense treatment fluid for a short period of time. In some embodiments, the treatment actuation model **738** provides actuation instructions that instruct a flow rate for one or more valves. For example, the plant treatment instructions include flow rate for dispensing the treatment fluid. The treatment actuation model **738** provides actuation instructions to the component array **720** to adjust the flow rate accordingly. In some embodiments, the treatment actuation model **738** provides actuation instructions to the component array **720** based on other signals from one or more sensors **726**. The signals may include measurements associated with atmospheric pressure, wind, air temperature, velocity of farming machine, etc. In some embodiments, the treatment actuation model **738** may compare the measurements to various threshold measurement values to determine appropriate actuation instructions (e.g., enabling or disabling certain values, flow rate, etc.) to provide to the component array **720**.

(74) The network **710** connects nodes of the system environment **700** to allow microcontrollers and devices to communicate with each other. In some embodiments, the components are connected within the network **710** as a Controller Access Network (CAN). In this case, within the CAN each element has an input and output connection, and the CAN may translate information between the various elements. For example, the CAN receives input information from the component array **720**, processes the information, and transmits the information to the control system **730**. The control system **730** generates a farming action based on the information and transmits instructions to implement the farming action to the appropriate component(s) **722** of the component array **720**.

(75) Additionally, the system environment **700** may be other types network environments and include other networks, or a combination of network environments with several networks. For example, the system environment **700**, can be a network such as the Internet, a LAN, a MAN, a WAN, a mobile wired or wireless network, a private network, a virtual private network, a direct communication line, and the like.

V. Treating a Plant

(76) FIG. **8** is a flow chart illustrating a method of treating a plant, in accordance with an example embodiment. The method **800** may be performed from the perspective of the control system **130**. The method **800** can include greater or fewer steps than described herein. Additionally, the steps can be performed in different order, or by different components than described herein.

(77) The control system **130** receives **810** a plant treatment instruction for treating a plant. The plant treatment instruction may include a treatment position for a nozzle holder. The treatment position allows a nozzle of a plurality of nozzles included in the nozzle holder to apply a treatment to the plant. The plant treatment instruction may further include a type of application of treatment fluid, what treatment fluid to apply, and a flow rate for dispensing the treatment fluid.

(78) The control system **130** determines **820** a current position of the nozzle holder in the treatment

mechanism. To do so, in one embodiment, the control system **130** receives a magnetic field measurement produced by one or more magnets positioned in the nozzle holder. The control system **130** identifies the current position of the nozzle holder based on the measurement of the magnetic field. In some embodiments, the control system **130** may determine which nozzle of the plurality of nozzles is currently coupled to a valve.

(79) The control system **130** automatically adjusts **830** the current position of the nozzle holder to the treatment position such that the nozzle can apply the treatment to the plant. In some embodiments, the control system **130** automatically adjusts the current position of a nozzle holder in a first group of nozzle holders to the treatment position and maintains a current position of other nozzle holders in a second group of nozzle holders. In some embodiments, the control system **130** may determine a nozzle of the plurality of nozzles associated with the nozzle holder is unable to dispense fluid. For example, the control system **130** may receive a pressure measurement from a sensor (e.g., a pressure sensor) at the nozzle and/or at the valve. The control system **130** may automatically adjust the current position of the nozzle holder such that a different nozzle of the plurality of nozzles can apply the treatment to the plant.

(80) The control system **130** actuates **840** the treatment mechanism such that the plant is treated via the nozzle while the nozzle holder is in the treatment position.

VI. Control System

(81) FIG. **9** is a block diagram illustrating components of an example machine for reading and executing instructions from a machine-readable medium. Specifically, FIG. **9** shows a diagrammatic representation of control system **130** in the example form of a computer system **900**. The computer system **900** can be used to execute instructions **924** (e.g., program code or software) for causing the machine to perform any one or more of the methodologies (or processes) described herein. In alternative embodiments, the machine operates as a standalone device or a connected (e.g., networked) device that connects to other machines. In a networked deployment, the machine may operate in the capacity of a server machine or a client machine in a server-client network environment, or as a peer machine in a peer-to-peer (or distributed) network environment.

(82) The machine may be a server computer, a client computer, a personal computer (PC), a tablet PC, a set-top box (STB), a smartphone, an internet of things (IoT) appliance, a network router, switch or bridge, or any machine capable of executing instructions **924** (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term “machine” shall also be taken to include any collection of machines that individually or jointly execute instructions **924** to perform any one or more of the methodologies discussed herein.

(83) The example computer system **900** includes one or more processing units (generally processor **902**). The processor **902** is, for example, a central processing unit (CPU), a graphics processing unit (GPU), a digital signal processor (DSP), a control system, a state machine, one or more application specific integrated circuits (ASICs), one or more radio-frequency integrated circuits (RFICs), or any combination of these. The computer system **900** also includes a main memory **904**. The computer system may include a storage unit **916**. The processor **902**, memory **904**, and the storage unit **916** communicate via a bus **908**.

(84) In addition, the computer system **900** can include a static memory **906**, a graphics display **910** (e.g., to drive a plasma display panel (PDP), a liquid crystal display (LCD), or a projector). The computer system **900** may also include alphanumeric input device **912** (e.g., a keyboard), a cursor control device **914** (e.g., a mouse, a trackball, a joystick, a motion sensor, or other pointing instrument), a signal generation device **918** (e.g., a speaker), and a network interface device **920**, which also are configured to communicate via the bus **908**.

(85) The storage unit **916** includes a machine-readable medium **922** on which is stored instructions **924** (e.g., software) embodying any one or more of the methodologies or functions described herein. For example, the instructions **924** may include the functionalities of modules of the control system **130** described in FIGS. **1**A-**1**C, **7** and **8**. The instructions **924** may also reside, completely or

at least partially, within the main memory **904** or within the processor **902** (e.g., within a processor's cache memory) during execution thereof by the computer system **900**, the main memory **904** and the processor **902** also constituting machine-readable media. The instructions **924** may be transmitted or received over a network **926** via the network interface device **920**.

VII. Additional Considerations

(86) In the description above, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the illustrated system and its operations. It will be apparent, however, to one skilled in the art that the system can be operated without these specific details. In other instances, structures and devices are shown in block diagram form in order to avoid obscuring the system.

(87) Reference in the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the system. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

(88) Some portions of the detailed descriptions are presented in terms of algorithms or models and symbolic representations of operations on data bits within a computer memory. An algorithm is here, and generally, conceived to be steps leading to a desired result. The steps are those requiring physical transformations or manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

(89) It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

(90) Some of the operations described herein are performed by a computer physically mounted within a machine. This computer may be specially constructed for the required purposes, or it may comprise a general-purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of non-transitory computer readable storage medium suitable for storing electronic instructions.

(91) The figures and the description above relate to various embodiments by way of illustration only. It should be noted that from the following discussion, alternative embodiments of the structures and methods disclosed herein will be readily recognized as viable alternatives that may be employed without departing from the principles of what is claimed.

(92) One or more embodiments have been described above, examples of which are illustrated in the accompanying figures. It is noted that wherever practicable similar or like reference numbers may be used in the figures and may indicate similar or like functionality. The figures depict embodiments of the disclosed system (or method) for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the

structures and methods illustrated herein may be employed without departing from the principles described herein.
(93) Some embodiments may be described using the expression “coupled” and “connected” along with their derivatives. It should be understood that these terms are not intended as synonyms for each other. For example, some embodiments may be described using the term “connected” to indicate that two or more elements are in direct physical or electrical contact with each other. In another example, some embodiments may be described using the term “coupled” to indicate that two or more elements are in direct physical or electrical contact. The term “coupled,” however, may also mean that two or more elements are not in direct physical or electrical contact with each other, but yet still co-operate or interact with each other. The embodiments are not limited in this context.
(94) As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such process, method, article or apparatus. Further, unless expressly stated to the contrary, “or” refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B is true (or present).
(95) In addition, use of the “a” or “an” are employed to describe elements and components of the embodiments herein. This is done merely for convenience and to give a general sense of the system. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.
(96) Upon reading this disclosure, those of skill in the art will appreciate still additional alternative structural and functional designs for a system and a process for identifying and treating plants with a farming machine including a control system executing a semantic segmentation model. Thus, while particular embodiments and applications have been illustrated and described, it is to be understood that the disclosed embodiments are not limited to the precise construction and components disclosed herein. Various modifications, changes and variations, which will be apparent to those, skilled in the art, may be made in the arrangement, operation and details of the method and apparatus disclosed herein without departing from the spirit and scope defined in the appended claims.

Claims

1. A method for treating a plant in a field by a farming machine that moves through the field, the farming machine comprising a treatment mechanism for treating the plant in the field, and the treatment mechanism comprising a plurality of nozzle holders with each nozzle holder comprising a plurality of nozzles and each of the nozzles corresponding to a unique magnet having a unique magnetic field, the method comprising: receiving a plant treatment instruction for treating the plant, the plant treatment instruction comprising a treatment nozzle of the plurality of nozzles having a treatment position in a nozzle holder of the plurality of nozzle holders, the treatment position allowing the treatment nozzle to apply a treatment to the plant in the field; determining a current nozzle of the plurality of nozzles in a current position of the nozzle holder in the treatment mechanism by: measuring a unique magnetic field produced by a unique magnet corresponding to the current nozzle, and identifying the current nozzle in the current position of the nozzle holder based on the measurement of the unique magnetic field; automatically exchanging the current nozzle for the treatment nozzle by adjusting the current position of the nozzle holder to the treatment position such that the treatment nozzle can apply the treatment to the plant in the field; and actuating, based on the plant treatment instruction, the treatment mechanism such that the plant

is treated via the treatment nozzle while the nozzle holder is in the treatment position as the farming machine moves past the plant in the field.

2. The method of claim 1, wherein the treatment mechanism further comprises a valve, and wherein determining the current position of the nozzle holder in the treatment mechanism further comprises determining which nozzle of the plurality of nozzles is currently coupled to the valve.

3. The method of claim 1, wherein the plurality of nozzle holders are divided into at least a first group of nozzle holders and a second group of nozzles holders, and wherein automatically adjusting the current position of the nozzle holder to the treatment position comprises adjusting the current position of each nozzle holder in the first group of nozzle holders to the treatment position and maintaining a position of each nozzle holder in the second group of nozzle holders.

4. The method of claim 1, wherein the plurality of nozzle holders are divided into a least a first group of nozzle holders and a second group of nozzle holders, and wherein actuating, based on the plant treatment instruction, the treatment mechanism further comprises dispensing fluid from a nozzle of the plurality of nozzles associated with the first group of nozzle holders.

5. The method of claim 1, wherein the plant treatment instruction further comprises a flow rate for the treatment mechanism, and the method further comprising: adjusting the flow rate of the treatment mechanism prior to actuating the treatment mechanism.

6. The method of claim 1, wherein the plant is treated via the treatment nozzle with at least one of an herbicide treatment, a pesticide treatment, a fungicide treatment, or a fertilizer treatment.

7. The method of claim 1, wherein the treatment mechanism comprises a valve, and the method further comprising: determining the treatment nozzle is unable to dispense fluid; and automatically adjusting the nozzle holder such that a different nozzle of the plurality of nozzles can apply the treatment to the plant in the field.

8. The method of claim 1, further comprising: capturing, using a detection mechanism, an image of the plant in the field as the farming machine moves through the field; identifying, based on the image, the plant in the field; and generating the plant treatment instruction for treating the plant.

9. The method of claim 1, further comprising: selecting the treatment position for the plant treatment instruction based on spray pattern for each nozzle in the plurality of nozzles.

10. The method of claim 1, further comprising: selecting the treatment position for the plant treatment instruction based on droplet size for each nozzle in the plurality of nozzles.

11. The method of claim 1, further comprising: selecting the treatment position for the plant treatment instruction based on flow rate for each nozzle in the plurality of nozzles.

12. The method of claim 1, further comprising: selecting the treatment position for the plant treatment instruction based on orientation for each nozzle in the plurality of nozzles.

13. The method of claim 1, further comprising: selecting the treatment position for the plant treatment instruction based on a treatment type of the treatment.

14. The method of claim 1, further comprising: selecting the treatment position for the plant treatment instruction based on a treatment fluid of the treatment.

15. The method of claim 1, further comprising: selecting the treatment position for the plant treatment instruction based on a type of the plant.