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## Systems comprising agricultural implements connected to lifting hitches and related control systems and methods

### Abstract

A system includes a tractor comprising a lifting hitch, and an implement comprising an implement frame carried by the lifting hitch. The implement frame has an integrated elongate toolbar carrying at least one row unit. A sensor is configured to sense a position of the at least one row unit relative to the ground. A control system is configured to receive a signal related to the sensed position of the at least one row unit relative to the ground and cause the lifting hitch to raise or lower a portion of the implement frame connected to the lifting hitch relative to the tractor based at least in part on the signal. Control systems and related methods are also disclosed.

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## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) This application claims the benefit of the filing date of U.S. Provisional Patent Application 63/007,130, “Systems Comprising Agricultural Implements Connected to Lifting Hitches and Related Control Systems and Methods,” filed Apr. 8, 2020, the entire disclosure of which is incorporated herein by reference.

FIELD
(1) Embodiments of the present disclosure relate generally to machines and methods for working agricultural fields. In particular, embodiments relate to implements (e.g., planters, tillage, etc.) and to methods of controlling such implements.
BACKGROUND
(2) Crop yields are affected by a variety of factors, such as seed placement, soil quality, weather, irrigation, and nutrient applications. Seeds are typically planted in trenches formed by discs or other mechanisms of a planter row unit. Depth of seed placement is important because seeds planted at different depths emerge at different times, resulting in uneven crop growth. Trench depth can be affected by soil type, moisture level, row unit speed, and operation of the opening discs. It would be beneficial to have improved methods of controlling the location of planter row units so that seeds can be more precisely placed in a field.
BRIEF SUMMARY
(3) In some embodiments, a system includes a tractor comprising a lifting hitch, and an implement comprising an implement frame carried by the lifting hitch. The implement frame has an integrated elongate toolbar carrying at least one row unit. A sensor is configured to sense a position of the at least one row unit relative to the ground. A control system is configured to receive a signal related to the sensed position of the at least one row unit relative to the ground and cause the lifting hitch to raise or lower a portion of the implement frame connected to the lifting hitch relative to the tractor based at least in part on the signal.
(4) Other embodiments include a control system for a tractor having a lifting hitch and an implement having a frame carried by the lifting hitch. The frame has an integrated elongate toolbar carrying at least one row unit. The control system includes a sensor configured to sense a position of the at least one row unit relative to the ground, and a controller configured to receive a signal from the sensor indicating the position of the at least one row unit relative to the ground and raise or lower the lifting hitch based on the sensed position of the at least one row unit.
(5) Certain embodiments include a computer-implemented method for operating a tractor having a lifting hitch and an implement having a frame carried by the lifting hitch, the frame having an integrated elongate toolbar carrying at least one row unit. The method includes receiving an indication of a position of the at least one row unit relative to the ground sensed by a sensor, and causing the lifting hitch to raise or lower the implement frame relative to the tractor based at least in part on the indication of the position of the at least one row unit.

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## Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) While the specification concludes with claims particularly pointing out and distinctly claiming what are regarded as embodiments of the present disclosure, various features and advantages of embodiments of the disclosure may be more readily ascertained from the following description of

example embodiments when read in conjunction with the accompanying drawings, in which:
(2) FIG. **1** is a simplified side view of a tractor pulling an implement in accordance with one embodiment;
(3) FIG. **2** is a simplified side view of the tractor pulling the implement shown in FIG. **1**, wherein the tractor is at a higher elevation than the implement;
(4) FIG. **3** is a simplified rear view the implement shown in FIG. **1** on level ground;
(5) FIG. **4** is a simplified rear view the implement shown in FIG. **1** on sloped ground;
(6) FIG. **5** is a simplified flow chart illustrating a method of operating a tractor and implement; and
(7) FIG. **6** illustrates an example computer-readable storage medium comprising processor-executable instructions configured to embody one or more of the methods of operating a tractor and implement, such as the method illustrated in FIG. **5**.

DETAILED DESCRIPTION

(8) The illustrations presented herein are not actual views of any tillage implement or portion thereof, but are merely idealized representations that are employed to describe example embodiments of the present disclosure. Additionally, elements common between figures may retain the same numerical designation.

(9) The following description provides specific details of embodiments of the present disclosure in order to provide a thorough description thereof. However, a person of ordinary skill in the art will understand that the embodiments of the disclosure may be practiced without employing many such specific details. Indeed, the embodiments of the disclosure may be practiced in conjunction with conventional techniques employed in the industry. In addition, the description provided below does not include all elements to form a complete structure or assembly. Only those process acts and structures necessary to understand the embodiments of the disclosure are described in detail below. Additional conventional acts and structures may be used. Also note, the drawings accompanying the application are for illustrative purposes only, and are thus not drawn to scale.

(10) As used herein, the terms “comprising,” “including,” “containing,” “characterized by,” and grammatical equivalents thereof are inclusive or open-ended terms that do not exclude additional, unrecited elements or method steps, but also include the more restrictive terms “consisting of” and “consisting essentially of” and grammatical equivalents thereof.

(11) As used herein, the term “may” with respect to a material, structure, feature, or method act indicates that such is contemplated for use in implementation of an embodiment of the disclosure, and such term is used in preference to the more restrictive term “is” so as to avoid any implication that other, compatible materials, structures, features, and methods usable in combination therewith should or must be excluded.

(12) As used herein, the term “configured” refers to a size, shape, material composition, and arrangement of one or more of at least one structure and at least one apparatus facilitating operation of one or more of the structure and the apparatus in a predetermined way.

(13) As used herein, the singular forms following “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise.

(14) As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

(15) As used herein, spatially relative terms, such as “beneath,” “below,” “lower,” “bottom,” “above,” “upper,” “top,” “front,” “rear,” “left,” “right,” and the like, may be used for ease of description to describe one element's or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Unless otherwise specified, the spatially relative terms are intended to encompass different orientations of the materials in addition to the orientation depicted in the figures.

(16) As used herein, the term “substantially” in reference to a given parameter, property, or condition means and includes to a degree that one of ordinary skill in the art would understand that the given parameter, property, or condition is met with a degree of variance, such as within

acceptable manufacturing tolerances. By way of example, depending on the particular parameter, property, or condition that is substantially met, the parameter, property, or condition may be at least 90.0% met, at least 95.0% met, at least 99.0% met, or even at least 99.9% met.

(17) As used herein, the term “about” used in reference to a given parameter is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the given parameter).

(18) FIG. **1** is a simplified side view of a system **100** including a tractor **102** and an implement **120**. The tractor **102** includes a chassis **104** supported by wheels **106** and/or tracks. An operator cab **108** is typically supported by the chassis **104** and includes a control system **110** that may control operation of the tractor **102** and/or the implement **120**. In some embodiments, the operator cab **108** may be omitted if the tractor **102** is configured to function without an onboard human operator (e.g., as a remotely operated drone or a computer-operated machine). The control system **110** may include a central processing unit (“CPU”), memory, and graphical user interface (“GUI”) (e.g., a touch-screen interface). A global positioning system (“GPS”) receiver may be mounted to the tractor **102** and connected to communicate with the control system **110**. The tractor **102** has a power source **112** configured to move the wheels **106**, which may include an internal combustion engine, an electric motor, or other source. The power source **112** may also provide power to a lifting hitch **114** carried by the tractor **102**. Note that one of the rear wheels **106** has been omitted from view to more clearly show the lifting hitch **114**. The lifting hitch **114** may be a 3-point hitch commonly carried by agricultural and other tractors.

(19) The lifting hitch **114** may be attached to the chassis **104** and include two lower lifting arms **116** to which the implement **120** may be attached. An additional top link **118** (depicted in FIG. **1** as a piston-type actuator) may connect the implement **120** to the tractor **102**.

(20) As shown in FIG. **1**, the implement **120** has a frame **122** including an integrated toolbar **124** supporting row units **126**. That is, the frame **122** and the toolbar **124** may form a rigid structure. The row units **126** may be any type of ground-engaging device for planting, seeding, fertilizing, tilling, or otherwise working crops or soil, typically in rows. As an example, the row unit **126** is shown in the form of a planter row unit. The row unit **126** has a body **128** pivotally connected to the toolbar **124** by a parallel linkage **130**, enabling the row unit **126** to move vertically independent of the toolbar **124**. In some embodiments, the body **128** of the row unit **126** may be connected to the toolbar **124** by another structure, such as a rotating arm. The body **128** may be a unitary member, or may include one or more members coupled together (e.g., by bolts, welds, etc.). The body **128** operably supports one or more hoppers **132**, a seed meter **134**, a seed delivery mechanism **136**, a seed trench opening assembly **138**, a trench closing assembly **140**, and any other components as known in the art. It should be understood that the row unit **126** shown in FIG. **1** may optionally be a part of a central fill planter, in which case the hoppers **132** may be one or more mini-hoppers fed by a central hopper carried by the implement **120**.

(21) At least one sensor **142** and/or **144** may be used to determine a position of a row unit **126** relative to the ground. In some embodiments, the sensor(s) **142**, **144** may be carried on the body **128** of the row unit **126** itself. In other embodiments, sensor(s) may be carried by the toolbar **124**, the tractor **102**, or even by another vehicle (e.g., another ground vehicle, an unmanned aerial vehicle, etc.). The sensor **142** may be a rotary sensor configured to measure an angle of an element of the parallel linkage **130** relative to the body **128** of the row unit **126** or to the toolbar **124**, and may be connected to a pivot point of the body **128** of the row unit **126** or to the toolbar **124**. In some embodiments, an additional sensor **145** may be configured to detect the position of the toolbar **104** relative to the ground.

(22) The sensor(s) **144**, **145** depicted may include a non-contact depth sensor, for example, an optical sensor, an ultrasonic transducer, an RF (radio frequency) sensor, lidar, radar, etc. Such sensors are described in, for example, U.S. Patent Application Publication 2019/0075710, “Seed Trench Depth Detection Systems,” published Mar. 14, 2019.

(23) The sensor(s) **142**, **144**, **145** may provide information to the control system **110**, which information can be used by the control system **110** to determine how to adjust the lifting hitch **114**. That is, the control system **110** is configured to receive a signal (e.g., a wired or wireless signal) related to the position of the row unit **126** relative to the ground and cause the lifting hitch **114** to raise or lower a portion of the frame **122** connected to the lifting hitch **114** relative to the tractor **102** based at least in part on the signal.
(24) Movement of the lifting hitch **114** changes the position of the frame **122** and the toolbar **124** relative to the ground. The top link **118** may be used to change an angle of the frame **122** and the toolbar **124**, and to control an orientation and position of the implement **120** relative to the tractor **102**. Thus, the lifting hitch **114** may be used to raise or lower the toolbar **124** and independently change an angle of the toolbar **124** relative to the ground. The lifting hitch **114** may be configured such that upward movement of the lifting hitch **114** can cause upward movement of an entirety of the implement frame **122**. Movement of the top link **118** separate from the lifting arms **116** may cause a change in the orientation of the frame **122**.
(25) As depicted in FIG. **2**, when the tractor **102** encounters a change in field elevation and/or slope, the sensor(s) **142**, **144**, **145** may provide a signal to the control system **110**, and the control system **110** may use that signal to calculate how to change the position of the implement frame **122** to maintain a preselected position of the toolbar **124** and/or the row unit **126**. For example, the lifting hitch **114** may lower the implement frame **122** as the tractor **102** goes up a slope, and after the row unit **126** goes up the slope, the lifting hitch **114** may raise the implement frame **122** back to its prior position. The parallel linkages **130** of each row unit **126** may also adjust to move the row units **126** independent of one another. As depicted in FIG. **2**, movement of the lifting hitch **114** may be performed while maintaining a preselected orientation of the toolbar **124** by moving both the lifting arms **116** and the top link **118**.
(26) The implement **120** may not have any tires coupled to the toolbar **124** for supporting the weight of the implement **120**. Thus, the weight of the implement **120** may be supported by the lifting hitch **114**. In some embodiments, the row units **126** may include wheels in contact with the ground, such as in the seed trench opening assembly **138** or the trench closing assembly **140**. Such wheels may support a portion of the weight of the implement **120**. However, the implement **120** depicted lacks wheels or other ground support other than the row units **126**.
(27) The height of each row unit **126** may be adjusted independently of the other row units **126** by adjusting the individual parallel linkages **130**. In certain field terrain, each parallel linkage **130** may be adjusted within its operating range such that each row unit **126** interacts with the ground at a preselected position. Movement of the toolbar **124** based on the lifting hitch **114** can increase the effective range of height of the row units **126** relative to the tractor **102**. Thus, the implement **120** in combination with the tractor **102** as described may effectively be used to work fields having contours that are steeper than contours that can be effectively worked by conventional implements.
(28) FIG. **3** shows a simplified rear view of the implement **120** traveling over level ground. The lifting hitch **114** (FIG. **1**) is adjusted such that the row units **126** may each engage the ground by appropriate adjustment of the parallel linkages **130**. The parallel linkages **130** may adjust the depth at which individual row units **126** operate (e.g., plant seeds) in the ground.
(29) FIG. **4** shows a simplified rear view of the implement **120** traveling over sloped ground, and illustrates how the implement **120** may adjust to different terrain. In FIG. **4**, the ground at the left-hand side is sloped upward from the center, and the ground at the right-hand side is level. The toolbar **124** may be coupled to one or more adjustable wing sections **124*a*** that can flex (i.e., move relative to the toolbar **124**) to match different terrain, such as described in U.S. Pat. No. 10,582,654, "Implement Load Balancing System," issued Mar. 10, 2020. One or more actuators **302** may raise or lower the wing section **124*a*** such that the row units **126** carried by that wing section **124*a*** remain at a preselected position with respect to the ground. That is, in addition to the parallel linkage **130**, which is adjustable on a per-row-unit basis, the actuator **302** and the lifting

hitch **114** may adjust the height and/or angle of the toolbar **124** or wing section(s) **124***a*, based at least in part on the sensed positions of the row units **126**. Adjustment of the actuator **302** provides an additional range of adjustment beyond that provided by the parallel linkages **130** and the lifting hitch **114**. That is, the row units **126** may be adjusted by moving the toolbar **124** upward or downward (i.e., by moving the lifting hitch **114**), by moving the actuator **302**, and by moving the row units **126** with respect to the toolbar **124** (i.e., by rotating the parallel linkage **130**). Thus, each row unit **126** may exhibit a wider total range of motion than an implement **120** having only the parallel linkage **130** to adjust the height of the row unit **126** with respect to the tractor **102**.
(30) Typically, there may be multiple row units **126** on each of the toolbar **124** and the wing section(s) **124***a*. Thus, movement of the actuator **302** typically changes the position of the multiple row units **126**. The control system **110** may calculate an appropriate position of the actuator **302**, the lifting hitch **114**, and the parallel linkages **130** so that the row units **126** on the toolbar **124** and the wing section(s) **124***a* can each be at a preselected depth. That is, the control system **110** may select an actuator position and a hitch position such that the row units **126** can each be adjusted with the parallel linkages **130** to be at a preselected depth. The actuator **302** may enable a wider range of operating conditions (e.g., maximum field slope variation) than conventional wing control systems and may enable the control system **110** to respond more quickly to changing field terrain.
(31) Though the implement **120** is described herein as a planter, other types of implements may have other types of row units, such as tillage implements (e.g., disc harrows, chisel plows, field cultivators, etc.) and seeding tools (e.g., grain drills, disc drills, etc.).
(32) FIG. **5** is a simplified flow chart illustrating a computer-implemented method **500** of using the implement **120** to work an agricultural field. In block **502**, an indication is received of a position of at least one row unit relative to ground sensed by a sensor. For example, a signal from the sensor may be received by a controller. In block **504**, a lifting hitch raises or lowers an implement frame based at least in part on a sensed position of the at least one row unit. For example, a signal may be sent to a control component associated with the tractor **102**. In some embodiments, the orientation of the toolbar may be maintained when the implement frame is raised or lowered.
(33) Still other embodiments involve a computer-readable storage medium (e.g., a non-transitory computer-readable storage medium) having processor-executable instructions configured to implement one or more of the techniques presented herein. An example computer-readable medium that may be devised is illustrated in FIG. **6**, wherein an implementation **600** includes a computer-readable storage medium **602** (e.g., a flash drive, CD-R, DVD-R, application-specific integrated circuit (ASIC), field-programmable gate array (FPGA), a platter of a hard disk drive, etc.), on which is computer-readable data **604**. This computer-readable data **604** in turn includes a set of processor-executable instructions **606** configured to operate according to one or more of the principles set forth herein. In some embodiments, the processor-executable instructions **606** may be configured to cause a computer associated with the tractor **102** (FIG. **1**) to perform operations **608** when executed via a processing unit, such as at least some of the example method **500** depicted in FIG. **5**. In other embodiments, the processor-executable instructions **606** may be configured to control a system, such as at least some of the example system **100** depicted in FIG. **1**. Many such computer-readable media may be devised by those of ordinary skill in the art that are configured to operate in accordance with one or more of the techniques presented herein.
(34) Additional non limiting example embodiments of the disclosure are described below.
(35) Embodiment 1: A system comprising a tractor comprising a lifting hitch, an implement comprising an implement frame carried by the lifting hitch, the implement frame having an integrated elongate toolbar carrying at least one row unit, a sensor configured to sense a position of the at least one row unit relative to ground, and a control system configured to receive a signal related to the sensed position of the at least one row unit relative to the ground and cause the lifting hitch to raise or lower at least a portion of the implement frame connected to the lifting hitch relative to the tractor based at least in part on the signal.

(36) Embodiment 2: The system of Embodiment 1, wherein the lifting hitch comprises a 3-point hitch.
(37) Embodiment 3: The system of Embodiment 2, wherein the lifting hitch is configured to control an orientation and position of the implement frame relative to the tractor.
(38) Embodiment 4: The system of Embodiment 2 or Embodiment 3, wherein the lifting hitch is configured such that upward movement of the lifting hitch causes upward movement of an entirety of the implement frame.
(39) Embodiment 5: The system of any one of Embodiment 1 through Embodiment 4, wherein the at least one row unit is coupled to the toolbar by a parallel linkage.
(40) Embodiment 6: The system of Embodiment 5, wherein the sensor comprises a rotary sensor configured to measure an angle of an element of the parallel linkage.
(41) Embodiment 7: The system of any one of Embodiment 1 through Embodiment 6, wherein the sensor comprises an ultrasonic, lidar, or radar sensor.
(42) Embodiment 8: The system of any one of Embodiment 1 through Embodiment 7, further comprising at least one adjustable wing section rotatably coupled to the toolbar.
(43) Embodiment 9: The system of Embodiment 8, further comprising an actuator configured to raise or lower the at least one wing section of the toolbar.
(44) Embodiment 10: The system of Embodiment 9, wherein the control system is configured to control the actuator based at least in part on the sensed position of the at least one row unit.
(45) Embodiment 11: The system of any one of Embodiment 1 through Embodiment 10, wherein a weight of the implement frame is supported by the lifting hitch.
(46) Embodiment 12: The system of any one of Embodiment 1 through Embodiment 11, wherein the implement frame is not supported by tires connected to the implement frame.
(47) Embodiment 13: A control system for a tractor having a lifting hitch and an implement having a frame carried by the lifting hitch, the frame having an integrated elongate toolbar carrying at least one row unit. The control system comprises a sensor configured to sense a position of the at least one row unit relative to ground, and a controller configured to receive a signal from the sensor indicating the position of the at least one row unit relative to the ground and raise or lower the lifting hitch based on the sensed position of the at least one row unit.
(48) Embodiment 14: A computer-implemented method for operating a tractor having a lifting hitch and an implement having a frame carried by the lifting hitch, the frame having an integrated elongate toolbar carrying at least one row unit. The method comprises receiving an indication of a position of the at least one row unit relative to ground sensed by a sensor, and causing the lifting hitch to raise or lower the implement frame relative to the tractor based at least in part on the indication of the position of the at least one row unit.
(49) Embodiment 15: The method of Embodiment 14, wherein receiving an indication of a position of the at least one row unit relative to ground sensed by a sensor comprises receiving a signal from the sensor.
(50) Embodiment 16: The method of Embodiment 14 or Embodiment 15, wherein causing the lifting hitch to raise or lower the implement frame relative to the tractor comprises maintaining a preselected orientation of the toolbar.
(51) The structures and methods shown and described herein may be used in conjunction with those shown in U.S. Provisional Patent Application 60/007,114, “Agricultural Implements Having Row Unit Position Sensors and at Least One Adjustable Wheel, and Related Control Systems and Methods,” filed Apr. 8, 2020; U.S. Provisional Patent Application 63/007,152, “Agricultural Implements Having Row Unit Position Sensors and a Rotatable Implement Frame, and Related Control Systems and Methods,” filed Apr. 8, 2020; and U.S. Provisional Patent Application 63/007,182, “Agricultural Implements Having Row Unit Position Sensors and Actuators Configured to Rotate Toolbars, and Related Control Systems and Methods,” filed Apr. 8, 2020. All references cited herein are incorporated herein in their entireties. If there is a conflict between

definitions herein and in an incorporated reference, the definition herein shall control.
(52) While the present invention has been described herein with respect to certain illustrated embodiments, those of ordinary skill in the art will recognize and appreciate that it is not so limited. Rather, many additions, deletions, and modifications to the illustrated embodiments may be made without departing from the scope of the invention as hereinafter claimed, including legal equivalents thereof. In addition, features from one embodiment may be combined with features of another embodiment while still being encompassed within the scope of the invention as contemplated by the inventors. Further, embodiments of the disclosure have utility with different and various agricultural machine types and configurations.

## Claims

1. A system, comprising: a tractor comprising a lifting hitch; an implement comprising an implement frame carried by the lifting hitch, the implement frame having an integrated elongate toolbar carrying a plurality of planter row units, wherein the implement frame is not supported by tires connected to the implement frame; a sensor configured to sense a position of at least one planter row unit relative to ground; and a control system configured to receive a signal related to the sensed position of the at least one planter row unit relative to the ground and cause the lifting hitch to raise or lower at least a portion of the implement frame connected to the lifting hitch relative to the tractor based at least in part on the signal.
2. The system of claim 1, wherein the lifting hitch comprises a 3-point hitch.
3. The system of claim 2, wherein the lifting hitch is configured to control an orientation and position of the implement frame relative to the tractor.
4. The system of claim 2, wherein the lifting hitch is configured such that upward movement of the lifting hitch causes upward movement of an entirety of the implement frame.
5. The system of claim 1, wherein each planter row unit of the plurality is coupled to the toolbar by a parallel linkage.
6. The system of claim 5, wherein the sensor comprises a rotary sensor configured to measure an angle of an element of the parallel linkage.
7. The system of claim 1, wherein the sensor comprises an ultrasonic, lidar, or radar sensor.
8. The system of claim 1, further comprising at least one adjustable wing section rotatably coupled to the toolbar.
9. The system of claim 8, further comprising an actuator configured to raise or lower the at least one wing section relative to the toolbar.
10. The system of claim 9, wherein the control system is configured to control the actuator based at least in part on the sensed position of the at least one planter row unit.
11. The system of claim 1, wherein a weight of the implement frame is supported by the lifting hitch.
12. The system of claim 1, wherein each planter row unit comprises a seed meter.
13. The system of claim 1, wherein each planter row unit comprises at least one wheel configured to be in contact with the ground.