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(54) Title: PATH PLANNING WITH FIELD ATTRIBUTE INFORMATION

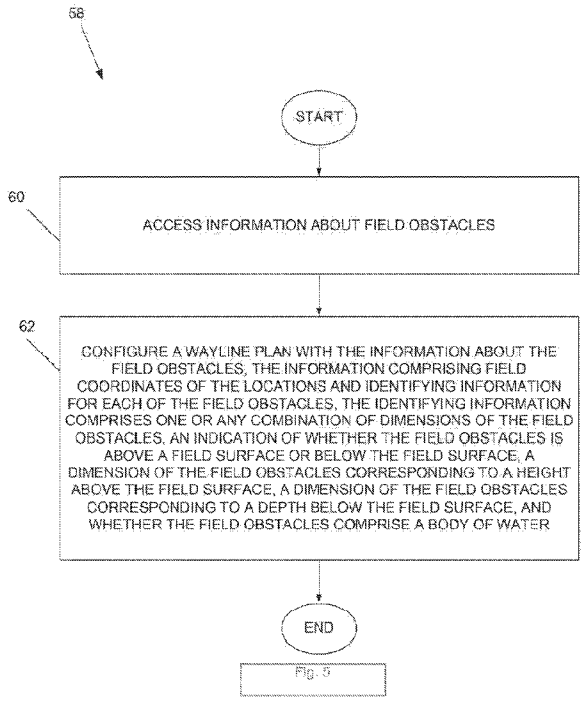


Fig. 5

(57) Abstract: In one embodiment, a wayline planning method, comprising: accessing information about field obstacles; and configuring a wayline plan with the information about the field obstacles, the information comprising field coordinates of the locations and identifying information for each of the field obstacles, the identifying information comprises one or any combination of dimensions of the field obstacles, an indication of whether the field obstacles is above a field surface or below the field surface, a dimension of the field obstacles corresponding to a height above the field surface, a dimension of the field obstacles corresponding to a depth below the field surface, and whether the field obstacles comprise a body of water.

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PATH PLANNING WITH FIELD ATTRIBUTE INFORMATION

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 62/268,598, filed 17 DEC 2015, which is hereby incorporated by reference in its entirety.

BACKGROUND

Technical Field

[0002] The present disclosure is generally related to agriculture technology, and, more particularly, computer-assisted farming.

Description of Related Art

[0003] Recent efforts have been made to automate or semi-automate farming operations. Such efforts serve not only to reduce operating costs but also improve working conditions on operators and reduce operator error, enabling gains in operational efficiency and yield. For instance, agricultural machines may employ a guidance system that autonomously traverses a field according to a wayline plan, which may enable a reduction in operator fatigue and costs. However, obstacles present in the field require the operator to maintain vigilance in preventing collisions between the agricultural machine and the obstacles, ensuring proper navigation around the obstacles to prevent damage to the machine and/or environment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Many aspects of certain embodiments of a path planning system and method can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of a path planning system and method. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

[0005] FIGS. 1A-1B are schematic diagrams that graphically illustrate, in overhead and side elevation views respectively, example operations of an embodiment of an example path planning system.

[0006] FIGS. 2A-2C are schematic diagrams that illustrate in overhead view how an embodiment of a path planning system determines whether or not to cause a mobile machine to change operation in response to obstacles encountered in a field.

[0007] FIG. 3A is a block diagram of that illustrates an embodiment of an example control system that may be used in an embodiment of a path planning system.

[0008] FIG. 3B is a block diagram that illustrates an embodiment of an example computing device that may be used in the control system of FIG. 3A.

[0009] FIGS. 4A-4B are screen diagrams that illustrate user interface screens that may be used to present feedback to an operator in an embodiment of a path planning system.

[0010] FIG. 5 is a flow diagram that illustrates an embodiment of an example path planning method.

DESCRIPTION OF EXAMPLE EMBODIMENTS

Overview

[0011] In one embodiment, a wayline planning method, comprising: accessing information about field obstacles; and configuring a wayline plan with the information about the field obstacles, the information comprising field coordinates of the locations and identifying information for each of the field obstacles, the identifying information comprises one or any combination of dimensions of the field obstacles, an indication of whether the field obstacles is above a field surface or below the field surface, a dimension of the field obstacles corresponding to a height above the field surface, a dimension of the field obstacles corresponding to a depth below the field surface, and whether the field obstacles comprise a body of water or any physical characteristics which may be relevant for a farming operation or path planning.

Detailed Description

[0012] Certain embodiments of a path planning system and method are disclosed that integrate, as part of a wayline plan, information about obstacles in a field, the wayline plan followed by a mobile machine using auto-guidance/auto-steer features during operations in a field. In one embodiment, the wayline plan may be generated based on a field map that identifies a coordinate location of each of the obstacles and

identifying information about each of the obstacles, such as dimensions of the obstacles, an indication of whether the obstacles are above a field surface or below the field surface, a dimension of the obstacles corresponding to a height above the field surface, a dimension of the obstacles corresponding to a depth below the field surface, and a nature or characteristic(s) of the obstacles (e.g., whether the obstacles comprise a body of water, a pipe, electric cable, etc.) As a machine follows a path of the field according to a wayline plan and as guided using auto-guidance functionality of the mobile machine, certain embodiments of a path planning system are equipped, based on location information, machine information (e.g., width and/or height of the mobile machine and coupled implement, tire width of the tracks or width of the tracks, clearance of the mobile machine and coupled implement relative to a field surface or equivalently, height of the lowest portion of the mobile machine and coupled implement), and the information about the obstacles established in wayline planning, to determine whether or not to change operations based on the obstacle. For instance, the change in operation may be based on deciding whether to navigate over or around the obstacles, or whether to change a product (e.g., chemicals) dispensing operation including activating, deactivating, increasing a dispense rate or decreasing a dispense rate. Such determinations may reduce or eliminate the risk of collision between the mobile machine and the obstacles and/or reduce or eliminate the risk of damage to the mobile machine and/or the environment. A wayline plan including a location of each of the obstacles and identifying information about each of the obstacles may be used in different ways and with varying degrees of automation. In a manned vehicle system, for example, the information may be used to inform the operator or change the operation under surveillance of the operator. In an unmanned system, an autonomous vehicle may use the location and identifying information to plan and follow waylines without operater knowledge or intervention. Thus, the identifying information may be stored and selectively used (for display and/or control) based on the type of operation

[0013] Digressing briefly, when an operator wishes to use an auto-guidance feature today, the typical procedure is for the operator to navigate the machine over an initial path (whether it is a straight A-B wayline, a contour, etc.) and the system generates successive waylines based on the width of a coupled implement. In some instances, the paths of the waylines may be generated as a preliminary farming management step prior to entering and working the field. In either case, the field map may identify locations where obstacles exist, enabling the operator to use a nudge command to navigate

around the obstacles (or offsets) as the mobile machine approaches the obstacles, which enables in the case of nudge commands a return to the previous wayline path without re-engaging auto-steer. In certain circumstances, navigation may be beyond the limits of the nudge function, requiring a disengagement of the auto-steer functionality and re-computation of a wayline path when the auto-guidance feature is once again desired. A lack of information about the obstacles, beyond information of their location, requires a constant awareness by the operator of their presence when approaching the obstacles to enable operator-controlled navigation around the obstacles, sometimes even when unnecessary in view of the dimensions of the obstacle relative to clearances of the mobile machine or coupled implement, or generally even when the obstacle presents no risk of collision with the mobile machine or damage (harm) to the environment, such as when the obstacle is entirely beneath a field surface and the operation occurs at or above a surface level. In other words, conventional wayline-guided systems may identify obstacles in a map, yet have insufficient information about the obstacles to enable informed decisions on whether or not to continue operations. Accordingly, the manner of operation of the machine, when encountering the obstacles, is left to the discretion of the operator. Such discretion requires vigilant awareness by the operator, which may mitigate the benefits generally accruing to operation using auto-guidance/auto-steer functionality. In contrast, certain embodiments of a path planning system store sufficient information about the obstacles as part of the wayline plan to automatically and intelligently respond to the obstacles of the field, which may reduce the fatigue, reduce inefficiencies in traversing the field, and/or reduce operator error.

[0014] Having summarized certain features of a path planning system of the present disclosure, reference will now be made in detail to the description of the path planning system as illustrated in the drawings. While the path planning system will be described in connection with these drawings, there is no intent to limit it to the embodiment or embodiments disclosed herein. For instance, in the description that follows, one focus is on an agricultural machine embodied as a mobile machine with a coupled implement, though it should be appreciated that some embodiments of path planning systems may use other machines (in the same or different industries), such as self-propelled sprayers or other machines where the functionality of the implement is an integral part and function of the machine (as opposed to being coupled to a multi-purpose tractor or other mobile machine via a hitch). Further, although the description identifies or describes specifics of one or more embodiments, such specifics are not necessarily part of every

embodiment, nor are all various stated advantages necessarily associated with a single embodiment or all embodiments. On the contrary, the intent is to cover all alternatives, modifications and equivalents included within the spirit and scope of the disclosure as defined by the appended claims. Further, it should be appreciated in the context of the present disclosure that the claims are not necessarily limited to the particular embodiments set out in the description.

[0015] Note that reference herein to causing a change in operations may involve directly causing a change (such as to deliver a signal or signals to appropriate actuators, or intervening devices, that actuate auto-steer functionality and/or actuate (or shut off) dispensing functionality), indirectly causing a change (e.g., by prompting an operator to act to cause the change in operation through manipulation of various machine controls), or a combination of both.

[0016] Referring now to FIGS. 1A-1B, shown are schematic diagrams that graphically illustrate, in overhead and side elevation views respectively, example operations of an embodiment of an example path planning system. Shown is a field 10 (e.g., agricultural field), and representations using mobile machines 12, obstacles 14, and symbols (e.g., "X" and a checkmark) to illustrate various scenarios that the mobile machine 12, controlled at least in part by an example path planning system, may encounter over the course of operations in the field 10. Two types of mobile machines 12 are illustrated, including a sprayer machine 12A and a tiller machine 12B, which are assumed to be navigating the field 10 according to a wayline plan that incorporates information about the obstacles 14. Note that the sprayer machine 12A is illustrated as a tractor towing an implement (e.g., a spray boom), but is collectively referred to as a sprayer machine 12A. In some embodiments, functionality of the tractor and the implement may be self-contained on a single, self-propelled mobile machine, such as demonstrated by an AGCO® Rogator®. Also, note that the tiller machine 12B is depicted as a tractor towing a tiller, though collectively referred to as a tiller machine 12B. References are made to the implement that dispenses product (e.g., chemicals) or penetrates a surface of the field (the tiller), regardless of whether the implement is towed or part of a self-contained machine. Further, note that the types of mobile machines 12 depicted in FIG. 1A are merely used as examples, and that other mobile machines (whether the implement is part of a towed or self-contained assembly) may be used to illustrate operations that are done above a field surface (e.g., combine harvester,

windrowers, etc.) and operations that require penetration of the field surface (e.g., planters, etc.).

[0017] Also shown are various types of obstacles 14. As best shown in FIG. 1B, an illustrative yet non-exhaustive list of types of obstacles 14 include sub-surface obstacles 14A (e.g., stones, trunks, roots), mixed level obstacles 14B (e.g., stones, trunks, roots extending above and below the surface), sub-surface conduit 14C (e.g., underground drain pipe or tile, underground cabling, etc.), bodies of water 14D (e.g., rivers, creeks, or other pools of either flowing or stagnant water), power line pillars 14E, and above-surface power lines 14F (though the pillars 14E and lines 14F may be substituted with other types of structures in some implementations, such as cellular towers, telephone lines and posts, radio dishes, or even naturally-occurring structures, such as trees, etc.). The symbol "X" in FIG. 1A signifies that the mobile machines 12 should not traverse directly over the obstacle 14 or continue dispensing product (e.g., the continuing traversal according to the current trajectory and dispensing collectively referred to as continuing operations), but instead change operations by either discontinuing the trajectory of the present path (e.g., stop and/or or navigate around the obstacle 14) and/or halt dispensing operations. That is, for determinations that lead up to a scenario corresponding to an "X", logic of the path planning system compares information about the obstacle 14 that the mobile machine 12 is about to traverse over with information about the mobile machine 12, and determines that there is a risk of collision between the mobile machine 12 and obstacle 14 (or risk of damage to one or both) by continuing operations as is (e.g., by maintaining the current path and traveling over or under the obstacle, by continuing of dispensing operations while traveling over or within a predetermined distance of the obstacle). The checkmark symbol signifies that the mobile machine 12 should continue on its current path or continue dispensing operations, with no change in operations. In other words, the logic of the path planning system determines, based on a comparison of information for the obstacle 14 to be encountered by the mobile machine 12 with information about the mobile machine 12, that there is no risk of collision between the mobile machine 12 and/or the obstacle 14 (and/or damage to either or both of the mobile machine 12 and the obstacle 14) by continuing the current path trajectory towards the obstacle 14.

[0018] For example, and beginning at the upper left portion of FIG. 1A, shown is the sub-surface obstacle 14A, and an illustration of operations, and in particular, decision

making by the path planning system of the mobile machines 12 as the mobile machines 12 (e.g., 12A, 12B) navigate according to a wayline plan toward the sub-surface obstacle 14A. As represented by the "X" adjacent the tiller machine 12B, the path planning system has determined that the tiller machine 12B (e.g., in this instance, the implement of the tiller machine 12B) may collide with the sub-surface obstacle 14A, and hence causes the tiller machine 12B to change operations. The path planning system may effect this causation by directly actuating auto-steer functionality to alter the navigation path of the tiller machine 12B (e.g., causing an autonomous steer-away), or indirectly cause the change by prompting an operator to navigate the tiller machine 12B away from (around) the sub-surface obstacle 14A. The sprayer machine 12A has a checkmark adjacent it, signifying that the path planning system of the sprayer machine 12A has determined that there is no risk of collision between the sprayer machine 12A and the obstacle 14A. In other words, the path planning system, upon evaluation of the information about the obstacle 14A and the machine information, has determined that because of the clearance between the sprayer boom and a surface of the field (or because of the clearance between a top height of the obstacle 14A and the bottom height dimension of the boom), and since the sub-surface obstacle 14A resides entirely beneath the surface, there is no risk of collision between the obstacle 14A and the boom of the sprayer machine 12A (and because of the depicted path, no risk of collision between the obstacle 14A and the tractor of the sprayer machine 12A).

[0019] As another example scenario, and referring to the middle of FIG. 1A, shown is the tiller machine 12B and sprayer machine 12A, both adjacent to the body of water 14D (e.g., with portions of each machine 12 overlapping the body of water 14D). The "X" adjacent the tiller machine 12B signifies that there is a risk of submergence in the body of water 14D of the implement of the tiller machine 12B, and so the path planning system causes operations to change (e.g., directly cause, or via prompt or alert, causing operator intervention) by navigation away from the body of water 14D. Similarly, the boom of the sprayer machine 12A overlaps the body of water 14D, which may present an environmental risk to the body of water 14D due to, for instance, dispensing of chemicals into the water. Accordingly, the path planning system of the sprayer machine 12A causes a change in operations of the sprayer machine 12A (e.g., directly or via prompt or alert influencing operator intervention), which results in one or any combination of actions, such as navigation away from the body of water 14D and/or

halting of dispensing of chemicals at or near (e.g., in advance of according to a predetermined distance) the body of water 14D.

[0020] Referring to the scenario in the upper right hand corner of FIG. 1A, the sprayer machine 12A is depicted as traversing toward a mixed level obstacle 14B. The path planning system of the sprayer machine 12A determines that, in this instance, the boom clearance relative to a top dimension of the mixed level obstacle 14B enables the sprayer machine 12A to pass over the obstacle 14B, and hence the path planning system permits traversal along the current path without a change in operation. It is also noted that the path planning system also determines that the obstacle 14B is not in the path of the tractor-portion of the sprayer machine 12A, and hence poses no risk of collision with the obstacle 14B.

[0021] In the lower portion of FIG. 1A, shown is the power line 14F spanning transversely across FIG. 1A, with pillars 14E spaced apart from each other and collectively supporting the power line 14F. The path planning system of the tiller machine 12B has determined that there is no risk of collisions (e.g., based on machine height and line height) between the tiller machine 12B and the lines 14F (or the pillars 14E), and hence the check mark signifies this determination (resulting in a continuation along the projected path or equivalently, no change in operations). In contrast, the path planning system of the sprayer machine 12A determines that a collision is expected between the boom of the sprayer machine 12A and the pillars 14E (e.g., because the width of the boom spans beyond two adjacent pillars 14E), and hence "X" signifies this determination, resulting in a change in operation (e.g., halt travel along the path and/or navigation around it).

[0022] Now turning to FIGS. 2A-2C, shown are some schematic diagrams that illustrate in overhead view how an embodiment of a path planning system determines whether or not to cause the mobile machine 12 (e.g., sprayer machine 12A) to change operation in response to obstacles 14 in its projected path which extend above the field surface (and may or may not penetrate into the soil). Referring to the example of FIG. 2A, the path planning system of the sprayer machine 12A determines that the clearance between the top of the obstacle 14 and the bottom of the boom of the sprayer machine 12A permits the sprayer machine 12A to continue along its projected path, but that obstacle 14 is in the path of the tracks of the sprayer machine 12A. Accordingly, the

path planning system of the sprayer machine 12A causes a change in the trajectory by causing the sprayer machine 12A to navigate around the obstacle 14.

[0023] With respect to FIG. 2B, shown are two obstacles 14, which include a sub-surface obstacle 14A and another obstacle 14 that extends above the field surface. The obstacle 14A is located within the path of the tracks and the boom of the sprayer machine 12A, but resides underneath the surface. Accordingly, the path planning system, with knowledge of the sub-surface nature of the obstacle 14A and the machine information (e.g., spray boom clearance, machine clearance, etc.), determines that the sprayer machine 12A can pass the obstacle 14A without a change in operation. As to the obstacle 14, the path planning system, based on the clearance between the boom bottom and the top of the obstacle 14, also determines that the sprayer machine 12A can pass over the obstacle 14 without changing operations. In contrast, an operator observing that the mobile machine 12 is bearing down on either or both of the obstacles 14A, 14 may decide, given the absence of information about the obstacles 14A, 14, that the obstacles present a risk of harm to the machine and hence causes the machine to navigate around the obstacles.

[0024] Referring to FIG. 2C, the obstacles in the path of the mobile machine 12 include the sub-surface obstacle 14A and the obstacle 14 that extends at least partially above the field surface. The path planning system determines that, even though the sub-surface obstacle 14A is in the path of the mobile machine 12, its location lies beneath the surface and coupled with machine information that indicates that there is no sub-surface operations presently being performed by the machine 12, the path planning system determines that the sub-surface obstacle 14A does not pose a risk of collision between the mobile machine 12 (or any coupled implement). As to the obstacle 14, although it resides above the field surface, it also resides between the tracks of the mobile machine 12. The mobile machine 12 assesses the clearance between the bottom of the mobile machine 12 and the top portion of the obstacle 14 and determines that there is no risk of collision, thus resulting in a determination that no change in operations is warranted.

[0025] Note that in some embodiments, one or more of the visual representations depicted in FIGS. 1A-2C may be presented at last partly in a user interface to the operator (on a user interface co-located with the mobile machine 12 or located remote from the mobile machine 12), enabling feedback in real-time or during pre-planned

wayline planning. For instance, during farming operations, the operations represented in the FIGS. 1A-2C may correspond to logical operations performed by the hardware and/or software of the path planning system and hence transparent to the operator, or in some embodiments, presented visibly in real-time, including the presentation of feedback to afford the operator an opportunity to be involved, at least to some extent, in the determinations and/or actions made by embodiments of the path planning system.

[0026] Attention is now directed to FIG. 3A, which illustrates an embodiment of a control system 16 used in an embodiment of a path planning system. It should be appreciated within the context of the present disclosure that some embodiments may include additional components or fewer or different components, and that the example depicted in FIG. 3A is merely illustrative of one embodiment among others. The control system 16 comprises one or more computing devices, such as the computing device 18. In one embodiment, the path planning system may include all of the components depicted in FIG. 16, or a subset thereof (e.g., a computing device 18 only). Note that the computing device 18, though depicted as a component of the control system 16 residing in the mobile machine 12 (FIG. 1), may be implemented remotely from the field to be farmed or at least external to the mobile machine 12. The computing device 18 is described hereinafter (with exceptions where noted) as a component of (e.g., hosted by) the mobile machine 12, with the understanding that all or a portion of the computing device functionality may be located remotely or otherwise external to the mobile machine 12 in some embodiments. The computing device 18 is coupled to one or more networks, such as a network 20, which in one embodiment may comprise a controller area network (CAN) bus, such as implemented according to the ISO 11783 standard (also referred to as "ISOBUS") and using a J1939 messaging protocol. In some embodiments, the network 20 may be configured according to one or more other industry and/or proprietary communication specification or standards, and is not limited to a single network. Also coupled to the network 20 is a position determining device 22 (e.g., a global navigation satellite systems (GNSS) receiver), a drive/navigation (Drive/Nav) system 24, an implement control system 26, a user interface 28, and a network interface 30. In some embodiments, functionality of one or more of the components may be combined into a single unit, (e.g., the network interface 30 may be embedded in the computing device 18).

[0027] The position determining device 22 (e.g., a GNSS receiver) may enable autonomous or semi-autonomous operation of the mobile machine 12 in cooperation with the drive/navigation system 24 and the computing device 18 (e.g., via auto-guidance software residing in the computing device 18).

[0028] The drive/navigation system 24 collectively comprises controls for the various power drive, gearing (e.g., transmission), and/or steering functionality, including actuators, sensors, and/or control subsystems (e.g., based on electrical or electronic, pneumatic, hydraulic mechanisms) residing on the mobile machine 12, including those used to control machine navigation (e.g., speed, direction (such as a steering system), etc.), among others.

[0029] The implement control system 26 comprises the controls (e.g., actuators, switches) for the various valves, pumps, flowmeters, and/or control subsystems residing on the mobile machine 12 to cause dispensing of product (e.g., chemicals, water, etc.) from the mobile machine 12, as well as to cause control positioning of the coupled implement, such to change height position and/or orientation (e.g., folding).

[0030] The user interface 28 may comprise any one or a combination of a keyboard, mouse, microphone, touch-type or keyboard/mouse/voice controlled display screen, headset, joystick, multifunctional handle (e.g., to enable nudge commands), steering wheel, or other devices (e.g., switches) that enable input by an operator and also enable monitoring and/or feedback to an operator of machine operations. Note that in some embodiments, the user interface 28 may be implemented remotely from the mobile machine 12.

[0031] The network interface 30 comprises hardware and software that enables remote control and/or monitoring of the mobile machine 12 and its associated operations. For instance, the network interface 30 may comprise a radio and/or cellular modem to enable connectivity with other devices of one or more networks, including a cellular network local area network, and the Internet. Internet connectivity may be further enables using interface software interface software (e.g., browser software, application programming interface (API), etc.) in the computing device 18. As indicated above, at least some of the functionality of the network interface 30 (or other components of the control system 16) may be integrated into the computing device 18 in some embodiments.

[0032] The computing device 18 is configured to receive and process information from, and output data to the components 22, 24, 26, 28, and 30. For instance, the computing device 18 may receive operator (or other user) input from the user interface, such as to enable operator intervention of machine operations, selection of wayline options, and/or access of machine and/or field or obstacle data. In some embodiments, the computing device 18 may receive input from the position determining device 22 and the implement control system 26 (e.g., to enable feedback as to the position or status of certain devices, such as an implement height and/or orientation, direction of the mobile machine 12, etc.). The computing device 18 may also access a local or remote data structure to use data to enable path planning or corresponding operations. The data structure may reside at a remote location (e.g., accessed via the network interface 30) or locally, such as from a storage device (e.g., memory stick, memory, etc.).

[0033] FIG. 3B further illustrates an embodiment of the example computing device 18. One having ordinary skill in the art should appreciate in the context of the present disclosure that the example computing device 18 is merely illustrative, and that some embodiments of computing devices may comprise fewer or additional components, and/or some of the functionality associated with the various components depicted in FIG. 3B may be combined, or further distributed among additional modules, in some embodiments. It should be appreciated that, though described in the context of residing in the mobile machine 12, in some embodiments, the computing device 18 or its corresponding functionality may be implemented in a computing device or devices located external to the mobile machine 12 and/or field. For instance, wayline planning according to an embodiment of the path planning system may be implemented off-site (remote from the mobile machine 12) on a device with functionality of the computing device 18. The wayline planning involves the generation of waylines for a given field in known manner, and according to certain embodiments of the path planning system, incorporates the location of the obstacles, as well as information about the obstacles. Such remote, off-line prepared wayline plans may be communicated to the computing device 18 of the mobile machine 12, such as via wireless communication and connection to the network interface 30, or via loading from a storage device, such as a portable memory that couples to an input interface (e.g., Universal Serial Bus connection, Near Field Communications Interface, Bluetooth interface, etc.) of the computing device 18 or control system 16. In some embodiments, the wayline path planning is implemented all or in part in real-time as the mobile machine 12 navigates a field.

[0034] The computing device 18 is depicted in this example as a computer system (e.g., a personal computer or workstation, an electronic control unit or ECU, etc.), but may be embodied as a programmable logic controller (PLC), FPGA, among other devices. It should be appreciated that certain well-known components of computer systems are omitted here to avoid obfuscating relevant features of the computing device 18. In one embodiment, the computing device 18 comprises one or more processors, such as processor 32, input/output (I/O) interface(s) 34, and memory 36, all coupled to one or more data busses, such as data bus 38. The memory 36 may include any one or a combination of volatile memory elements (e.g., random-access memory RAM, such as DRAM, SRAM, and SDRAM, etc.) and nonvolatile memory elements (e.g., ROM, Flash, solid state, EPROM, EEPROM, hard drive, CDROM, etc.). The memory 36 may store a native operating system, one or more native applications, emulation systems, or emulated applications for any of a variety of operating systems and/or emulated hardware platforms, emulated operating systems, etc. In the embodiment depicted in FIG. 3B, the memory 36 comprises an operating system 40 and auto-guidance software 42. The auto-guidance software 42 comprises wayline determination/generation software 44, auto-steer software 46, and data module 48 (e.g., a data structure, such as a database). It should be appreciated that in some embodiments, additional (e.g., browser, APIs, or if located remotely, web-host network software) or fewer software modules (e.g., combined functionality) may be employed in the memory 36 or additional memory. In some embodiments, a separate storage device may be coupled to the data bus 38 (or to network 20, FIG. 3A), such as a persistent memory (e.g., optical, magnetic, and/or semiconductor memory and associated drives). In some embodiments, the software modules 42-46 may be further distributed among additional application, or their respective functionality combined into fewer modules.

[0035] The auto-guidance software 42 enables wayline planning, such as executable code (executed by the processor 32) for wayline determination and generation, enabling the determination of wayline paths based on obstacles expected to be encountered by a mobile machine traversing a field according to the waylines, among other information. For instance, the wayline determination/generation software 44 determines waylines based on field maps and machine data or information stored in the data module 48 (or accessed from a remote storage device or a portable storage device). The field maps may comprise image data, boundaries, topography, and obstacle location and obstacle information. The obstacle information may comprise attributes manually input (e.g., via

user or operator entry) at the user interface 28, extracted from (e.g., via I/O interfaces 34) non-agricultural maps (e.g., which may contain rivers or in general, bodies of water, power lines, easements, conduit locations, etc.), and/or extracted from images or sensor data acquired via manned or unmanned scouting vehicles, satellite, or aerial vehicles (e.g., drones, planes, gliders, helicopters, etc.). An example of a data structure for the obstacles 14 may be as presented in Table 1 below:

Obstacle ID#	Type	Height (m)	Chemicals	Traversable
14A	Stone (Subsurface)	-0.1	Yes	Yes
14B	Stone (Above Ground)	+0.5	Yes	No
14C	Conduit	-0.8	Yes	Yes
14D	Body of Water	0	No	No
14E	Power Line	+8	Yes	Yes
14F	Pillar	+8	No	No

Table 1

[0036] Note that the data in Table 1 is illustrative one example among many other possible configurations and/or types of information of the data structure of the data module 48 for obstacle information, and that fewer, additional and/or different types of information may be stored for obstacles in some embodiments, including any physical characteristics which may be relevant to a farming operation or path planning.

[0037] The machine information, which may include dimensions and/or performance features of the mobile machine 12 and coupled (including integrated) implements, includes towing machine information (e.g., width, length, height, track width, ground clearance, function and/or type of machine, performance capabilities, etc.) and implement information (e.g., width, length, height, ground clearance, dispensing performance, such as nozzle types and dispensing trajectory range or other performance, type and/or function of the implement, etc.), the implement information being either for integrated implements and/or implements coupled to the front or rear of the towing machine via hitch assemblies. In some embodiments, the data stored in data module 48 may reside external to the computing device 18, such as in separate storage coupled to the network 20 or in a remote device in communication with the computing device 18 (e.g., via the network interface 30). The wayline determination/generation software 44 generates the waylines with the associated obstacle information and

provides the waylines and associated information to the auto-steer software 46. The auto-steer software 46 provides for auto-steer functionality of the mobile machine 12, as auto-steering is commonly known. For instance, the auto-steer software 46 receives the wayline information generated by the wayline determination/generation software 44, and enables autonomous or semi-autonomous traversal of the mobile machine 12 according to the generated waylines via signaling to the drive/navigation system 24.

[0038] In operation, the wayline determination/generation software 44 determines appropriate waylines for the field of interest based on the obstacle information and machine information, generating a field map with locations of the obstacles and obstacle information attributed to each of the obstacles. In some embodiments, prior field maps with the incorporated obstacle information are accessed, and the wayline paths re-determined based on the expected mobile machine to be used in the field. In some embodiments, the previously determined and generated waylines are accessed based on the use of the same machine and no change in field conditions. As described previously, the waylines are determined and generated in a manner that considers the information about the obstacles and the machine information, enabling traversal via the auto-steer software 46 over (or under) the obstacles or around the obstacles according to autonomous or operator-prompted operation. In the field, location information (e.g., via the position determining device 22) is fed to the auto-guidance software 42, enabling a comparison between the current location of the mobile machine 12 and the obstacle 14 and a determination of whether or not to cause a change in machine operations. Such a determination may be based on a flag or bit (or non-binary) value that corresponds to the pre-planned wayline determination to cause a change (e.g., to autonomously navigate around or prompt operator intervention) when the mobile machine 12 is on a trajectory to collide with the obstacle and the mobile machine 12 is within a predetermined distance from the obstacle (e.g., determined based on a turning ratio of the mobile machine, machine speed, stopping performance, etc.), or alternatively, to not cause a change in operation based on similar determination process. Also, a similar process is involved with determining whether or not to stop or change dispensing of chemicals, such as based on wind parameters, moisture, the distance to the obstacle, speed of the mobile machine, and/or the identification of the obstacle as a body of water.

[0039] Execution of the auto-guidance software 42 (and associated software 44-46) is implemented by the processor 32 under the management and/or control of the

operating system 40. The processor 32 may be embodied as a custom-made or commercially available processor, a central processing unit (CPU) or an auxiliary processor among several processors, a semiconductor based microprocessor (in the form of a microchip), a macroprocessor, one or more application specific integrated circuits (ASICs), a plurality of suitably configured digital logic gates, and/or other well-known electrical configurations comprising discrete elements both individually and in various combinations to coordinate the overall operation of the computing device 18.

[0040] The I/O interfaces 34 provide one or more interfaces to the network 20 and other networks. In other words, the I/O interfaces 34 may comprise any number of interfaces for the input and output of signals (e.g., analog or digital data) for conveyance of information (e.g., data) over the network 20. The input may comprise input by an operator or user (operator or user used interchangeably hereinafter, such as to control and/or monitor operations of the mobile machine 12 locally or remotely) through the user interface 28, and input from other devices or systems coupled to the network 20, such as the position determining device 22, the drive/navigation system 24, the implement control system 26, and/or the network interface 30, among other devices.

[0041] When certain embodiments of the computing device 18 are implemented at least in part as software (including firmware), as depicted in FIG. 3B, it should be noted that the software can be stored on a variety of non-transitory computer-readable medium for use by, or in connection with, a variety of computer-related systems or methods. In the context of this document, a computer-readable medium may comprise an electronic, magnetic, optical, or other physical device or apparatus that may contain or store a computer program (e.g., executable code or instructions) for use by or in connection with a computer-related system or method. The software may be embedded in a variety of computer-readable mediums for use by, or in connection with, an instruction execution system, apparatus, or device, such as a computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions.

[0042] When certain embodiment of the computing device 18 are implemented at least in part as hardware, such functionality may be implemented with any or a combination of the following technologies, which are all well-known in the art: a discrete logic circuit(s) having logic gates for implementing logic functions upon data signals, an application specific integrated circuit (ASIC) having appropriate combinational logic

gates, a programmable gate array(s) (PGA), a field programmable gate array (FPGA), etc.

[0043] Attention is now directed to FIGS. 4A-4B, which are screen diagrams 50 (e.g., 50A, 50B) that illustrate example user interface screens 52 (e.g., 52A, 52B) that may be used to present feedback to an operator during field operations. These user interface screens 52, or variants thereof, may be triggered by the flags mentioned above when the auto-guidance software 42 seeks to involve an operator in negotiating certain obstacles encountered along a path traversed by the mobile machine 12 according to a determined wayline. Referring to FIG. 4A, the user interface screen 52 may be overlaid over all or a portion of an image of the field a mobile machine 12 is traversing according to a wayline, or in some embodiments, over other visual presentations. In this example, the mobile machine 12 has a trajectory toward an obstacle embodied as a body of water, and the auto-guidance software 42 (e.g., the wayline determination/generation software 44) has determined that the obstacle warrants a change in operation to be effected. A prompt or alert 54 is presented in one embodiment upon the mobile machine 12 advancing within a predetermined distance of the body of water, alerting the operator of an impending collision (e.g., the risk of a coupled implement touching the body of water or dispensing chemicals into the body of water) with the obstacle and providing instructions prompting the operator to manually turn off (e.g., by selecting a switch of the user interface 28 or a touching an area of a display screen) or change dispensing functionality based on the determination to cause the change in the operation. In some embodiments, a different prompt may be used, such as a prompt soliciting operator input corresponding to a grant of permission to turn off the dispensing functionality automatically. In other words, the auto-guidance software 42 may be configured to signal to the implement control system 26 to arrange to turn off the dispensing functionality upon receiving an input from the operator permitting such functionality to be implemented. In some embodiments, the prompt may comprise an alert to the operator that the dispensing functionality has been automatically turned off (e.g., the auto-guidance software 42 signals the implement control system 26, after which or simultaneously with presentation of the prompt as feedback).

[0044] Referring to FIG. 4B, the mobile machine 12 has a path trajectory toward an obstacle embodied as a stone or other obstacle protruding from the surface of the field, and the auto-guidance software 42 (e.g., the wayline determination/generation software 44) has determined that the obstacle warrants a change in operation to be effected. A

prompt or alert 56 is presented on the user interface screen 52B, in one embodiment alerting the operator that there is an obstacle that is located within a predetermined distance of the mobile machine 12, the alert 56 prompting the operator to intervene to cause the mobile machine to navigate around the obstacle based on a determination to cause the change in the operation. In some embodiments, a different type of alert may be presented, such as an alert or prompt that solicits operator input corresponding to a grant of permission to cause the mobile machine 12 to autonomously navigate around the obstacle, or an alert informing the operator that the mobile machine is commencing an operation to autonomously navigate around the obstacle.

[0045] It should be appreciated that the user interface screens 52 are merely illustrative of a few examples, and that some embodiments may present feedback in a different way (e.g., via aural feedback, tactile feedback, or any combination thereof, or according to a different manner (e.g., format differences, type of information displayed, etc.) of visual presentation).

[0046] In view of the above description, it should be appreciated that one embodiment of a wayline planning method 58, depicted in FIG. 5, comprises accessing information about field obstacles (60); and configuring a wayline plan with the information about the field obstacles, the information comprising field coordinates of the locations and identifying information for each of the field obstacles, the identifying information comprises one or any combination of dimensions of the field obstacles, an indication of whether the field obstacles is above a field surface or below the field surface, a dimension of the field obstacles corresponding to a height above the field surface, a dimension of the field obstacles corresponding to a depth below the field surface, and whether the field obstacles comprise a body of water (62).

[0047] Any process descriptions or blocks in flow diagrams should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included within the scope of the embodiments in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure.

[0048] It should be emphasized that the above-described embodiments of the present disclosure, particularly, any “preferred” embodiments, are merely possible

examples of implementations, merely set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) of the disclosure without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

CLAIMS

At least the following is claimed:

1. A system, comprising:

a mobile machine, the mobile machine comprising a position determining device; and

a computing device coupled to the position determining device, the computing device configured to:

cause operation of the mobile machine according to a wayline plan, the wayline plan comprising information about field obstacles;

receive location information from the position determining device;

compare the location information with the information about the field obstacles, the information about the field obstacles comprising corresponding field coordinates of the field obstacles and identifying information for each of the field obstacles; and

automatically determine whether or not to cause a change in operation of the mobile machine within a predetermined distance from any one of the field coordinates based on the comparison.

2. The system of claim 1, wherein the operation is traversal of a field by the mobile machine, and wherein the computing device is configured to determine whether to traverse over one of the obstacles at the any one of the field coordinates according to the wayline or not traverse over the one of the obstacles at the any one of the field coordinates.

3. The system of claim 2, wherein the computing device is configured to determine whether or not to traverse over the one of the obstacles based on a comparison of the identifying information and the any one of the field coordinates with one or any combination of a track width of the mobile machine, a clearance dimension of the mobile machine, a clearance dimension of an implement coupled to the mobile machine relative to a field surface, a depth dimension of the implement relative to the field surface, a type of the implement, a width of the mobile machine, a width of the implement coupled to the mobile machine, a height of the mobile machine, and a height of the implement coupled to the mobile machine.

4. The system of claim 3, further comprising a user interface coupled to the computing device, wherein based on the determination, the computing device provides feedback to an operator of the mobile machine via the user interface, wherein the feedback comprises one or any combination of:

an alert prompting the operator to intervene to cause the mobile machine to navigate around the one of the obstacles based on a determination to cause the change in the operation;

a prompt soliciting operator input corresponding to a grant of permission to cause the mobile machine to autonomously navigate around the one of the obstacles; and

an alert informing the operator that the mobile machine is commencing an operation to autonomously navigate around the one of the obstacles.

5. The system of claim 3, wherein the computing device is configured to cause the mobile machine to autonomously navigate around the one of the obstacles based on the determination to cause the change in the operation.

6. The system of claim 3, wherein the computing device is configured to cause the mobile machine to navigate over the one of the obstacles according to the wayline based on the determination to not cause the change in the operation.

7. The system of claim 3, wherein the identifying information comprises one or any combination of dimensions of the one of the obstacles, an indication of whether the one of the obstacles is above a field surface or below the field surface, a dimension of the one of the obstacles corresponding to a height above the field surface, and a dimension of the one of the obstacles corresponding to a depth below the field surface.

8. The system of claim 1, wherein the operation is application of chemicals at the mobile machine or an implement coupled thereto, wherein the computing device is configured to determine whether or not to dispense the chemicals or to determine an amount of chemicals to dispense within the predetermined distance from one of the obstacles at the any one of the field coordinates.

9. The system of claim 8, wherein the computing device is configured to prohibit or change the dispensing of the chemicals within the predetermined distance of the one of

the obstacles based on determining from the corresponding identifying information that the one of the obstacles comprises a body of water, otherwise the computing device is configured to permit a continuation of the dispensing of the chemicals.

10. The system of claim 9, further comprising a user interface, wherein based on the determination, the computing device provides feedback to an operator of the mobile machine via the user interface, wherein the feedback comprises one or any combination of:

an alert with instructions prompting the operator to turn off or change dispensing functionality based on a determination to cause the change in the operation;

a prompt soliciting operator input corresponding to a grant of permission to turn off or change the dispensing functionality automatically; and

an alert to the operator that the dispensing functionality has been automatically turned off or changed.

11. The system of claim 9, wherein the computing device is configured to cause the mobile machine to automatically turn off or change dispensing functionality based on the determination to cause the change in the operation.

12. The system of claim 9, wherein the computing device is configured to permit the continuation of dispensing functionality based on the determination to not cause the change in the operation.

13. The system of claim 1, wherein the mobile machine and the computing device are co-located.

14. The system of claim 1, wherein the mobile machine and the computing device are located remote from each other and coupled via a wireless communications network.

15. The system of claim 1, further comprising a storage device coupled to the computing device, the storage device arranged to store one or any combination of the data structure, mobile machine information, and information for an implement coupled to the mobile machine.

16. A wayline planning method, comprising:

accessing information about field obstacles; and

configuring a wayline plan with the information about the field obstacles, the information comprising field coordinates of the locations and identifying information for each of the field obstacles, the identifying information comprises one or any combination of dimensions of the field obstacles, an indication of whether the field obstacles is above a field surface or below the field surface, a dimension of the field obstacles corresponding to a height above the field surface, a dimension of the field obstacles corresponding to a depth below the field surface, and whether the field obstacles comprise a body of water.

17. The method of claim 16, further comprising executing the wayline plan in a mobile machine based on the information.

18. An apparatus, comprising:

a processor configured to:

execute a wayline plan for a mobile machine;

compare location information with information about field obstacles, the information comprising field coordinates of the field obstacles and identifying information for each of the field obstacles; and

determine whether or not to cause a change in operation of the mobile machine within a predetermined distance from any one of the field coordinates based on the comparison.

19. The apparatus of claim 18, wherein the processor is further configured to cause the change in operation when an intersection of the any one of the field coordinates with the location information will result in a collision between the mobile machine and the obstacle, damage to one of the obstacles, or a combination of a collision between the mobile machine and the one of the obstacles and damage to the one of the obstacles.

20. The apparatus of claim 19, wherein the identifying information comprises one or any combination of dimensions of the field obstacles, an indication of whether the field obstacles is above a field surface or below the field surface, a dimension of the field obstacles corresponding to a length or width, a dimension of the field obstacles corresponding to a height above the field surface, a dimension of the field obstacles corresponding to a depth below the field surface, and whether the field obstacles comprise a body of water.

1/8

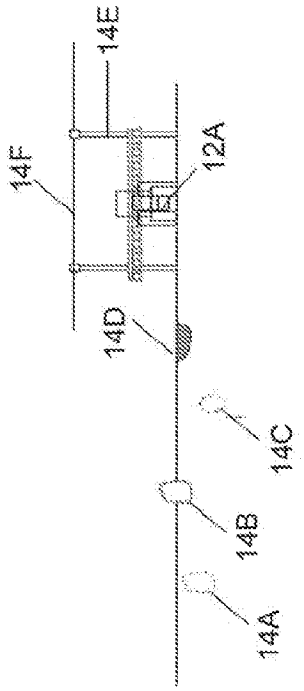


FIG. 1B

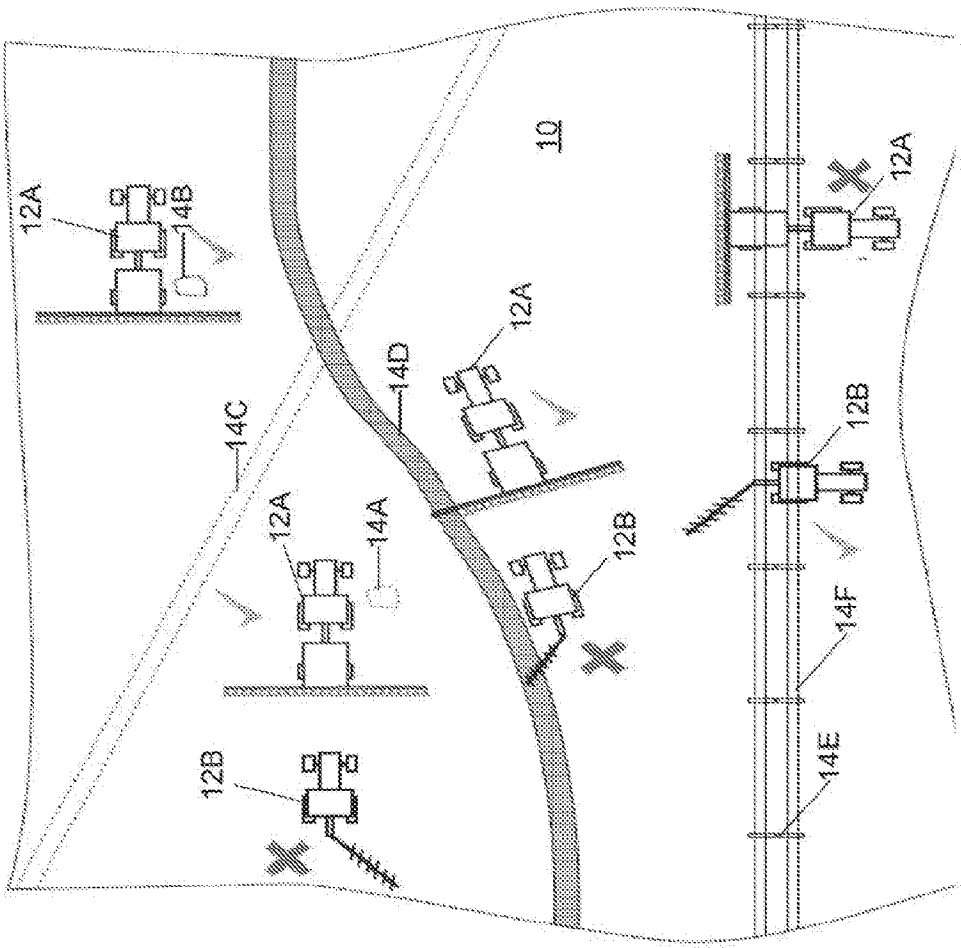


FIG. 1A

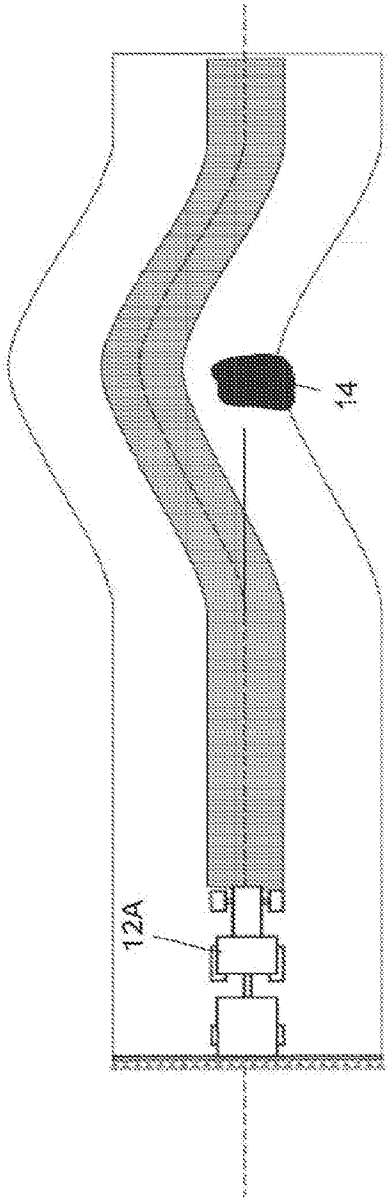


FIG. 2A

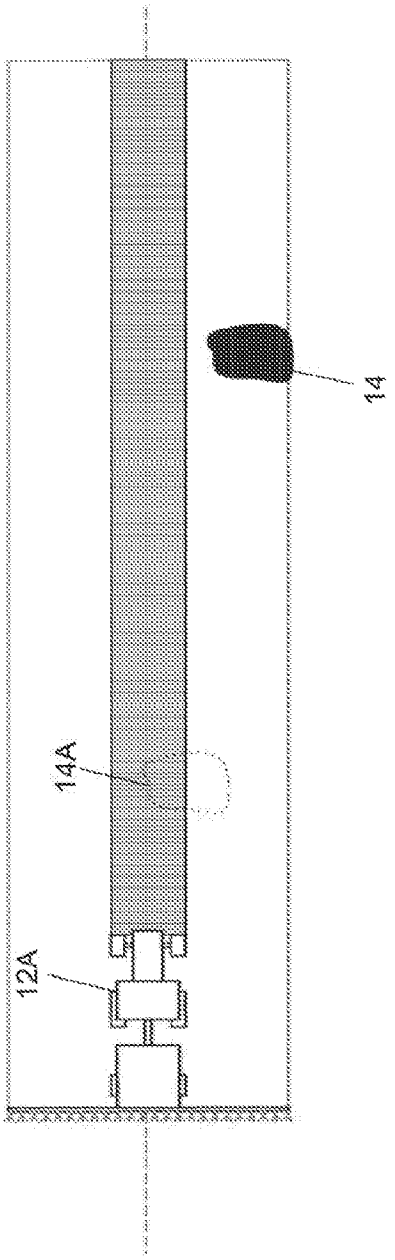


FIG. 2B

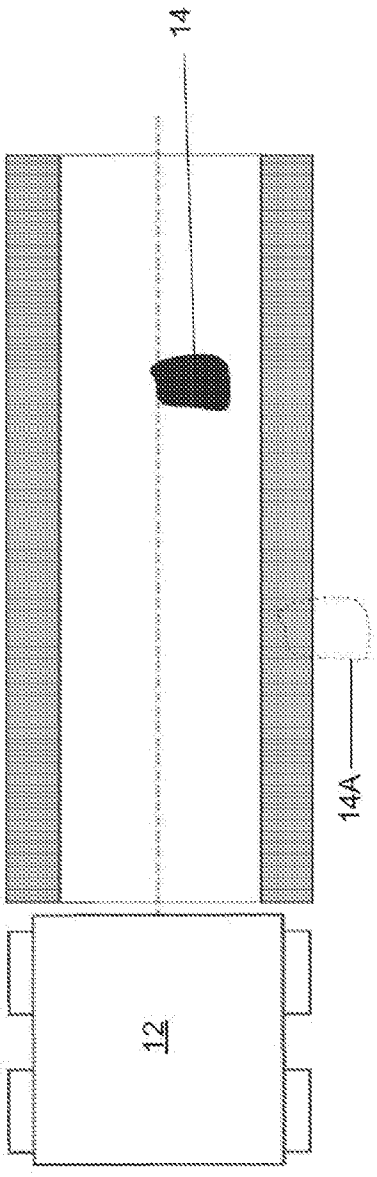


FIG. 2C

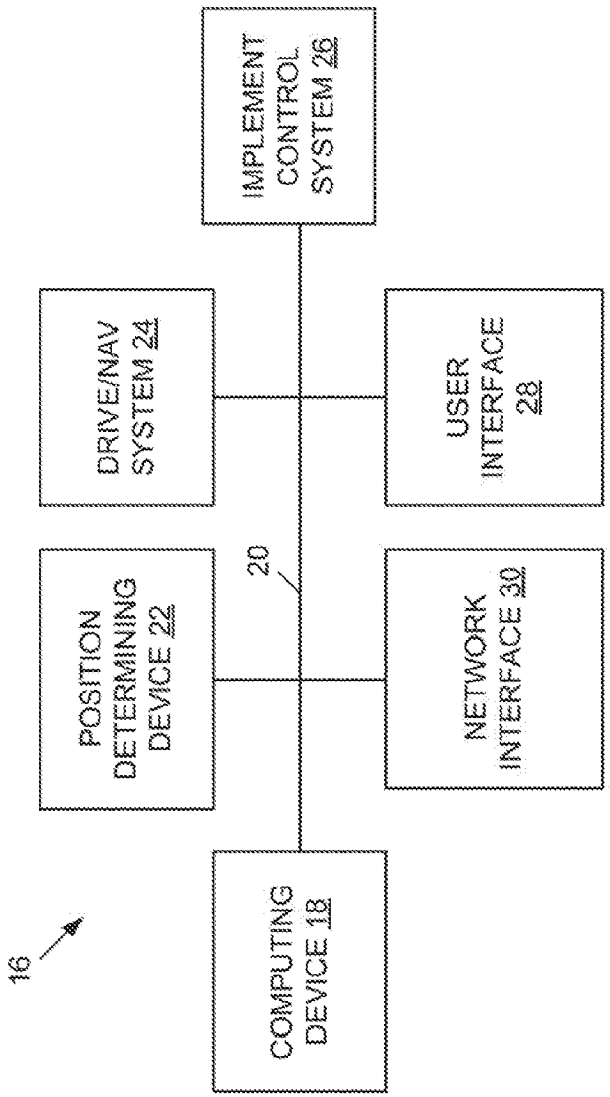

IMPLEMENT CONTROL SYSTEM 26
DRIVE/NAV SYSTEM 24
USER INTERFACE 28
20
POSITION DETERMINING DEVICE 22
NETWORK INTERFACE 30
COMPUTING DEVICE 18
16

FIG. 3A

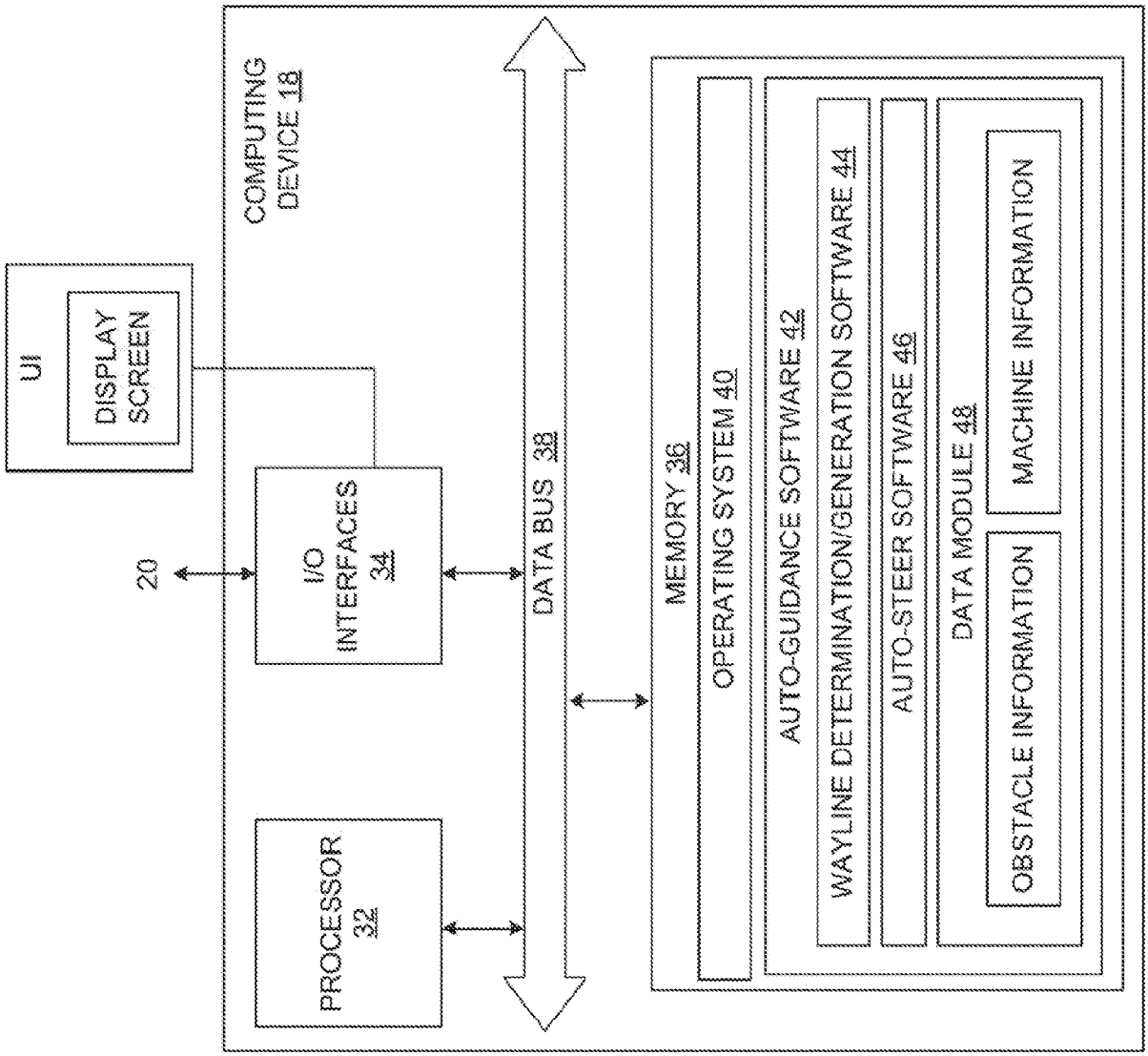

COMPUTING DEVICE 18
UI
DISPLAY SCREEN
20
I/O INTERFACES 34
PROCESSOR 32
DATA BUS 38
MEMORY 36
OPERATING SYSTEM 40
AUTO-GUIDANCE SOFTWARE 42
WAYLINE DETERMINATION/GENERATION SOFTWARE 44
AUTO-STEER SOFTWARE 46
DATA MODULE 48
OBSTACLE INFORMATION
MACHINE INFORMATION

FIG. 3B

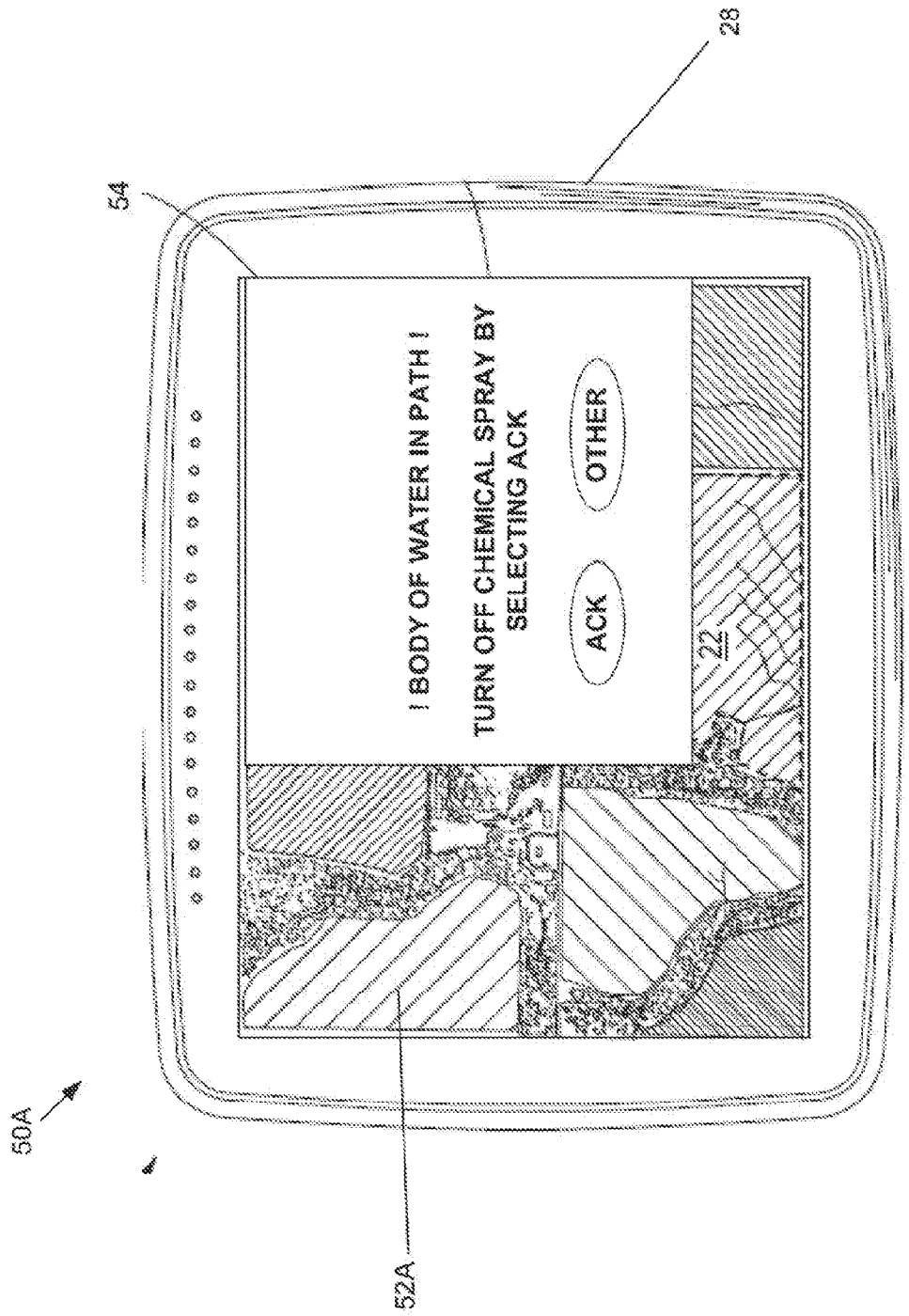

28
54
! BODY OF WATER IN PATH !
TURN OFF CHEMICAL SPRAY BY SELECTING ACK
ACK
OTHER
22
50A
52A

FIG. 4A

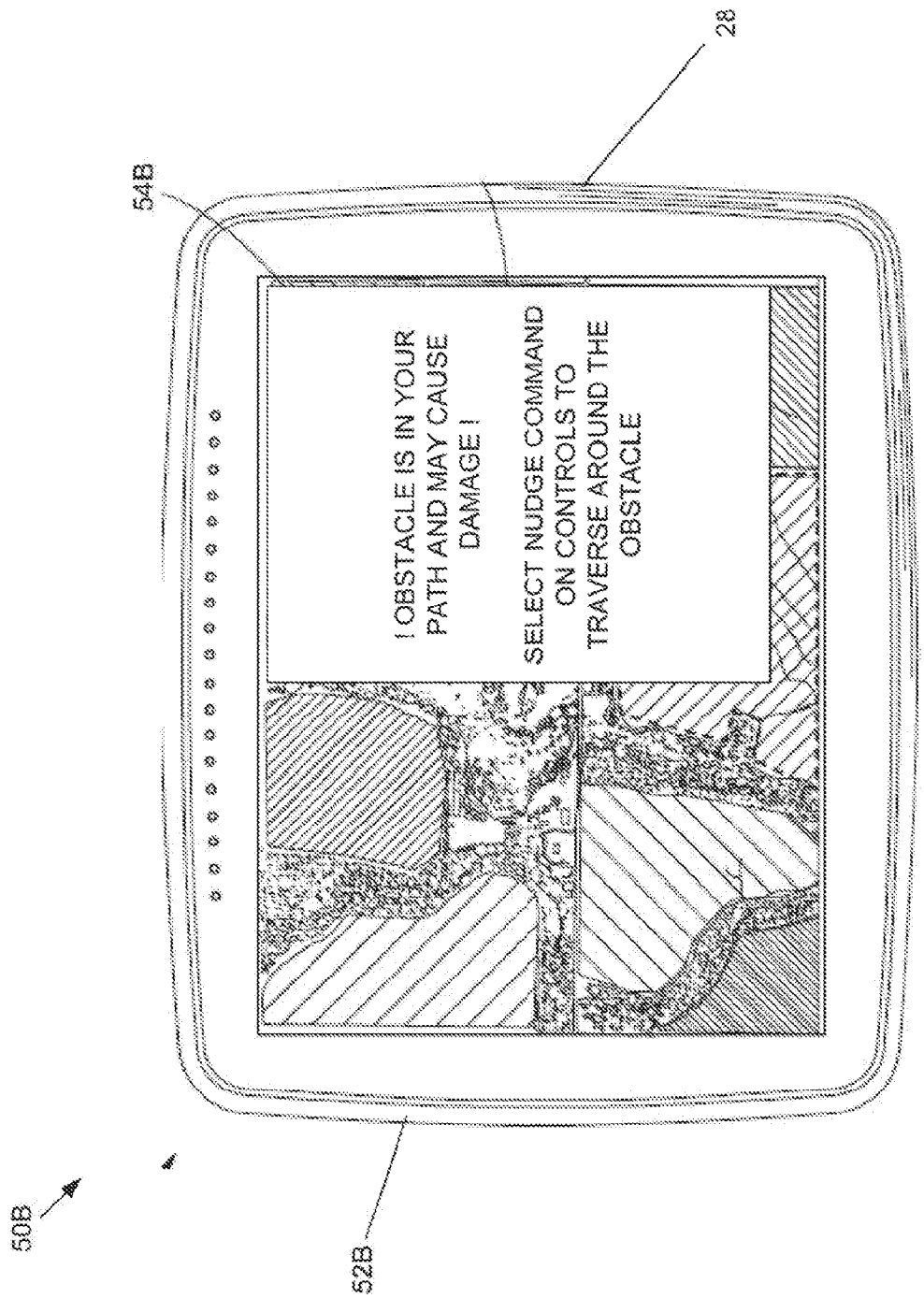

28
54B
! OBSTACLE IS IN YOUR PATH AND MAY CAUSE DAMAGE !
SELECT NUDGE COMMAND ON CONTROLS TO TRAVERSE AROUND THE OBSTACLE
50B
52B

FIG. 4B

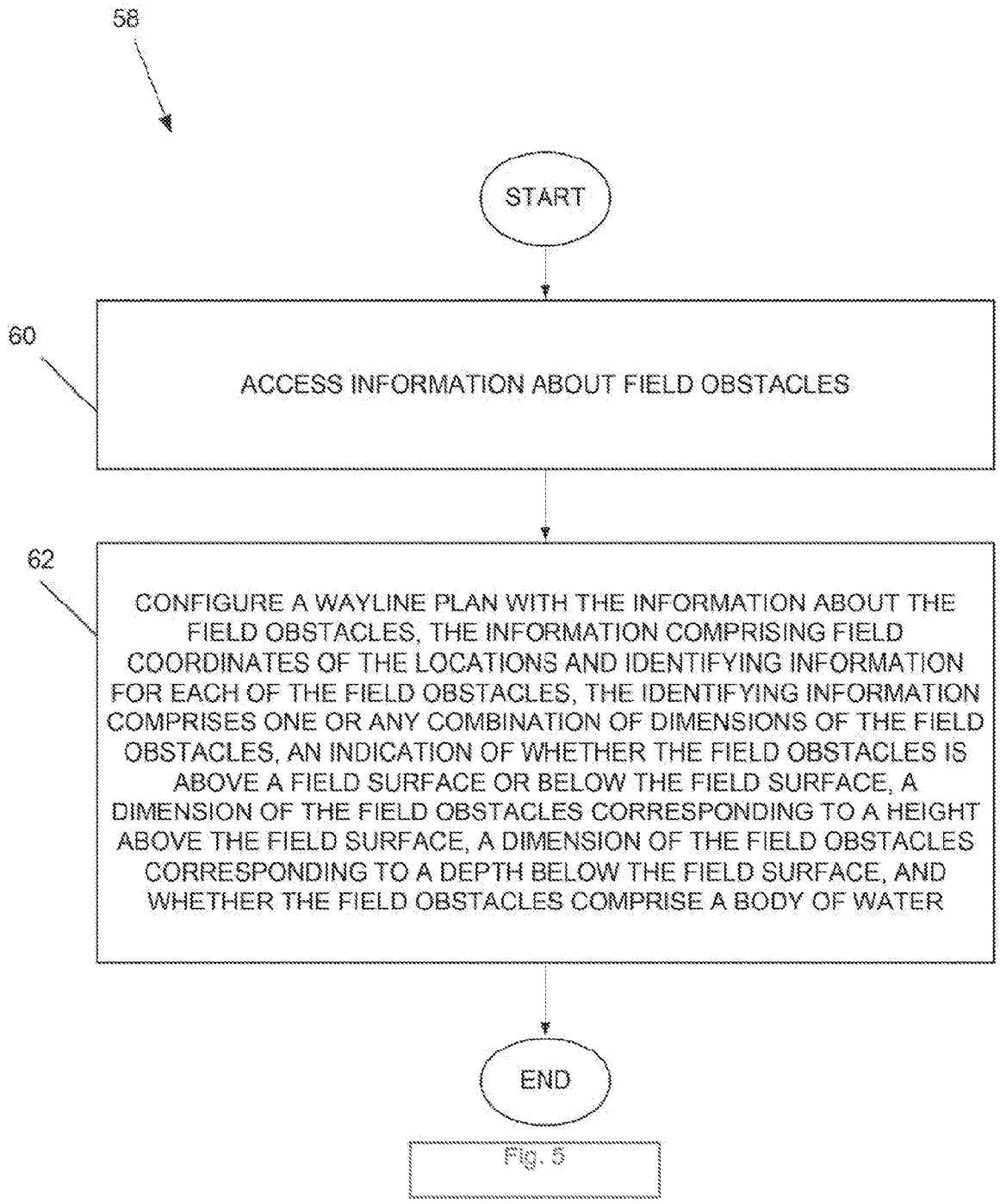

58
START
60
ACCESS INFORMATION ABOUT FIELD OBSTACLES
62
CONFIGURE A WAYLINE PLAN WITH THE INFORMATION ABOUT THE FIELD OBSTACLES, THE INFORMATION COMPRISING FIELD COORDINATES OF THE LOCATIONS AND IDENTIFYING INFORMATION FOR EACH OF THE FIELD OBSTACLES, THE IDENTIFYING INFORMATION COMPRISES ONE OR ANY COMBINATION OF DIMENSIONS OF THE FIELD OBSTACLES, AN INDICATION OF WHETHER THE FIELD OBSTACLES IS ABOVE A FIELD SURFACE OR BELOW THE FIELD SURFACE, A DIMENSION OF THE FIELD OBSTACLES CORRESPONDING TO A HEIGHT ABOVE THE FIELD SURFACE, A DIMENSION OF THE FIELD OBSTACLES CORRESPONDING TO A DEPTH BELOW THE FIELD SURFACE, AND WHETHER THE FIELD OBSTACLES COMPRISE A BODY OF WATER
END

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/066898

A. CLASSIFICATION OF SUBJECT MATTER
INV. A01B69/04 A01B79/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A01B G01D

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/158355 A1 (HOLMQVIST HANS ROBERT [SE] ET AL) 12 August 2004 (2004-08-12)	1-5, 13-15, 18,19
Y	paragraphs [0004], [0047] - [0059], [0195] - [0200]; figures 1-10,17	6-12,17, 20

X	US 2012/237083 A1 (LANGE ARTHUR F [US] ET AL) 20 September 2012 (2012-09-20)	16
Y	paragraphs [0174], [0181] - [0236]; figures 7-31	6,7,17, 20
A		1-5

Y	WO 2013/063225 A1 (PETERSON JOHN [US]; AGCO CORP [US]) 2 May 2013 (2013-05-02)	8-12
A	paragraph [0036]	1,16,18

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 April 2017	18/04/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lucchesi-Palli, C

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/066898

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 987 383 A (KELLER RUSSELL J [US] ET AL) 16 November 1999 (1999-11-16) column 3, line 3 - column 11, line 61; figures 1-9	1-20
A	US 2006/178825 A1 (EGLINGTON MICHAEL L [US] ET AL) 10 August 2006 (2006-08-10) paragraphs [0031] - [0082], [0121]; figures 1-15	1-7, 13-20
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