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(54) **SYSTEMS AND METHODS FOR GRADE CONTROL WINDOW ACTIVATION**

(57) Systems and methods for using a two-dimensional (2D) grade control system wherein the 2D grade control system remains enabled both while a blade of a bladed work machine performs a grading operation as the work machine makes a pass along the ground, and remains enabled while the blade is raised as the work machine is repositioned for another pass. Moreover, once enabled, the 2D grade control system can remain enabled, and transition between an active mode, where the 2D grade control system automatically orients the blade, and an inactive mode, wherein the operator may have overridden the 2D grade control system. By remaining enabled during both the active and inactive modes, the operator need not take the extra actions of repeatedly re-enabling the 2D grade control system after each time that the operator may have overridden the 2D grade control system, thereby saving the time and effort of the operator.

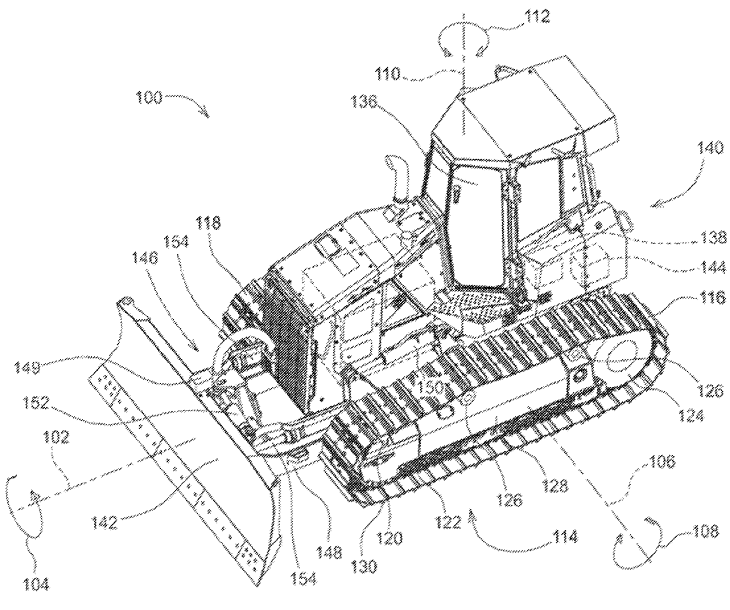

FIGURE 1

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Description

[0001] The present disclosure generally relates to grade control systems for work machines, and, more specifically, operating enabled two-dimensional (2D) grade control systems in both an active mode and an inactive, or armed, mode.

[0002] Work machines with ground-engaging blades can be used to shape and smooth ground surfaces. For example, work machines, including dozers, crawlers, and motor graders among other bladed work machines are well-suited for moving relatively large volumes areas of earth, including, for example, in connection with performing grading operations. Bladed work machines can be configured to accommodate an operator to manipulate a blade of the work machine in multiple degrees of freedom (DOFs). For example, an operator may be able to adjust the height, pitch, and rotational angle of the blade through an electro-hydraulic system. Such multi-DOF blade movement provides a powerful and flexible tool in grading operations, including, for example, with respect to leveling and/or providing a slope(s) to an area(s) of ground surface.

[0003] With respect to a bladed work machine being operated during a grading operation, as the work machine performs the grading operation, the operator of the work machine may be need to repeatedly move the position of the blade. For example, when the work machine is to move, or perform a pass, along the ground, the operator may have to move the blade, such as, for example, lower the blade, to a position at which the blade is, or will become, oriented to perform a grading related operation on the ground surface. When a particular pass is completed, the operator may again move the blade, such as, for example, raise the blade, away from the ground so that the blade does not contact ground material as the work machine is repositioned for another pass. With the work machine repositioned to perform another pass, the operator may again reposition the blade, such as, for example, lower the blade, so that the blade is, or will become, positioned to again perform a grading related operation on the ground surface. As grading the ground surface to attain a particular grade can take numerous passes, the operator can, at least with some systems, repeatedly being raising and lowering the blade. Such time and effort can be further exacerbated if the operator has to also repeatedly perform additional operations in addition to the raising and lowering of the blade, including with respect to additional repeated operations relating to the enablement of a grade control system, such as, for example, a two-dimensional (2D) grade control system.

[0004] The present disclosure may comprise one or more of the following features and combinations thereof.

[0005] In one embodiment of the present disclosure, a method is provided for controlling a two-dimensional grade control system of a bladed work machine. The method can include enabling the two-dimensional grade control system, and determining at least a portion of a blade of the bladed work machine is positioned inside an activation window. Additionally, the enabled two-dimensional control system can be placed in an active mode in response to the determining the portion of the blade is positioned inside the activation window, wherein, in the active mode, the two-dimensional grade control system automatically controls an orientation of the blade. The method can also include determining the blade of the bladed work machine is positioned outside the activation window, and placing the enabled two-dimensional control system in an inactive mode in response to the determining the blade is positioned outside the activation window. In the inactive mode, the two-dimensional grade control system remains enabled but does not automatically control the orientation of the blade. The method can further include changing, while the two-dimensional grade control system has continuously remained enabled, the two-dimensional grade control system from the inactive mode to the active mode in response to determining the portion of the blade that had previously been outside the activation window is positioned in the activation window.

[0006] In another embodiment, and apparatus is provided that can include a bladed work machine having a blade, the blade configured to engage a ground material. The apparatus can also include a control system having a two-dimensional grade control system, the two dimensional grade control system comprising a memory device coupled with at least one processor. The memory device can include instructions that, when executed by the at least one processor, cause the at least one processor to receive a signal from a user interface of the bladed work machine that enables the two-dimensional grade control system to provide an enabled two-dimensional grade control system, and determine at least a portion of a blade of the bladed work machine is positioned inside an activation window. Further, the memory device can include instructions that, when executed by the at least one processor, cause the at least one processor to place the enabled two-dimensional control system in an active mode in response to the portion of the blade being determined to be positioned inside the activation window, wherein, in the active mode, the enabled two-dimensional grade control system automatically controls an orientation of the blade, and determine the blade of the bladed work machine is positioned outside the activation window. Additionally, the memory device can include instructions that, when executed by the at least one processor, cause the at least one processor to place the enabled two-dimensional control system in an inactive mode in response to the blade being determined to be positioned outside the activation window, wherein, in the inactive mode, the enabled two-dimensional grade control system remains enabled but does not automatically control the orientation of the blade. The memory device can also include instructions that, when executed by the at least one processor, cause the at least one processor to change, while the enabled two-dimensional grade control system has remained enabled and not subsequently entered a disabled state, the enabled two-dimensional grade control system from the inactive mode to the active mode in response to determining the portion of the blade that had previously been outside the activation window is positioned in the activation window.

[0007] These and other features of the present disclosure will become more apparent from the following description of the illustrative embodiments.

[0008] The disclosure contained herein is illustrated by way of example and not by way of limitation in the accompanying figures. For simplicity and clarity of illustration, elements illustrated in the figures are not necessarily drawn to scale. For example, the dimensions of some elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference labels have been repeated among the figures to indicate corresponding or analogous elements.

Figure 1 illustrates a perspective view of a tracked work vehicle incorporating an embodiment of a grade control system and method as disclosed herein.

Figure 2 illustrates a block diagram of an exemplary control system that includes a blade actuation system having a two-dimensional (2D) grade control system.

Figure 3 illustrates an exemplary method for controlling an operation of a work vehicle having a 2D grade control system.

Figures 4A and 4B illustrate exemplary representations of first and second activation windows, respectively, positioned relative to an area of ground on which a grading operation is to be performed by a work machine.

Figure 5 illustrates an exemplary representation of a blade of a work machine being positioned outside of an activation window, as determined at least in part based on a location of an implement angle corresponding to a blade slope, such that an enabled 2D grade control system is in an inactive, or armed, mode.

Figure 6 illustrates an exemplary representation of the blade of the work machine shown in Figure 5 positioned inside the activation window, as determined at least in part based on the location of an implement angle corresponding to a blade slope, such that the enabled grade control system is in an active mode.

Figure 7 illustrates an exemplary representation of the blade of the work machine shown in Figure 5 positioned outside of another activation window, as determined at least in part based on the location of an implement angle corresponding to the blade slope, such that the enabled grade control system is in the inactive, or armed, mode.

Figure 8 illustrates another exemplary representation of a determination of whether the blade of the work machine is inside or outside of the activation window being based, at least in part, on a location of an implement angle corresponding to an orientation of a C-frame of the work machine relative to the activation window.

Figure 9 illustrates another exemplary representation of a determination of whether the blade of the work machine is inside or outside of the activation window being based, at least in part, on a height of the blade above the ground or a corresponding tracking plane.

[0009] Corresponding reference numerals are used to indicate corresponding parts throughout the several views.

[0010] While the concepts of the present disclosure are susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and will be described herein in detail. It should be understood, however, that there is no intent to limit the concepts of the present disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives consistent with the present disclosure and the appended claims.

[0011] References in the specification to "one embodiment," "an embodiment," "an illustrative embodiment," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may or may not necessarily include that particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. Additionally, it should be appreciated that items included in a list in the form of "at least one A, B, and C" can mean (A); (B); (C); (A and B); (A and C); (B and C); or (A, B, and C). Similarly, items listed in the form of "at least one of A, B, or C" can mean (A); (B); (C); (A and B); (A and C); (B and C); or (A, B, and C).

[0012] In the drawings, some structural or method features may be shown in specific arrangements and/or orderings. However, it should be appreciated that such specific arrangements and/or orderings may not be required. Rather, in some embodiments, such features may be arranged in a different manner and/or order than shown in the illustrative figures. Additionally, the inclusion of a structural or method feature in a particular figure is not meant to imply that such feature is required in all embodiments and, in some embodiments, may not be included or may be combined with other features.

[0013] A number of features described below may be illustrated in the drawings in phantom. Depiction of certain features in phantom is intended to convey that those features may be hidden or present in one or more embodiments, while not necessarily present in other embodiments. Additionally, in the one or more embodiments in which those features may be present, illustration of the features in phantom is intended to convey that the features may have location(s) and/or position(s) different from the locations(s) and/or position(s) shown.

[0014] The embodiments of the present disclosure described below are not intended to be exhaustive or to limit the disclosure to the precise forms in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art may appreciate and understand the principles and practices of the present disclosure.

[0015] Figure 1 illustrates a perspective view of a tracked work machine 100 incorporating an embodiment of a grade control system and method as disclosed herein. While Figure 1 illustrates the work machine 100 as a crawler, the work machine 100 can be a variety of other vehicles, machines, or devices having, or configured to be coupled to, a ground-engaging blade 142 (also referred to herein as a blade 142), such as, for example, a compact track loader, motor grader, scraper, skid steer, backhoe, and tractor, to name but a few examples. The work machine 100 can be operated to engage the ground and grade, cut, and/or move material to achieve simple or complex features on the ground. While operating, the work machine 100 can experience movement in three directions and rotation in three directions. A direction for the work machine 100 can also be referred to with regard to a longitudinal direction 102, a latitudinal or lateral direction 106, and a vertical direction 110. Rotation for work machine 100 may be referred to as roll 104 or the roll direction, pitch 108 or the pitch direction, and yaw 112 or the yaw direction or heading.

[0016] The work machine 100 can include an operator cab 136 that can be located on a chassis 140 of the work machine 100. The operator cab 136 and the ground-engaging blade 142 can both be mounted on the chassis 140 so that, at least in certain embodiments, a front side of the operator cab 136 can face in a working, or forward, direction of the ground-engaging blade 142, such as for example where the ground-engaging blade 142 is front-mounted. A control station, including a user interface 168 (Figure 2), can be located in the operator cab 136. As used herein, directions with regard to work machine 100 can be referred to from the perspective of an operator seated within the operator cab 136. Thus, reference to the left of work machine 100 is to the left of such an operator, the right of work machine 100 is to the right of such an operator, the front or fore of the work machine 100 is the direction such an operator faces, the rear or aft of work machine 100 is behind such an operator, the top of work machine 100 is above such an operator, and the bottom of work machine 100 is below such an operator.

[0017] The illustrated work machine 100 further includes a control system 138 including a work vehicle controller 160 (Figure 2). The work vehicle controller 160 can be part of the control system 138 of the working machine 100, or it can be a separate control module. Further, as discussed below, the control system 138 can at least generate control signals for controlling an operation(s) of various actuators throughout the work machine 100, including, for example, hydraulic motors, hydraulic piston-cylinder units, electric actuators, as well as combinations thereof, among others.

[0018] The work machine 100 is supported on the ground by an undercarriage 114 that can include ground engaging units 116, 118. In the illustrated embodiment, the ground engaging units 116, 118 are formed by a left track and a right track, and provide tractive force for the work machine 100. According to such an embodiment, each ground engaging unit 116, 118 can be comprised of shoes with grousers that sink into the ground to increase traction, and interconnecting components that allow the ground engaging unit 116, 118, in this example, tracks, to rotate about front idlers 120, track rollers 122, rear sprockets 124 and top idlers 126. Such interconnecting components can include links, pins, bushings, and guides, to name a few components. Front idlers 120, track rollers 122, and rear sprockets 124, on both the left and right sides of the work machine 100, provide support for the work machine 100 on the ground. Front idlers 120, track rollers 122, rear sprockets 124, and top idlers 126 can be pivotally connected to the remainder of the work machine 100 and rotationally coupled to their respective ground engaging unit 116, 118, or track, so as to rotate with those engaging units 116, 118. A track frame 128 can provide structural support or strength to these components and the remainder of the undercarriage 114. In alternative embodiments, the ground engaging units 116, 118 can comprise wheels on the left and right sides of the work machine 100.

[0019] Front idlers 120 can be positioned at the longitudinal front of the left ground engaging unit 116, or left track, and the right ground engaging unit 118, or right track, and provide a rotating surface for the ground engaging units 116, 118 to rotate about and a support point to transfer force between the work machine 100 and the ground. The left and right ground engaging units 116, 118 rotate about the front idlers 120 as they transition between their vertically lower and vertically upper portions parallel to the ground, so approximately half of the outer diameter of each of the front idlers 120 is engaged with the respective left ground engaging unit 116 or right ground engaging unit 118. This engagement can be through a sprocket and pin arrangement, where pins included in the left ground engaging unit 116 and the right ground engaging unit 118 are engaged by recesses in the front idler 120 so as to transfer force. This engagement also results in the vertical height of the left and right ground engaging units 116, 118 being only slightly larger than the outer diameter of each of the front idlers 120 at the longitudinal front of the tracks. Forward engaging points 130 of the ground engaging units 116, 118 can be approximated as the point on each ground engaging unit 116, 118, or track, vertically below the center of the front idlers 120, which is the forward point of the ground engaging units 116, 118 that engages the ground.

[0020] Track rollers 122 can be longitudinally positioned between the front idler 120 and the rear sprocket 124 along the bottom left and bottom right sides of the work machine 100. Each of the track rollers 122 can be rotationally coupled to the left ground engaging unit 116 or the right ground engaging unit 118 through engagement between an upper surface of the ground engaging units 116, 118 and a lower surface of the track rollers 122. This configuration can allow the track rollers 122 to provide support to the work machine 100, and in particular can allow for the transfer of forces in the vertical direction between the work machine 100 and the ground. This configuration also resists the upward deflection of the left and right tracks 116, 118 as they traverse an upward ground feature whose longitudinal length is less than the distance between the front idler 120 and the rear sprocket 124.

[0021] The undercarriage 114 is affixed to, and provides support and tractive effort for, the chassis 140 of the work machine 100. The chassis 140 is the frame which provides structural support and rigidity to the work machine 100, allowing for the transfer of force between the ground-engaging blade 142 and the left ground engaging unit 116 and right ground engaging unit 118. The chassis 140 can be a weldment comprised of multiple formed and joined steel members, but in alternative embodiments the chassis 140 can be comprised of any number of different materials or configurations.

[0022] The ground-engaging blade 142 can be configured to at least engage the ground or related material, such as, for example, to move ground or material positioned on the ground (collectively referred to as ground material) from one location to another, and to create features on the ground. For example, the ground-engaging blade 142 can be configured such the blade 142 can engaged ground material in a manner in which, during movement of the associated work machine 100, ground material is moved in a manner that is utilized to form flat areas, grades, hills, roads, or more complexly shaped features on the ground surface. According to certain embodiments, the ground-engaging blade 142 can be referred to as a six-way blade, six-way adjustable blade, or power-angle-tilt (PAT) blade. The ground-engaging blade 142 can be hydraulically actuated to move vertically up or down ("lift"), roll left or right ("tilt"), and yaw left or right ("angle"). According to other embodiments, the ground-engaging blade 142 can have different numbers of degrees of freedom, including different hydraulically controlled degrees of freedom. For example, according to certain embodiments, the ground-engaging blade 142 is a four-way blade that can be actuated to move vertically up or down ("lift") and to roll left or right ("tilt"), but which may not be angled or actuated in the direction of yaw 112.

[0023] The ground-engaging blade 142 is movably connected to the chassis 140 of the work machine 100 through a linkage 146 that can support and actuate the ground-engaging blade 142, and is configured to allow the ground-engaging blade 142 to be lifted (i.e., raised or lowered in the vertical direction 110) relative to the chassis 140. The linkage 146 can include multiple structural members to carry forces between the ground-engaging blade 142 and the remainder of the work machine 100, and can provide attachment points for hydraulic cylinders which can actuate the ground-engaging blade 142 in the lift, tilt, and angle directions. A blade actuation system 162 (Figure 2) can, for example, comprise the linkage 146, along with the hydraulic cylinders, and additional and/or equivalent structures associated with actuation of the ground-engaging blade 142 in the lift, tilt, and angle directions.

[0024] The illustrated linkage 146 can include a C-frame 148, which can comprise a C-shape structural member positioned rearward of the ground-engaging blade 142, with the C-shape open of the C-frame 148 being toward the rear of the work machine 100. Each rearward end of the C-frame 148 can be pivotally connected to the chassis 140 of the work machine 100, such as through a pin-bushing joint, allowing the front of the C-frame 148 to be raised or lowered relative to the work machine 100 about the pivotal connections at the rear of the C-frame 148. The front portion of the C-frame 148, which is approximately positioned at the lateral center of the work machine 100, can connect to the ground-engaging blade 142 through a ball-socket joint, among other connections. Such use of a ball-socket joint can allow the ground-engaging blade 142 three degrees of freedom (e.g., lift-tilt-angle) in the orientation of the ground-engaging blade 142 relative to the C-frame 148, while still transferring rearward forces on the ground-engaging blade 142 to the remainder of the work machine 100.

[0025] The ground-engaging blade 142 can be lifted (i.e., raised or lowered) relative to the work machine 100 by the actuation of one or more lift cylinders 150 (Figure 2), which can raise and lower the C-frame 148. For each of the lift cylinders 150, a rod end of the lift cylinder 150 is pivotally connected to an upward projecting clevis of the C-frame 148, and a head end of the lift cylinder 150 is pivotally connected to the remainder of the work machine 100 just below and forward of the operator cab 136. The configuration of the linkage 146 and the positioning of the pivotal connections for the head end and rod end of the lift cylinders 150 can result in extension of the lift cylinders 150 lowers the ground-engaging blade 142, while retraction of the lift cylinders 150 raises the ground-engaging blade 142. In alternative embodiments, the ground-engaging blade 142 can be raised or lowered by a different mechanism, or the lift cylinders 150 can be configured differently, such as a configuration in which extension of the lift cylinders 150 raises the ground-engaging blade 142, and retraction of the lift cylinders 150 lowers the ground-engaging blade 142.

[0026] The ground-engaging blade 142 can be tilted relative to the work machine 100 by the actuation of a tilt cylinder 152, which can also be referred to as moving the ground-engaging blade 142, in the direction of roll 104. A rod end of the tilt cylinder 152 can be pivotally connected to a clevis positioned on the back and left sides of the ground-engaging blade 142, above the ball-socket joint between the ground-engaging blade 142, and the C-frame 148 and a head end of the tilt cylinder 152 can be pivotally connected to an upward projecting portion of the linkage 146. The positioning of the pivotal connections for the head end and the rod end of the tilt cylinder 152 can result in extension of the tilt cylinder 152 tilting the ground-engaging blade 142, to the left (or counterclockwise when viewed from the operator cab 136) and retraction of the tilt cylinder 152 tilting the ground-engaging blade 142, to the right (or clockwise when viewed from the operator cab 136. In alternative embodiments, the ground-engaging blade 142 can be tilted by a different mechanism (e.g., an electrical or hydraulic motor) or the tilt cylinder 152 can be configured differently, such as a configuration in which the tilt cylinder 152 is mounted vertically and positioned on the left or right side of the ground-engaging blade 142, or a configuration with two tilt cylinders 152.

[0027] The ground-engaging blade 142 can be angled relative to the work machine 100 by the actuation of angle cylinders 154, which can also be referred to as moving the ground-engaging blade 142 in the direction of yaw 112. For each of the angle cylinders 154, a rod end is pivotally connected to a clevis of the ground-engaging blade 142 while a head end is pivotally connected to a clevis of the C-frame 148. One of the angle cylinders 154 can be positioned on the left side of the work machine 100, left of the ball-socket joint between the ground-engaging blade 142 and the C-frame 148, and the other of the angle cylinders 154 can be positioned on the right side of the work machine 100, right of the ball-socket joint between the ground-engaging blade 142 and the C-frame 148. Such positioning of the angle cylinders 154 can result in an extension of the left of the angle cylinders 154 and a retraction of the right of the angle cylinders 154 angling the ground-engaging blade 142 rightward, or yawing the ground-engaging blade 142 clockwise when viewed from above, and a retraction of left of the angle cylinders 154 and an extension of the right of the angle cylinders 154 angling the ground-engaging blade 142 leftward, or yawing the ground-engaging blade 142 counterclockwise when viewed from above. However, the ground-engaging blade 142 can also be angled by a different mechanism(s), or the angle cylinders 154 can be configured differently.

[0028] Each of the lift cylinders 150, tilt cylinder 152, and angle cylinders 154 can be a double acting hydraulic cylinder. One end of each cylinder can be referred to as a head end, and the end of each cylinder opposite the head end can be referred to as a rod end. Each of the head end and the rod end can be fixedly connected to another component or, as in this embodiment, pivotally connected to another component, such as a through a pin-bushing or pin-bearing coupling, to name but two examples of pivotal connections. As a double acting hydraulic cylinder, each can exert a force in the extending or retracting direction. Directing pressurized hydraulic fluid into a head chamber of the cylinders will tend to exert a force in the extending direction, while directing pressurized hydraulic fluid into a rod chamber of the cylinders will tend to exert a force in the retracting direction. The head chamber and the rod chamber can both be located within a barrel of the hydraulic cylinder and can both be part of a larger cavity which is separated by a movable piston connected to a rod of the hydraulic cylinder. The volumes of each of the head chamber and the rod chamber change with movement of the piston, while movement of the piston results in extension or retraction of the hydraulic cylinder.

[0029] As seen in Figure 2, the control system 138 can include a work vehicle controller 160 that can include, or can be associated with, one or more processors 164 that can follow instructions, including control instructions, contained with, or are part of, one or more memory devices 166, including, for example, a non-transitory machine-readable medium. Various operations, steps or algorithms as described in connection with the work vehicle controller 160 can be embodied directly in hardware, in a computer program product such as a software module executed by the processor 164, or in a combination of the two. The computer program product can reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, as well as combinations thereof, among any other form of computer-readable medium. Further, the work vehicle controller 160 can be a single controller having all of the described functionality, or it can include multiple controllers wherein the described functionality is distributed among the multiple controllers.

[0030] The work vehicle controller 160 can be coupled to one or more user interfaces 168 of the work machine 100 that can be utilized by the human operator to input instructions that can be received by at least the work vehicle controller 160. The user interface 168 can take a variety of forms, including, for example, be or include a monitor, screen, touch screen, keyboard, keypad, mouse, switch, joystick, button, or steering wheel, as well as any combination thereof, among other types of controls or user inputs for operating the work machine 100, including operation of the engine, hydraulic cylinders, and the like. According to certain embodiments, the user interface 168 can further comprise a display unit and/or other outputs from the system such as indicator lights, audible alerts, and the like.

[0031] According to certain embodiments, the user interface 168 can be positioned in the operator cab 136 of the work machine 100. Such an onboard user interface 168 can be coupled to a control system 138 via, for example, a CAN bus arrangement or other equivalent forms of electrical and/or electro-mechanical signal transmission. Another form of the user interface 168 can take the form of a display unit that is generated on a remote (i.e., not onboard) computing device, which can display outputs, such as, for example, status indications and/or otherwise enable user interaction such as the providing of inputs to the system 138. In the context of a remote user interface 168, data transmission between for example the control system 138 and the user interface 168 can utilize a communication unit 170 of the control system 138, and can take the form of a wired and/or wireless communications system(s) and associated components and protocol(s).

[0032] The communication unit 170 can support or provide communications between the work vehicle controller 160 and external systems or devices, and/or support or provide communication interface with respect to internal components of the work machine 100. The communications unit can include wireless communication system components (e.g., via cellular, Wi-Fi, Bluetooth or the like) and/or can include one or more wired communications terminals, such as universal serial bus ports, among others. According to certain embodiments, the communication unit 170 can be communicatively coupled to a network, including, for example, via internet, cellular, and/or Wi-Fi networks. Such connection to the network can facilitate an exchange of information, including information between the work machine 100 and a secondary device, including a central database, cloud based server, or other work machines, as well as combinations thereof.

[0033] As also seen in Figure 2, the control system 138 can also include a blade actuation system 162 that can be communicatively coupled to at least the work vehicle controller 160, among other components of the control system 138. According to certain embodiments, the blade actuation system 162 can include sensors 144, 149 and various actuators, valves, and linkages, among other components, associated with the movement, positioning, and/or orientation of the blade 142.

[0034] The blade actuation system 162 can include a two-dimensional (2D) grade control system 172 having a grade controller 174 that can comprise one or more processors 176 and a memory device 178 that are similar to the processor(s) 164 and memory device 166, respectively, discussed above with respect to the work vehicle controller 160. While the grade controller 174 is illustrated as being part of a grade control system in the form of a 2D grade control system 172, the grade controller 174 can additionally, or alternatively, be part of other grade control systems, including, for example, a laser system or a global positioning system, among others. With respect to a 2D grade control system 172, the illustrated 2D grade control system 172 does not use an external reference of the position of the work machine 100. Further, with respect to the 2D grade control system 172, the 2D grade control system 172 may be unaware of the vertical height or vertical position at which the slope being formed by operation of the work machine 100 is located. Instead, the 2D grade control system 172 can use sensors to sense the orientation of the blade 142 (e.g., mainfall and cross slope) on the work machine 100 relative to another piece of the work machine 100, such as, for example the frame (e.g., chassis 140 or mainframe) of the work machine 100, or relative to gravity, among other ways. The 2D grade control system 172, including, for example, the grade controller 174, can attempt to control the orientation of the blade 142 in order to produce a planar grade along the ground at a desired cross slope and mainfall. Further, the automatic 2D grade control system 172 can use 2D control functionality and the orientation of frame or chassis 140, the orientation of the blade 142 (e.g., relative to gravity or relative to the frame, powertrain, or chassis 140) and the target mainfall and cross slope of the grade to control the position/height and tilt, which can each be at least part of the orientation, of the blade 142 to make a preselected planar cut at a desired mainfall and cross slope. Thus, the automatic 2D grade control system 172, including the grade controller 174, can generate control signals to control other portions of the blade actuation system 162 so as to control the orientation of the blade 142 accordingly.

[0035] The processor(s) 176 of the grade controller 174 can therefore, according to certain embodiments, execute instructions on the memory device 178, among in connection with other information and/or instructions, to automatically control the orientation of the blade 142 of the work machine 100. Moreover, the grade controller 174 can generate commands that generally facilitate an automatic control of the movement of the blade 142, including, for example, with respect to the orientation of the blade 142 in connection with cut depths and slopes to arrive at a ground surface having a predetermined grade.

[0036] According to certain embodiments, the grade controller 174 can be a computing device with an associated processor(s) 176 and memory device(s) 178 having a variety of different architectures, including, but not limited to, hard-wired computing circuit (or circuits), as a programmable circuit, as a hydraulic, electrical or electro-hydraulic controller, or otherwise. As such, the grade controller 174 can be configured to execute various computational and control functionality with respect to the work machine 100 (or other machinery). In some embodiments, the grade controller 174 can be configured to receive input signals in various formats (e.g., as hydraulic signals, voltage signals, current signals, and so on), and to output command signals in various formats (e.g., as hydraulic signals, voltage signals, current signals, mechanical movements, and so on). In some embodiments, the grade controller 174 (or a portion thereof) can be configured to control operation of hydraulic components (e.g., valves, flow lines, pistons and cylinders, and so on) such that control of various devices (e.g., pumps or motors) can be effected with, and based upon, hydraulic, mechanical, or other signals and movements. The grade controller 174 can be in electronic, hydraulic, mechanical, or other communication with various other systems or devices of the work machine 100 (or other machinery). For example, the grade controller 174 can be in electronic or hydraulic communication with various actuators, sensors, and other devices within (or outside of) the work machine 100. The grade controller 174 can communicate with other systems or devices in various known ways, including via a CAN bus (not shown) of the work machine 100, via wireless or hydraulic communication means, or otherwise. The grade controller 174 can be communication with the work vehicle controller 160 and other components of the blade actuation system 162 in a variety of different manners, including, for example, over a suitable communication architecture, such as a CAN bus associated with the work machine 100.

[0037] Electronic control signals from the grade controller 174 can, for example, be received by one or more electro-hydraulic control valves associated with respective actuators, including, for example, a pilot valve 180 and/or a control valve 182. Such electro-hydraulic control valves can be utilized to control the flow of hydraulic fluid to and from the respective hydraulic actuators to control the actuation thereof in response to the control signal from the grade controller 174. Additionally, according to certain embodiments, the grade controller 174 can include, or be functionally linked to, the user interface 168, including, for example a user interface 168 mounted in the operator cab 136 at a control panel.

[0038] The grade controller 174 is configured to receive input signals from some or all of various sensors associated with the work machine 100. For example, the grade controller 174 can receive input signals from one or more first sensors 144 of the 2D grade control system 172 that can be affixed to the chassis 140 of the work machine 100. The first sensors 144 can be configured to at least provide a signal indicative of an inclination (slope) of the chassis 140. Further, the first sensor 144 can be directly or indirectly affixed to the chassis 140, such as, for example, indirectly coupled to the chassis 140 through intermediate components or structures, such as, for example, rubberized mounts. Moreover, the first sensor 144 can be coupled, including directly or indirectly affixed, to the chassis at a fixed relative position so that the first sensor 144 can experience the same motion as the chassis 140.

[0039] The first sensor 144 can be configured to provide at least a signal indicative of the inclination of the chassis 140, or other portion of the work machine 100, relative to the direction of gravity. The first sensor 144 can also be configured to provide a signal or signals indicative of other positions or velocities of the chassis 140. For example, referencing Figure 1, the first sensor 144 can provide information indicating an angular position, velocity, or acceleration of the chassis 140 in one or more directions, including for example, in the direction(s) of roll 104, pitch 108, yaw 112. Additionally, the one or more first sensors 144 can also provide information regarding linear acceleration of the chassis 140 in a longitudinal direction 102, latitudinal direction 106, and/or vertical direction 110. The first sensor 144 can further be configured to directly measure inclination, or for example to measure angular velocity and integrate to arrive at inclination.

[0040] According to certain embodiments, the first sensor 144 can comprise an inertial measurement unit (IMU) mounted on the chassis 140 and configured to provide, as inputs, at least a chassis inclination (slope) signal, or signals corresponding to the scope of the chassis 140, to at least the grade controller 174. Further, according to certain embodiments, the first sensor 144 can, for example, be an IMU in the form of a three-axis gyroscopic unit configured to detect changes in orientation of the first sensor 144, and thus of the chassis 140 relative to an initial orientation. Further, according to certain embodiments, the one or more first sensors 144 can comprise a camera based system that can observe surrounding structural features via image processing, and can identify changes in the orientation and/or position of the working machine 100 relative to those surrounding structural features.

[0041] The grade controller 174 can also receive input signals from one or more second sensors 149 of the 2D grade control system 172 that can be configured to provide at least a signal indicative of a blade inclination (e.g., slope). In a particular embodiment, at least one of the second sensors 149 can be located in association with the lift cylinders 150 to, for example, generate an output signal corresponding to an extension and/or retraction of the lift cylinders 150.

[0042] Similar to the first sensor(s) 144, the one or more second sensors 149 can be a blade inclination sensor that is configured to provide at least a blade inclination signal, which can, for example, indicate the angle of the blade 142 relative to gravity. In certain embodiments, the second sensor 149 can be configured to additionally, or alternatively, measure an angle of the linkage 146, such as, for example, an angle between the linkage 146 and the chassis 140, in order to determine a position of the blade 142. In other alternative embodiments, the second sensor 149 can be configured to measure a position of the ground-engaging blade 142 by measuring a different angle, such as, for example, an angle between the linkage 146 and the ground-engaging blade 142, or the linear displacement of a cylinder attached to the linkage 146 or the ground-engaging blade 142.

[0043] The blade actuation system 162 can also include, or be operably coupled to, the above-discussed lift cylinders 150, tilt cylinders 152, and angle cylinders 154. For example, the grade controller 174 can be communicatively coupled to the pilot valve 180 and/or the control valve 182 in a manner that can control the flow of hydraulic fluid to/from the lift, tilt, and angle cylinders 150, 152, 154 and/or a fluid source or reservoir 184 containing hydraulic fluid. Such control of the flow of hydraulic fluid can be utilized in connection with individually controlling whether the lift, tilt, and angle cylinders 150, 152, 154 are, individually, in either the extended or retracted positions, as well as positions therebetween. Such control of the extent the cylinders 150, 152, 154 are, or are not, actuated, can be utilized by the grade controller 174 to facilitate automatic adjustments in the orientation of the blade 142 in connection with operation of a 2D grade control system 172. Additionally, or alternatively, the grade controller 174 can adjust the orientation of the blade 142 via controlling the actuation of the cylinders 150, 152, 154 in response to an input of a command by an operator, including, for example, a command inputted by the operator via use of the user interface 168.

[0044] When performing a grading operation, or similar task, the work performed using the 2D grade control system 172 can be divided into multiple operational phases, including, for example, a loading phase, carry phase, offloading or shedding phase, and a return phase. During the loading phase, the work machine 100 can be controlled by the 2D grade control system 172, including at least partially be automatically controlled by the grade controller 174. For example, the grade controller 174 can automatically provide information or signals to the blade actuation system 162 that can adjust the orientation of the blade 142, as discussed above, such that the blade 142 penetrates into the ground material to a desired cut depth at a desired height above a grade and at a selected roll, pitch, and/or yaw, which can also be part of the orientation of the blade 142. Generally, the grade for the ground surface is predefined by the operator prior to the grading operation, such as, for example, with respect to the selected mainfall and cross slope for the grade that is formed via operation(s) of the work machine 100. During loading, forward movement of the work machine 100 will typically be primarily resisted by the forces against the blade 142 that may be to shear or dislodge the earth, or other materials, and introduce the displaced earth/materials into the volume of loose material, or ground material, being pushed by the blade 142 of the work machine 100.

[0045] After the work machine 100 completes a given loading phase, the blade 142 is often lifted such that minimal, if any, ground material is lifted or moved. The work machine 100 thus enters the carry phase. After pushing the ground material to a selected destination, the work machine 100 can disengage from the ground material, and thus be in the shedding phase.

[0046] The work machine 100 is then repositioned to perform another pass, which, again, can correspond to the return phase. The blade 142 can then again be lowered, such as, for example, into the ground material, and the work machine 100 can reenter the loading phase. Thus work cycle can then be repeated until the ground surface is formed to have a selected grade, including with respect to slope(s) and/or shape(s) along the ground surface.

[0047] Figure 3 illustrates an exemplary method for controlling an operation of a work machine 100 having the 2D grade control system 172. The method 300 is described below in the context of being carried out by the illustrated exemplary blade actuation system 162, including the 2D grade control system 172. However, it should be appreciated that method 300 can likewise be carried out by any of the other described implementations, as well as variations thereof. Further, the method 300 corresponds to, or is otherwise associated with, performance of the blocks described below in the illustrative sequence of Figure 3. It should be appreciated, however, that the method 300 can be performed in one or more sequences different from the illustrative sequence. Additionally, one or more of the blocks mentioned below may not be performed, and the method can include steps or processes other than those discussed below.

[0048] At block 302, an operator can enable the 2D grade control system 172, such as, for example, via use of the user interface 168. For example, such enablement can turn the 2D grade control system 172 on, such as, for example, with respect to the functionality or features provided by the 2D grade control system 172. Thus, conversely, disabling of the 2D grade control system 172 can involve the functionality or features provided by the 2D grade control system 172 being unavailable, including, for example, but not limited to, such functionalities being powered off. Thus, when disabled, the 2D grade control system 172 cannot be utilized until the 2D grade control system 172 again enabled by the operator. Further, according to certain embodiments, the enabling of the 2D grade control system 172 requires a specific action by the operator that may be solely directed to the enabling to the 2D grade control system 172. For example, according to certain embodiments, enabling to the 2D grade control system 172 may involve the operator moving, including displace, a joystick of the user interface 168 within the operator cab 136 or on a remote device to enable the 2D grade control system 172. According to such an embodiment, such movement of the joystick may not directly be associated, or combined, with any specific movement or travel of the work machine 100, including the blade 100, but instead may be solely for the purpose of enabling the 2D grade control system 172.

[0049] As discussed herein, according to embodiments discussed herein, upon performing an action, via the user interface 168, that enables the 2D grade control system 172, the operator may need not again engage the user interface 168 to either disable or re-enable the 2D grade control system 172 until the operator is, at least temporarily, done with performing a series of grading operations. Moreover, as discussed below, the operator may not need to engage in activities in which the operator, during a grading operation, is at least performing an action specifically directed to re-enabling the 2D grade control system 172, such as via use of the joystick of the user interface 168. Instead, as discussed below, the 2D grade control system 172 can remain enabled through a series of grading operations in which the blade 142 is, and is not, positioned to grade the ground surface. According to such embodiments, rather than the 2D grade control system 172 being disabled during such a collection of grading related operations, the 2D grade control system 172 can instead remain enabled and transition, while enabled, between an active mode and an inactive, or armed mode. Further, as discussed below, such transitions of the continuously enabled 2D grade control system 172 can be based on a location of the blade relative to an activation window.

[0050] More specifically, with the 2D grade control system 172 enabled, the 2D grade control system 172 can be in at least two modes, namely, an active mode, and an inactive / armed mode. In the active mode, the 2D grade control system 172 operates in a manner in which the 2D grade control system 172, such as, for example, the grade controller 174, automatically controls, including, if needed, adjusts, the orientation of the blade 142, including, for example, with respect to a height, position, pitch, roll, and/or yaw (generally collectively referred to herein as an orientation) of the blade 142. Thus, in the active mode, the 2D grade control system 172 automatically orients the blade 142 such that the blade 142 at least assists the work machine 100 in forming the preselected grade in the corresponding ground surface. Moreover, in the active mode, the orientation of the blade 142 can be automatically controlled by the 2D grade control system 172, including, for example, the grade controller 174, based at least in part on information relating to the grade that the work machine 100 is to impart on the corresponding ground surface, as may have been previously inputted to the control system 138.

[0051] In the inactive, or armed, mode, the 2D grade control system 172 also is enabled. However, unlike the active mode in which the 2D grade control system 172 is active, in the inactive, or armed, mode, the orientation of the blade 142, or associated movement with respect to the orientation of the blade 142, is not automatically controlled by the 2D grade control system 172. Instead, in the inactive mode, the orientation of the blade 142 can, for example, be controlled by the operator of the work machine 100. For example, the operator can at least temporarily override the 2D grade control system 172 without disabling the 2D grade control system 172 by raising, or otherwise moving, the blade 142 outside of an activation window. Thus, in such a situation, by placing the blade 142 outside of the activation window, the grade control system can enter the inactive, or armed, mode in which the 2D grade control system 172 remains enabled but is at least temporarily inactive, as the 2D grade control system 172 is not currently being used to automatically orient the blade 142. Additionally, as discussed below, the enabled 2D grade control system 172 can transition from the inactive, or armed, mode and back to the active mode in response to the operator repositioning, such as, for example, lowering, at least a portion of the blade 142 back into the activation window. For example, upon the operator positioning at least a portion of the blade 142 within the activation window, the 2D grade control system 172 can automatically return to the active mode, wherein the 2D grade control system 172 can again resume automatic control of the orientation of the blade 142. As discussed below, such a transition from the inactive mode to the active mode via the operator positioning at least a portion of the blade 142 in the activation window can accommodate the 2D grade control system 172 resuming automatic control of the orientation of the blade 142 without requiring that the operator take another, separate action with respect to re-enabling the 2D grade control system 172. Accordingly, while the operator may have initially enabled the 2D grade control system 172, including, for example, via an input involving movement of a joystick of the user interface 168, the operator does not need to repeat such a step for the 2D grade control system 172 to transition from the inactive mode to the active mode, or vice versa.

[0052] Accordingly, with the 2D grade control system 172 enabled, at block 304 a determination can be made as to whether at least a portion of the blade 142 is, or is not, position within the activation window. The size and shape of the area/position that is to be designated for the activation window can be based on a variety of criteria, including, but not limited to, characteristics relating to the slope that is to be formed in the ground surface by the grading operations, among other criteria. Additionally, as discussed below, the size of the activation window can be adjusted, wither automatically or based on operator preference. For example, according to certain embodiments, the grade controller 174 can at least initially determine the size and/or shape of the activation window using inputted information regarding the grade that is to be formed via operation of the work machine 100.

[0053] Figures 4A and 4B provide two non-limiting examples of different sized activation windows 186a, 186b designated to extend above the adjacent ground 188. As seen, the exemplary activation window 186a, 186b can be an area (as generally indicated by "A_1" and "A_2" Figures 4A and 4B, respectively) and/or distance (as generally indicated by "H_1" and "H2" Figures 4A and 4B, respectively) between a slope (as generally indicated by "S_1", and "S_2" Figures 4A and 4B, respectively) of the activation window 186a, 186b and the adjacent ground 188. The extent, or degree, to which the blade 142 is, or is not, located within the activation window 186a, 186b, so as to constitute being within the activation window by the 2D grade control system 172, can vary. For example, according to certain embodiments, only a portion of the blade 142 is to be within a portion of the activation window 186a, 186b, such as, for example, be below the corresponding slope ("S_1", "S_2") of the activation window 186a, 186b for the 2D grade control system 172 to determine the blade 142 is within the activation window 186a, 186b. Alternatively, according to other embodiments, a predetermined portion or percentage, if not all, of the blade 142 may be required to be within the activation window 186a, 186b, such as, for example, be below the corresponding slope ("S_1", "S_2"), for the 2D grade control system 172 to determine that the blade 142 is within the activation window 186a, 186b.

[0054] Whether the blade 142 is, or is not, within the activation window 186a, 186b can, according to certain embodiments, be based on a comparison of information from one or more sensors, including, for example, information relating to an implement angle 190, such as, for example, information regarding a slope of the blade 142, or blade slope, extends into the activation window 186a, 186b. Alternatively, according to other embodiments, the orientation of one or more other portions of the work machine 100 can be determined or identified, and used in connection with determining whether the blade 142 is, or is not, in the activation window 186. For example, Figure 8 illustrates an alternative embodiment in which the implement angle 190' is an angle of the C-frame 148, such as, for example, an angle related to the ground 188 or gravity, that is used to determine whether the blade 142 is, or is not, in the activation window 186. Alternatively, Figure 9 illustrates another exemplary representation of a determination of whether the blade 142 of the work machine 100 is inside or outside of the activation window 186‴ that is based, at least in part, on a height (as generally indicated in Figure 9 as "H_3") of the blade 142 above ground 188, or an associated tracking plane. For example, according to certain embodiments, the activation window 186‴ can correspond to a particular height ("H_3") above the ground 188, or some other surface or plane, which can also generally be referred to as a tracking plane. Thus, according to certain embodiments, when the blade 142 is brought to a position, such as, for example, lowered to a height that is at or less than the predetermined height ("H_3") of the activation window 186, the blade 142 can be deemed to be within the activation window 186'". Conversely, when the blade 142 is brought into a positioned, such as, for example, raised to a height that is higher than the predetermined height ("H_3") of the activation window 186, the blade 142 can be deemed to be outside of the activation window 186'".

[0055] The activation window 186a, 186b (generally referred to as activation window 186) can have a variety of shapes and sizes, such as, for example, be triangular, square, or rectangular (Figure 9), among others. Further, according to certain embodiments, the size of the activation window 186 is adjustable, either by the operator of the work machine 100 and/or via the 2D grade control system 172. Such adjustability can impact the sensitivity of the 2D grade control system 172 with respect to leaving and entering the activation window 186. For example, Figure 4A illustrates an example in which a first activation window 186a is, at least compared to a second activation window 186b shown in Figure 4B, relatively large. For example, as shown by a comparison of Figures 4A and 4B, the first activation window 186a shown in Figure 4A has a larger area ("A_1") and height ("H_1") then the corresponding area ("A_2") and height ("H_2") of second activation window 186b shown in Figure 4B. Such differences in the size of the activation windows 186a, 186b shown in Figures 4A and 4B can impact the sensitivity of the 2D grade control system 172. For example, the larger activation window 186a shown in Figure 4A may, compared to the activation window 186b shown in Figure 4B, accommodate the operator having to lower the blade 142 a shorter distance to have the blade 142 enter the activation window 186a. Thus, with respect to at least changing the enabled 2D grade control system 172 from the inactive mode to the active mode, the activation window 186a shown in Figure 4A may be associated with a lower level of sensitivity than the activation window 186b shown in Figure 4B, and thus may involve a shorter amount of time and effort on behalf of the operator for entering into the active mode. Conversely, the larger activation window 186a shown in Figure 4A can, compared to the smaller activation window 186b shown in Figure 4B, require that the operator lift the blade 142 a greater distance, and thus for a longer time, to change the 2D grade control system 172 from being in the active mode to being in the inactive mode. Thus, with respect to at least changing the enabled 2D grade control system 172 from the active mode to the inactive mode, the activation window 186b shown in Figure 4B can be associated with a lower level of sensitivity than the activation window 186a shown in Figure 4A.

[0056] When a determination is made at block 304, such as, for example, by the grade controller 174, that the blade 142 is outside of the activation window 186, then the enabled 2D grade control system 172 can be deemed to be in the inactive, or armed, mode, as indicated by block 305. Figure 5 illustrates an example of a blade 142 not being within the activation zone, which in this example is based on an implement angle 190 in the form of a slope of the blade 142 being outside of the activation window 186, among other information. Moreover, in the example shown in Figure 5, the grade controller 174 can determine, based, for example, on information provided by one or more sensors, among other information, that no portion of the blade 142 is within the activation window 186, as the implement angle 190 does not extend through the activation window 186, and/or the implement angle 190 is above the slope of the activation window 186. In such a situation, the operator can lower the blade 142 into the activation window 186, as indicated by block 306, wherein the 2D grade control system 172 can change from being in the inactive mode to the active mode, as illustrated by block 308. Thus, with respect to the example shown in Figure 5, the operator can lower the blade 142 at least until the implement angle 190 is within the activation window 186, or alternatively, is determined to be below the slope for the activation window 186.

[0057] Conversely, if at block 304 the grade controller 174 determines that the blade 142 is within the activation window 186, then the enable 2D grade control system 172 can be deemed to be in the active mode, as indicated by block 308, wherein the 2D grade control system 172 can automatically control the orientation of the blade 142, as previously discussed. For instance, Figure 6 illustrate a situation in which a portion of the blade 142 is within the activation window 186. Moreover, in the example shown in Figure 6, the grade controller 174 can determine, based, for example, on information provided by one or more sensors, among other information, that at least a portion of the blade 142 is within the activation window 186 based, for example, on the implement angle 190 extending through the activation window 186, and/or the implement angle 190 being below the slope of the activation window 186.

[0058] With the 2D grade control system 172 in the active mode, as indicated, for example, by block 309, the work machine 100 can be operated to grade the ground surface. For example, at block 310, the work machine 100 can operate in the loading phase, wherein the orientation of the blade 142 can be controlled by the blade actuation system 162, including at least partially be automatically controlled by the grade controller 174. Thus, the work machine 100 can proceed with grading the corresponding ground. After doing a grading pass over the ground and/or pushing ground material to a selected destination, the work machine 100 can disengage from the ground material, and thus be in the shedding phase at block 312.

[0059] The work machine 100 can then repositioned to perform another pass, which, again, can correspond to the return phase.

[0060] Accordingly, in connection with the conclusion of the loading phase and/or entering the shedding phase and/or return phase, the operator can raise the blade 142 out of the activation window 186 at block 314. As discussed above with respect to Figures 4A and 4B, the extent the operator is to raise the blade 142 to be outside of the activation window 186 can correspond to at least the size and/or height of the activation window 186. Thus, at block 316, the 2D grade control system 172, including, for example, the grade controller 174, can determine at block 316 as to whether the blade 142, or any portion thereof, is, or is not, within the activation window 186. Further, as previously discussed, such a determination can be made in a variety of manners, including, for example, based at least on information regarding whether the implement angle 190 is within the activation window 186 and/or is above or below the associated slope of the activation window 186, among other manners of determination of the position of the blade 142 relative to the activation window 186. If the blade 142 is determined at block 316 to be within the activation window 186, the 2D grade control system 172 can continue to monitor the position of the blade 142 relative to the activation window 186 as the blade 142 continues to be raised at block 314. Additionally, or alternatively, the 2D grade control system 172 can generate a signal for communication, such as, for example via the user interface 168, to indicate to the operator that the blade 142 is to be further raised at block 314 to be outside of the activation window 186.

[0061] When a determination is made at block 316 that the blade 142 is not within the activation window 186, then the enabled 2D grade control system 172 enters the inactive, or armed, mode, as indicated by block 317. Moreover, by raising the blade 142 outside of the activation window 186, the 2D grade control system 172 can automatically at least temporarily deactivate the enabled 2D grade control system 172 By having the 2D grade control system 172 enter the inactive, or armed mode without further action by the operator. The operator can then proceed with repositioning the work machine 100 at block 318 such as, for example, repositioning the work machine 100 for another pass along the ground. Moreover, in at least certain instances, with the blade 142 in the inactive, or armed, mode the blade 142 can be at a raised position above the ground 188 such that the blade 142 does not contact the ground 188, including ground material thereon, while the operator repositions the work machine 100.

[0062] Optionally, according to certain embodiments, in response to the 2D grade control system 172 changing from the active mode to the inactive, or armed, mode, the 2D grade control system 172 can determine at block 320 as to whether the predetermined grade has been formed in the ground surface. Such a determination can include considering the predetermined grade that was previously inputted into the 2D grade control system 172 and information from one or more sensors, including sensors that indicate an orientation of the blade 142. If any determination is made at block 320 that the predetermined grade has been obtained, then that block 322 the 2D grade control system 172 can be disabled, and the grading operation can be concluded at block 324.

[0063] Additionally, and optionally, according to certain embodiments, if the grading operation is to continue, such as, for example, the predetermined grade has not yet been attained in the ground surface, then at block 326 the size of the activation window 186 can be adjusted. For example, referencing Figures 4A and 4B, as the amount of ground material that is being removed decreases, the size of the activation window 186a, as shown by Figure 4A, may be decreased to a smaller size, such as, for example, the size of the activation window 186b shown in Figure 4B. Such adjustments may be beneficial with at least respect to the extent that the operator is to raise the blade 142 so as to be outside of the activation window 186, 186a, 186b, thereby requiring less time and effort on the part of the operator when the 2D grade control system 172 is to enter the inactive, or armed, mode. Thus, for example, Figure 5 may illustrate an example of a size of an activation window 186 at least during one or more initial passes along the ground surface, while Figure 7 indicates an adjustment in the size of the activation window 186' for subsequent passes over the ground surface. In these examples, the extent of time and effort utilized by the operator to raise the blade 142 outside of the activation window 186' can be relatively substantially reduced for the activation window 186' shown in Figure 7.

[0064] In the event the operator is to continue operating the work machine 100 to form the predetermined grade for the ground surface, then, with the work machine 100 can be repositioned, as indicated with respect to at least block 318, and the operator can proceed to lower the blade 142 back into the activation window 186 at block 328. Although the 2D grade control system 172 is in the inactive, or armed, mode at the time the operator begins lowering the blade 142 into the activation window 186, the 2D grade control system 172 is still enabled. Thus, the operator can simply lower the blade 142 without having to take any other actions with respect to having to enable, or re-enable, the 2D grade control system 172. Moreover, the operator does not need to take an additional step with respect to other operations using the interface with respect to re-enabling the 2D grade control system 172. Given that the operator may perform numerous passes, including, for example, hundreds of passes, in a single day, by being able to simply transition the 2D grade control system 172 from the inactive, or armed, mode to the active mode by lowering the blade 142, and without having to take additional or separate steps or actions to also repeatedly enable, or re-enable, the 2D grade control system 172 can provide a relatively significant savings with respect to the efforts and time of the operator, and thereby improve the ease with which the 2D grade control system 172 is operated. Therefore, with the blade 142 lowered into the activation window 186, as determined at block 304, the enabled 2D grade control system 172 can again enter the active mode, wherein the grade controller 174 can automatically orient the blade 142 such that the work machine 100 can proceed with again performing a loading phase at block 310, as previously discussed.

[0065] While the disclosure has been illustrated and described in detail in the foregoing drawings and description, the same is to be considered as exemplary and not restrictive in character, it being understood that only illustrative embodiments thereof have been shown and described and that all changes and modifications that come within the spirit of the disclosure are desired to be protected.

Claims

1. A method (300) for controlling a two-dimensional grade control system (172) of a bladed work machine (100), the method (300) comprising:

    enabling (302) the two-dimensional grade control system (172);
    determining (304) at least a portion of a blade (142) of the bladed work machine (100) is positioned inside an activation window (186);
    placing (309) the enabled two-dimensional grade control system (172) in an active mode in response to the determining (304) the portion of the blade (142) is positioned inside the activation window (186), wherein, in the active mode, the two-dimensional grade control system (172) automatically controls an orientation of the blade (142);
    determining (316) the blade (142) of the bladed work machine (100) is positioned outside the activation window (186);
    placing (317) the enabled two-dimensional grade control system (172) in an inactive mode in response to the determining the blade (142) is positioned outside the activation window (186), wherein, in the inactive mode, the two-dimensional grade control system (172) remains enabled but does not automatically control the orientation of the blade (142); and
    changing (309), while the two-dimensional grade control system (172) has continuously remained enabled, the two-dimensional grade control system (172) from the inactive mode to the active mode in response to determining (304) the portion of the blade (142) that had previously been outside the activation window (186) is positioned in the activation window (186).

2. The method (300) of claim 1, wherein the changing (309) of the two-dimensional grade control system (172) from the inactive mode to the active mode does not require a re-enabling of the two-dimensional grade control system (172).

3. The method (300) of claim 2, further including the enabled two-dimensional grade control system (172) automatically controlling the orientation of the blade (142) in response to a change of the enabled two-dimensional grade control system (172) from the inactive mode to the active mode.

4. The method (300) of claim 1, wherein the changing (309) of the two-dimensional grade control system (172) from the inactive mode to the active mode comprises detecting a height of the blade (142) relative to at least one of the activation window (186) and a ground surface.

5. The method (300) of claim 1, wherein the determining (304) at least the portion of the blade (142) is positioned inside the activation window (186) comprises determining an implement angle of the bladed

work machine (100) extends into the activation window (186).

6. The method (300) of claim 5, wherein the determining the blade (142) is positioned outside the activation window (186) comprises determining (304, 316) the implement angle does not extend into the activation window (186).

7. The method (300) of claim 5, wherein the implement angle is either a slope of the blade (142) or a slope of a C-frame (148) of the bladed work machine (100).

8. The method (300) of claim 1, wherein the determining (304) at least the portion of the blade (142) is positioned inside the activation window (186) comprises determining the blade (142) satisfies a predetermined height above a predetermined location.

9. The method (300) of claim 1, further comprising adjusting (326) a size of the activation window (186) in response to at least the determining the blade (142) has moved from being inside the activation window (186) to being outside the activation window (186).

10. An apparatus comprising:

a bladed work machine (100) having a blade (142), the blade (142) configured to engage a ground material;
a control system (162) having a two-dimensional grade control system (172), the two dimensional grade control system comprising a memory device (178) coupled with at least one processor (176), the memory device (178) including instructions that when executed by the at least one processor (176) cause the at least one processor (176) to:

receive a signal from a user interface (168) of the bladed work machine (100) that enables the two-dimensional grade control system (172) to provide an enabled two-dimensional grade control system (172);
determine at least a portion of a blade (142) of the bladed work machine (100) is positioned inside an activation window (186);
place the enabled two-dimensional grade control system (172) in an active mode in response to the portion of the blade (142) being determined to be positioned inside the activation window (186), wherein, in the active mode, the enabled two-dimensional grade control system (172) automatically controls an orientation of the blade (142);
determine the blade (142) of the bladed work machine (100) is positioned outside the activation window (186);
places the enabled two-dimensional grade control system (172) in an inactive mode in response to the blade (142) being determined to be positioned outside the activation window (186), wherein, in the inactive mode, the enabled two-dimensional grade control system (172) remains enabled but does not automatically control the orientation of the blade (142); and
change, while the enabled two-dimensional grade control system (172) has remained enabled and not subsequently entered a disabled state, the enabled two-dimensional grade control system (172) from the inactive mode to the active mode in response to determining the portion of the blade (142) that had previously been outside the activation window (186) is positioned in the activation window (186).

11. The apparatus of claim 10, wherein the memory device (178) including instructions that when executed by the at least one processor (176) further cause the at least one processor (176) to allow the two-dimensional grade control system (172) to remain enabled between periods in which the grade control system (172) is, and is not, in the active mode.

12. The apparatus of claim 10, wherein the memory device (178) including instructions that when executed by the at least one processor (176) further cause the at least one processor (176) to automatically control the orientation of the blade (142) in response to a change of the enabled two-dimensional grade control system (172) from the inactive mode to the active mode.

13. The apparatus of claim 10, wherein the change of the two-dimensional grade control system (172) from the inactive mode to the active mode comprises a detection of a height of the blade (142) relative to at least one of the activation window (186) and a ground surface.

14. The apparatus of claim 10, wherein the determination that at least the portion of the blade (142) is positioned inside the activation window (186) comprises a determination that an implement angle of the bladed work machine (100) extends into the activation window (186), and wherein the determination that the blade (142) is positioned outside the activation window (186) comprises a determination that the implement angle does not extend into the activation window (186).

15. The apparatus of claim 10, wherein the determination that at least the portion of the blade (142) is positioned inside the activation window (186) comprises a determination that blade (142) satisfies a predetermined height above a predetermined location, or wherein the memory device (178) including instructions that when executed by the at least one processor (176) further cause the at least one processor (176) to adjust a size of the activation window (186) in response to at least the determination that the blade (142) has moved from being inside the activation window (186) to being outside the activation window (186).

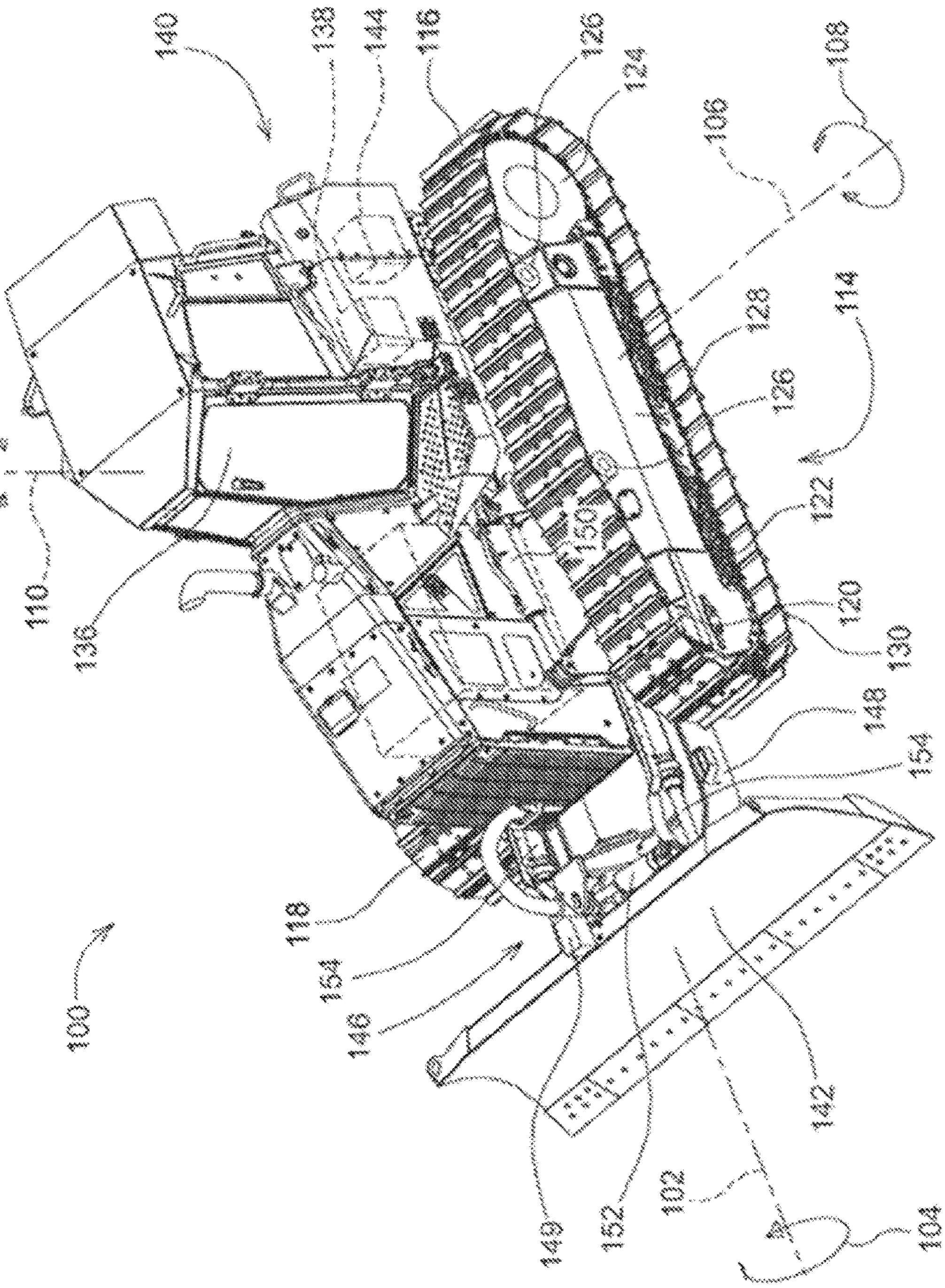
100
102
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FIGURE 1

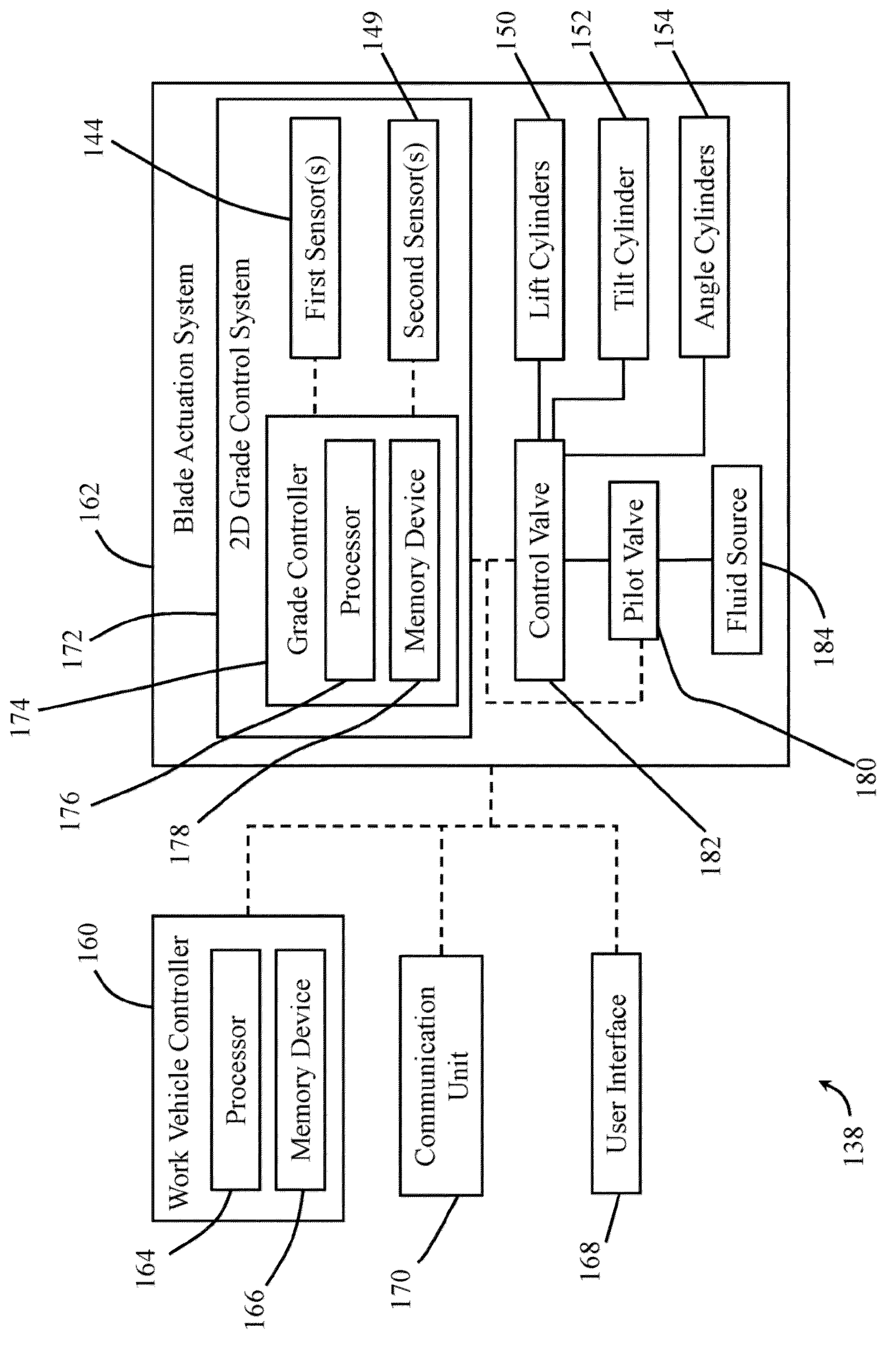
Blade Actuation System
2D Grade Control System
First Sensor(s)
Second Sensor(s)
Grade Controller
Processor
Memory Device
Lift Cylinders
Tilt Cylinder
Angle Cylinders
Control Valve
Pilot Valve
Fluid Source
Work Vehicle Controller
Processor
Memory Device
Communication Unit
User Interface
144
149
150
152
154
162
172
174
176
178
180
182
184
160
164
166
170
168
138

FIGURE 2

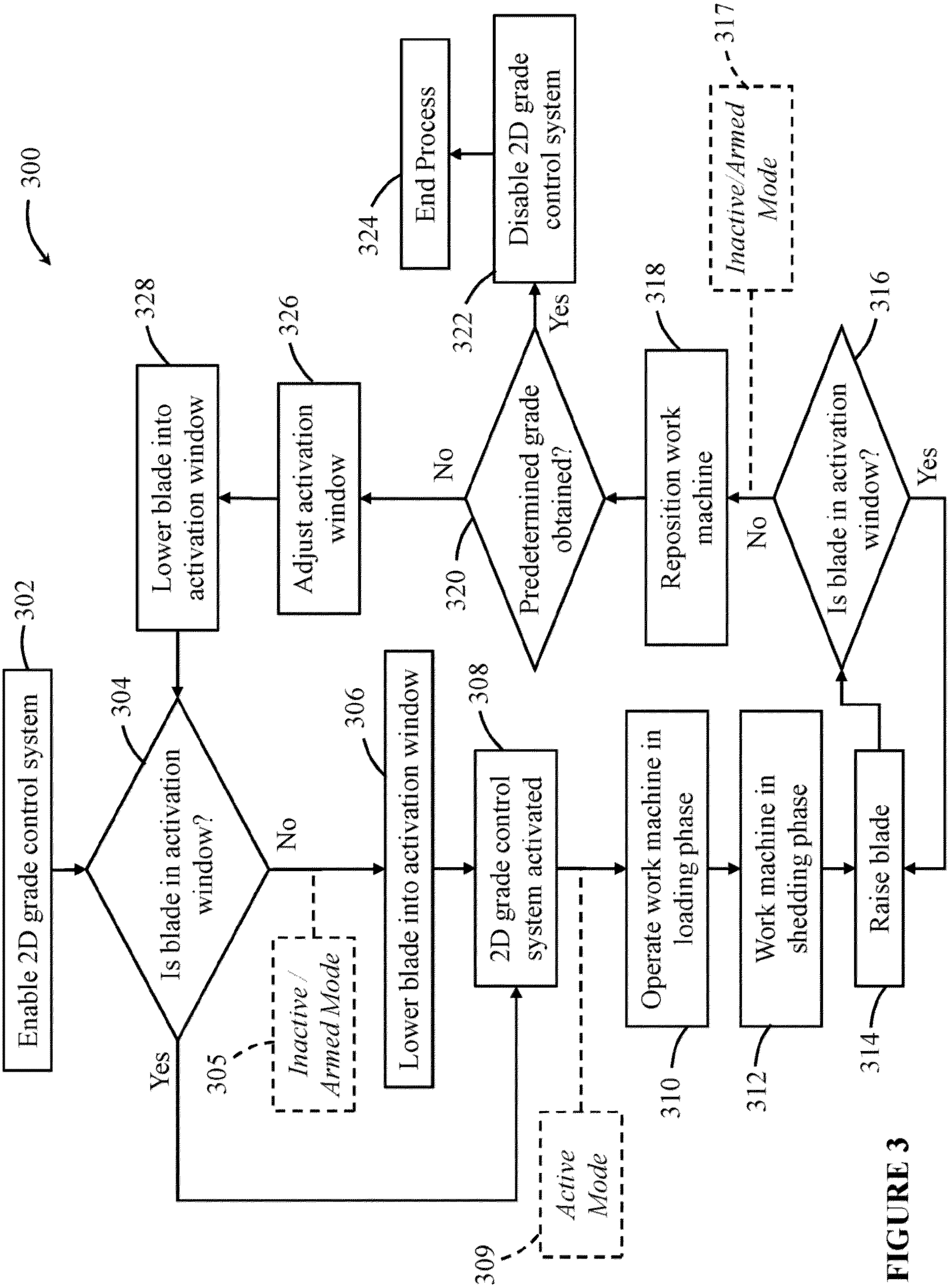
300
302
Enable 2D grade control system
304
Is blade in activation window?
Yes
No
305
Inactive / Armed Mode
306
Lower blade into activation window
308
2D grade control system activated
309
Active Mode
310
Operate work machine in loading phase
312
Work machine in shedding phase
314
Raise blade
316
Is blade in activation window?
Yes
No
317
Inactive/Armed Mode
318
Reposition work machine
320
Predetermined grade obtained?
Yes
No
322
Disable 2D grade control system
324
End Process
326
Adjust activation window
328
Lower blade into activation window

FIGURE 3

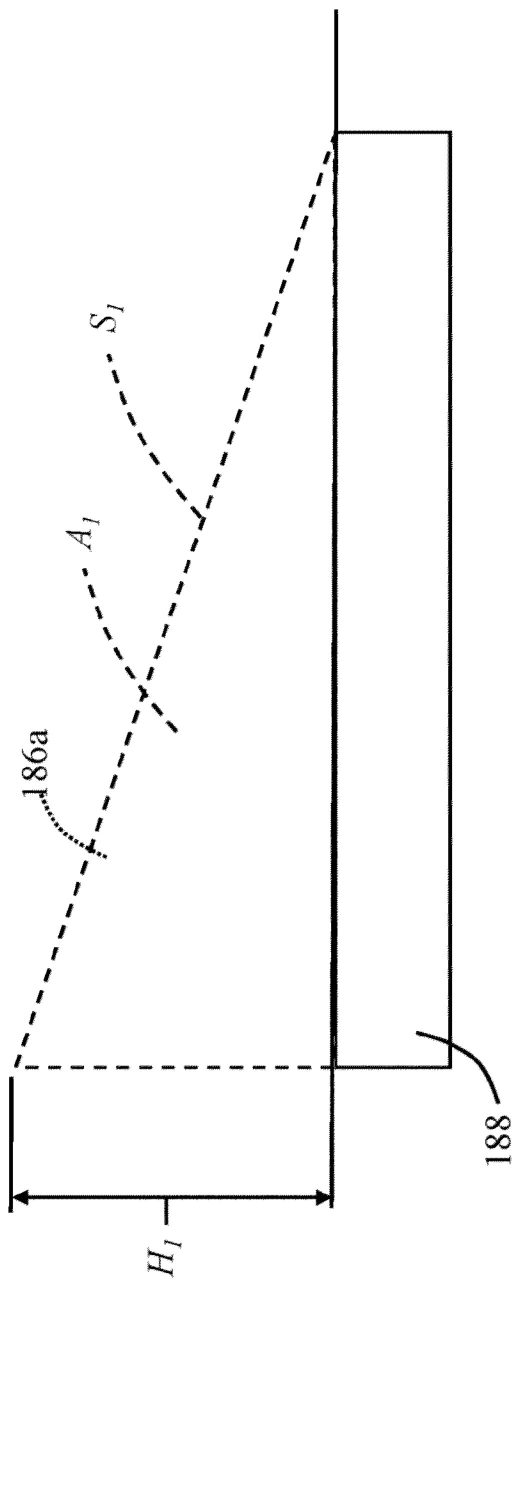

FIGURE 4A

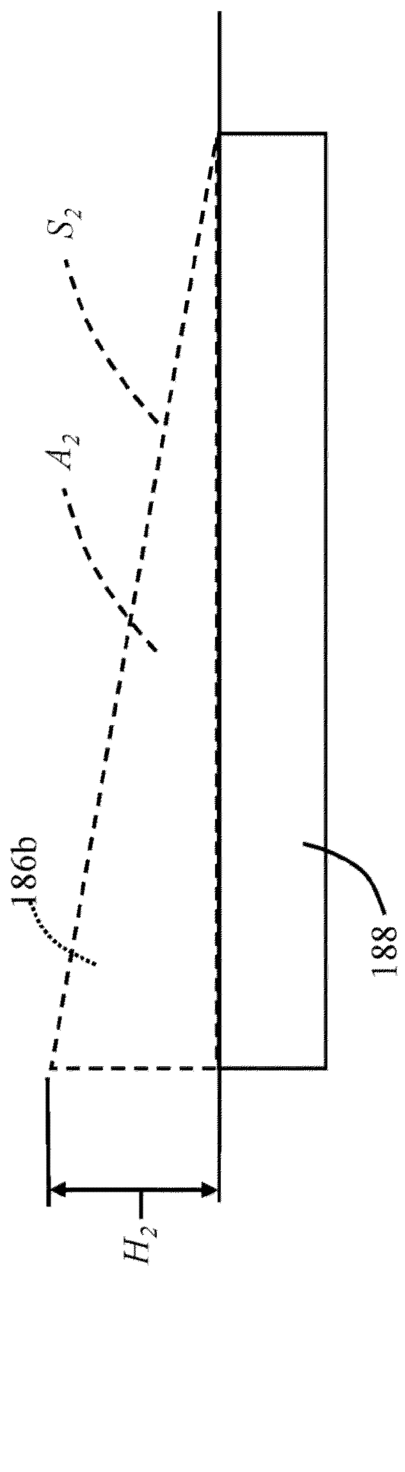

FIGURE 4B

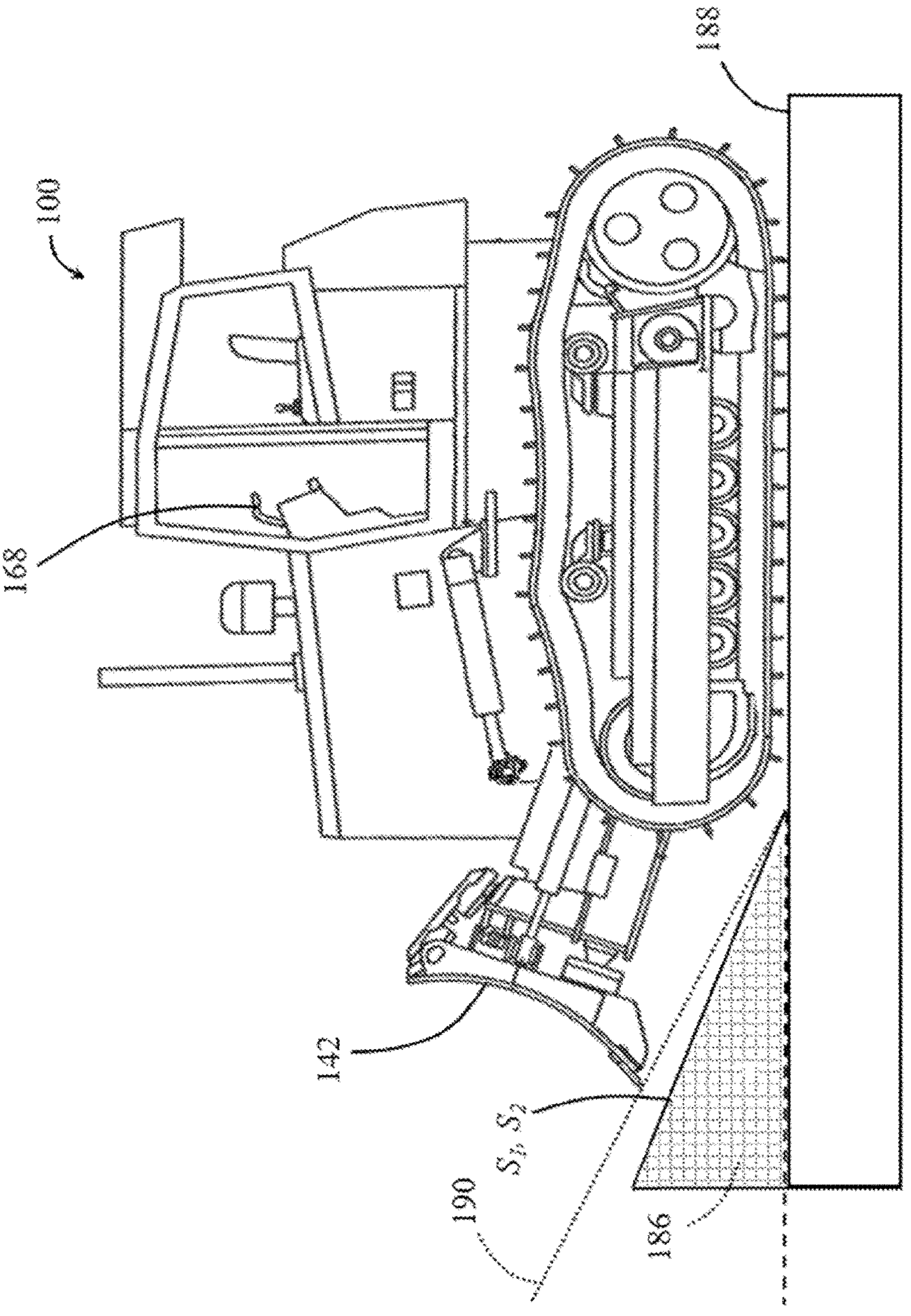

FIGURE 5

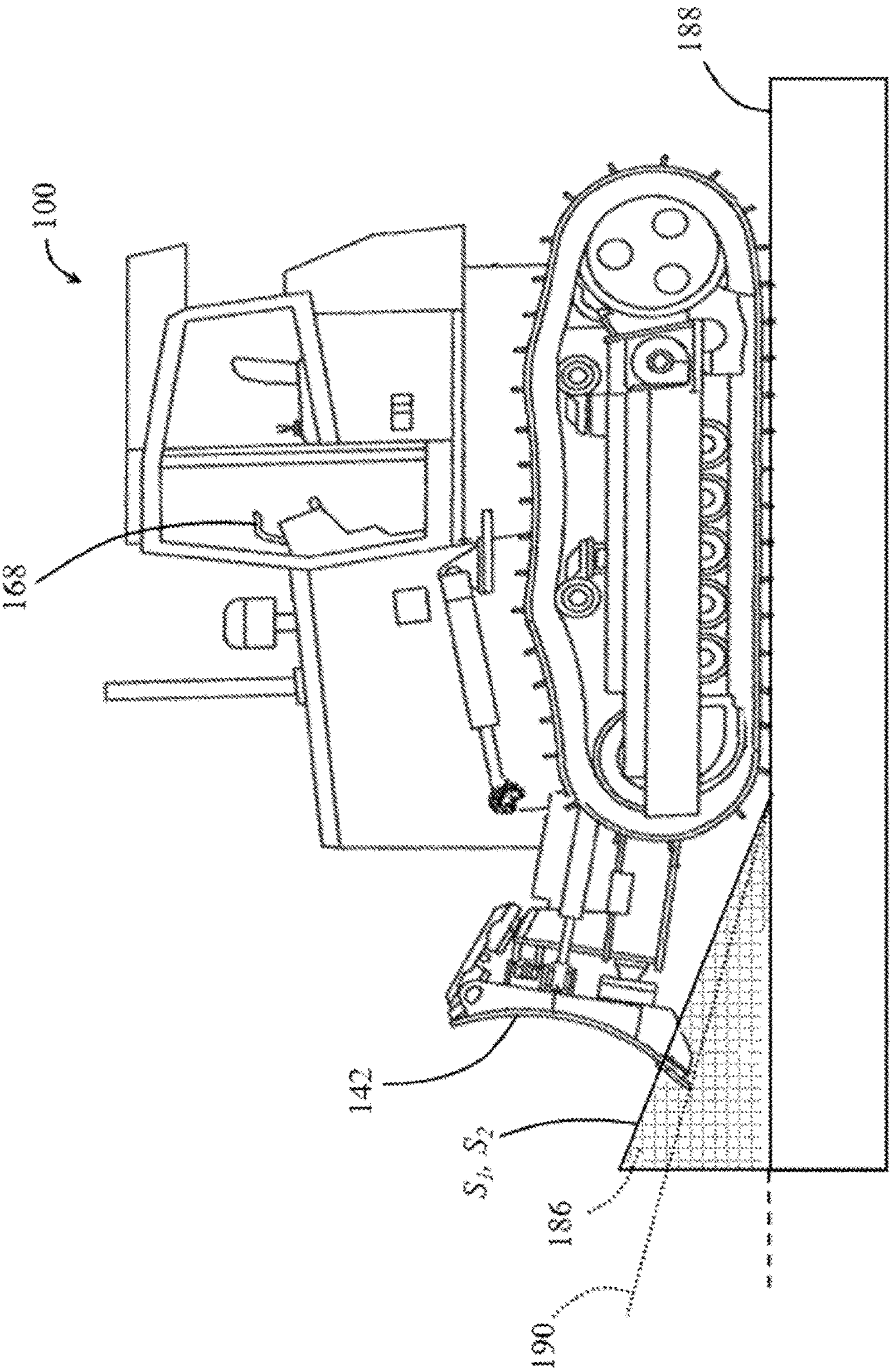

FIGURE 6

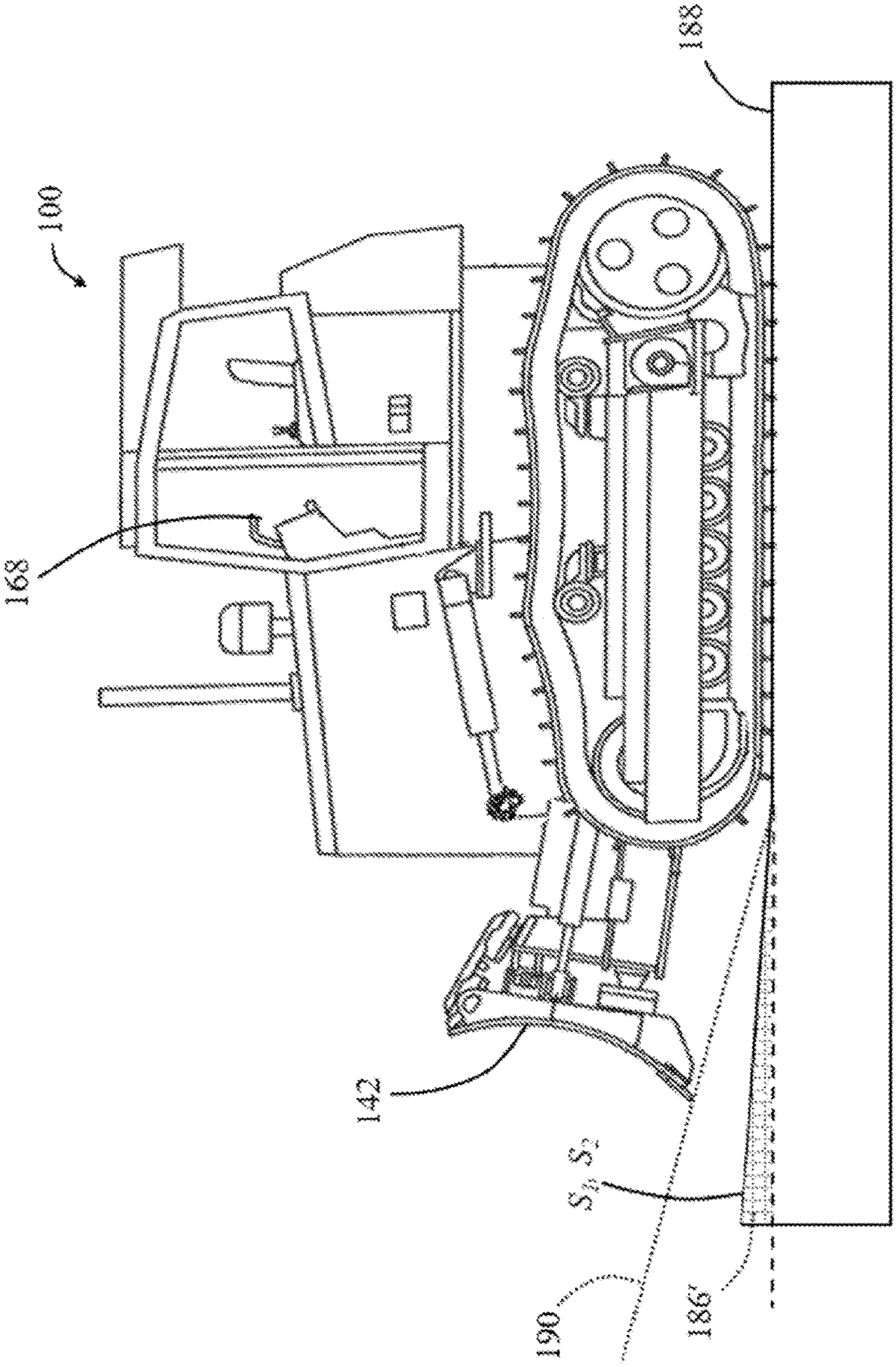

FIGURE 7

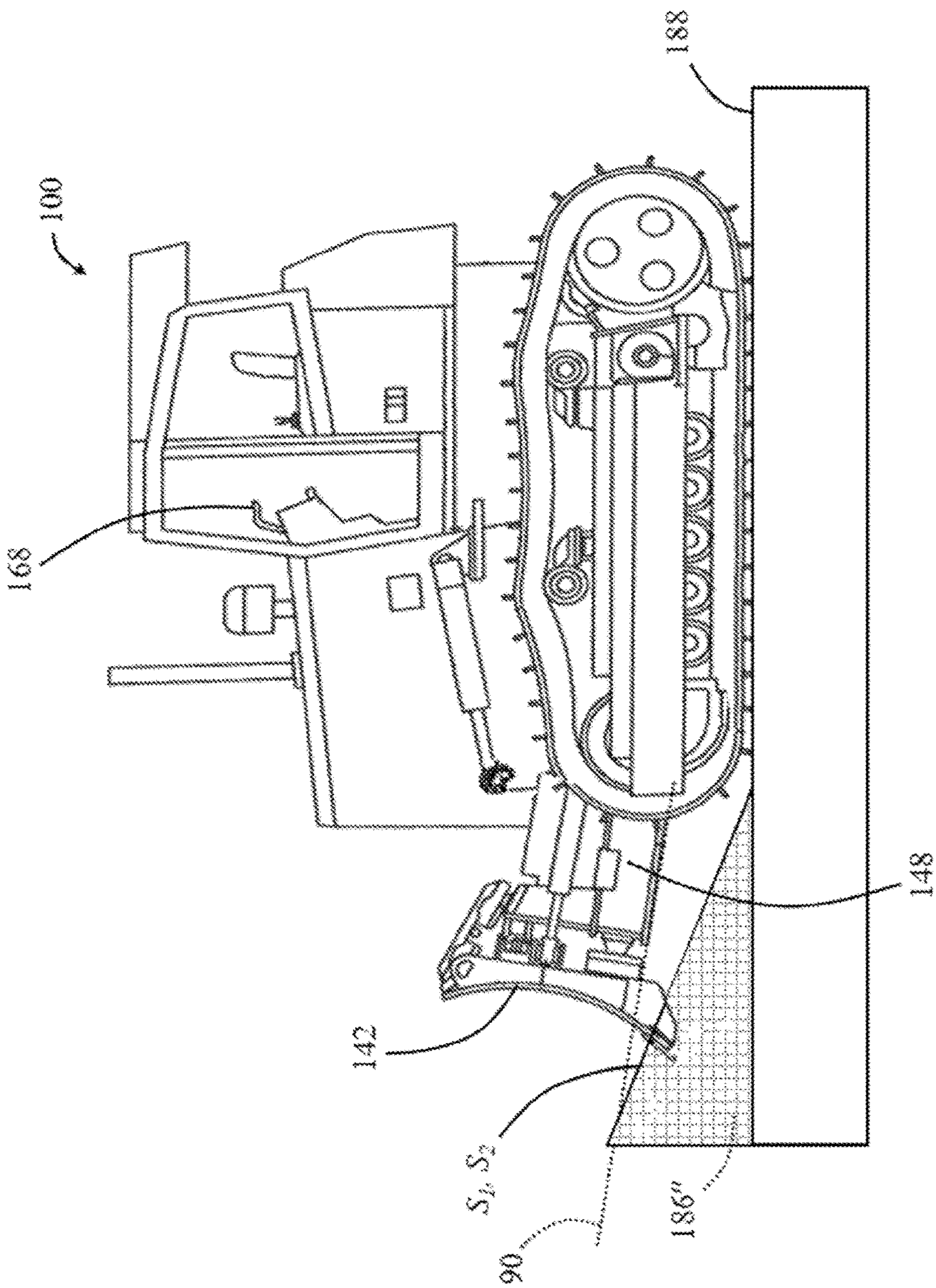

FIGURE 8

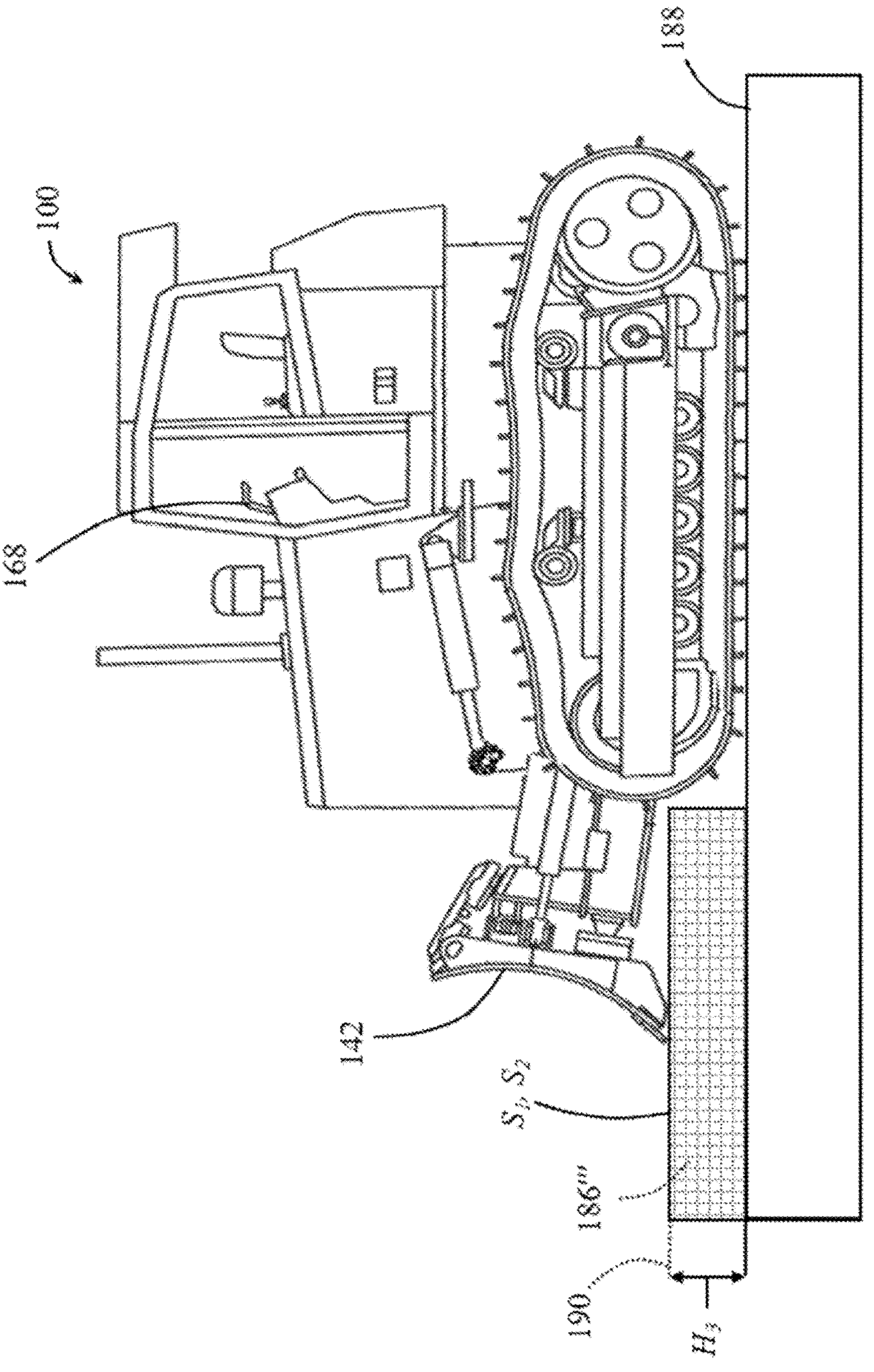

FIGURE 9

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 24 19 2672

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	JP H08 116718 A (MITSUBISHI AGRICULT MACH) 14 May 1996 (1996-05-14) * paragraph [0014] * * paragraph [0022] - paragraph [0023] * -----	1-4, 10-13 5-9,14, 15	INV. E02F3/84
A	US 2022/243423 A1 (KOENIG CARL J [US]) 4 August 2022 (2022-08-04) * the whole document * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			E02F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	17 January 2025	Dreyer, Christoph

1

CATEGORY OF CITED DOCUMENTS

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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
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17-01-2025

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		JP H08116718 A	14-05-1996
US 2022243423 A1	04-08-2022	CN 114830853 A	02-08-2022
		DE 102021213706 A1	04-08-2022
		US 2022243423 A1	04-08-2022
		US 2024026638 A1	25-01-2024

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82