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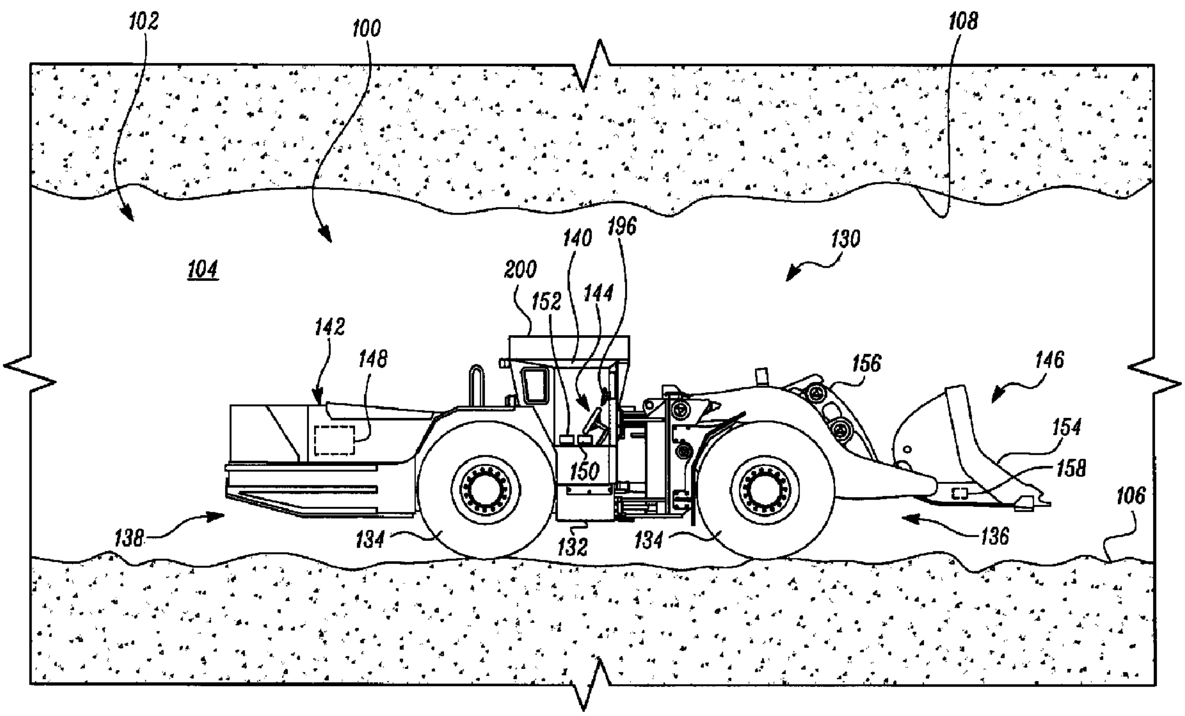

(57) Abrégé/Abstract:
A method for operating an underground loader is disclosed. The method includes detecting, by a controller, a first position of the underground loader within a worksite. The method also includes determining, by the controller, a location of a dumping pit within

(57) Abrégé(suite)/Abstract(continued):
the worksite. Further, the method includes determining, by the controller, a route for the underground loader to tram from the first position to the location of the dumping pit. Furthermore, the method includes controlling, by the controller, a movement of the underground loader along the route up to the location of the dumping pit. The method also includes moving, by the controller, an implement assembly of the underground loader based on a profile of a terrain along the route and a height of an embankment defined at an edge of the dumping pit.

Abstract

SYSTEM AND METHOD FOR OPERATING UNDERGROUND MACHINES

A method for operating an underground loader is disclosed. The method includes detecting, by a controller, a first position of the underground loader within a worksite. The method also includes determining, by the controller, a location of a dumping pit within the worksite. Further, the method includes determining, by the controller, a route for the underground loader to tram from the first position to the location of the dumping pit. Furthermore, the method includes controlling, by the controller, a movement of the underground loader along the route up to the location of the dumping pit. The method also includes moving, by the controller, an implement assembly of the underground loader based on a profile of a terrain along the route and a height of an embankment defined at an edge of the dumping pit.

Description

SYSTEM AND METHOD FOR OPERATING UNDERGROUND MACHINES

Technical Field

The present disclosure relates to an underground machine for dumping a pile of material at a worksite. More particularly, the present disclosure relates to a system and method for controlling the underground machine operating at the worksite.

Background

Earth moving machinery, such as excavators, shovel loaders, bulldozers, loaders, etc., has widespread use all over the world for performing a variety of missions. One example is underground mining/ore extraction in which extensive dozing and/or dumping operations are required. During such an extraction process, there is a need to operate one or more earth moving machines (such as an underground loader). Usually, the underground loaders are humanly operated. A human operator drives the underground loader to an underground mining site and then controls and operates the said loader within the worksite until completion of a desired task.

Such a task, as well as other missions/tasks/operations, may be long, routine, tedious and time-consuming, preventing a human operator from maintaining a high level of performance and operation of the underground loader. In addition, the human operator may not be able to calculate the optimal operating conditions of the operating underground loader as the optimal operation depends on many parameters that the human operator may be unable to process during operation. As a result, the underground loader's quality of performance during operation may not be optimal. Furthermore, some missions/operations may be designed to be carried out, for example, with the operator on board the wheel loader, in noxious areas or in low visibility conditions, which is undesirable.

US Patent number 3643828 (hereinafter referred to as US3643828) relates to an automatic control system for a front-end loader utilizing a bucket or fork at an end of a rigid boom. US3643828 teaches an automatic dumping cycle in parallel operation with a manual control system. The automatic control system may be changed to manual by an operator. US3643828 also discloses pressure sensitive means utilized to determine and control the position of various elements.

As used herein, except where the context requires otherwise the term “comprise” and variations of the term, such as “comprising”, “comprises” and “comprised”, are not intended to exclude other additives, components, integers or steps.

Reference to any prior art in the specification is not an acknowledgement or suggestion that this prior art forms part of the common general knowledge in any jurisdiction or that this prior art could reasonably be expected to be understood, regarded as relevant, and/or combined with other pieces of prior art by a skilled person in the art.

Summary of the Invention

In an aspect of the present disclosure, a method for operating an underground loader is disclosed. The method includes detecting, by a controller, a first position of the underground loader within a worksite. The method also includes determining, by the controller, a location of a dumping pit within the worksite. Further, the method includes determining, by the controller, a route for the underground loader to tram from the first position to the location of the dumping pit. Furthermore, the method includes controlling, by the controller, a movement of the underground loader along the route up to the location of the dumping pit. The method also includes moving, by the controller, an implement assembly of the underground loader based on a profile of a terrain along the route and a height of an embankment defined at an edge of the dumping pit.

In another aspect of the present disclosure, a control system for operating an underground loader at a worksite is disclosed. The underground loader has an implement assembly and the worksite has a terrain, a dumping pit, and an embankment defined at an edge of the dumping pit. The control system includes a positioning system configured to generate a positional data of the underground loader within the worksite and a controller communicably coupled to the positioning system. The controller is configured to detect a first position of the underground loader based on the positional data of the underground loader. The controller is further configured to determine a location of the dumping pit within the worksite. Furthermore, the controller is configured to determine a route for the underground loader to tram from the first position to the location of the dumping pit. The controller is also configured to control a movement of the underground loader along the route up to the location of the dumping pit and move the implement assembly of the underground loader based on a profile of the terrain along the route and a height of the embankment.

In yet another aspect of the present disclosure, an underground loader operating at a mining site is disclosed. The mining site has a terrain and including a dumping pit and an embankment. The embankment is defined at an edge of the dumping pit and having a height. The underground loader includes an implement assembly and a positioning system configured to generate a positional data of the underground loader within the mining site. The underground loader further includes a controller communicably coupled to the positioning system and configured to detect a first position of the underground loader based on the positional data of the underground loader, determine a location of the dumping pit within the mining site, determine a route for the underground loader to tram from the first position to the location of the dumping pit, control a movement of the underground loader along the route up to the location of the dumping pit and move the implement assembly of the underground loader based on a profile of the terrain along the route and the height of the embankment.

Brief Description of the Drawings

FIG. 1 is a diagrammatic illustration of a worksite, in accordance with an embodiment of the present disclosure;

FIG. 2 illustrates a portion of the worksite having a machine operating therein, in accordance with an embodiment of the present disclosure;

FIG. 3 illustrates a side view of the machine operating at the worksite, in accordance with an embodiment of the present disclosure;

FIG. 4 illustrates a control system of the machine, in accordance with an embodiment of the present disclosure;

FIG. 5 – FIG. 8 illustrates the control system operating the machine, in accordance with an embodiment of the present disclosure;

FIGS. 9 illustrates a digital rendition of the worksite with the machine working therein (**FIG. 9A**, **FIG. 9B**, **FIG. 9C** and **FIG. 9D** corresponding to **FIG. 5**, **FIG. 6**, **FIGS. 7** and **FIG. 8**, respectively), in accordance with an embodiment of the present disclosure; and

FIG. 10 depicts a method of operating the machine, in accordance with an embodiment of the present disclosure.

Detailed Description

Reference will now be made in detail to embodiments of the disclosure, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

Referring now to **FIG. 1** and **FIG. 2**, an exemplary worksite **100** is illustrated. The worksite **100** is illustrated as a mine site in the illustrations. However, in various other embodiments, the worksite **100** may embody and/or include, for example, a landfill, a quarry, a construction site, or any other type of worksites. Referring to **FIG. 2**, a front view of a machine **130** operating at the worksite **100** is illustrated. As can be seen here, the worksite **100** includes a terrain **102** having one or more sidewalls **104**, a ground surface **106** and a ceiling **108**. Each of the one or more sidewalls **104**, the ground surface **106** and the ceiling **108** may include a profile. In an embodiment, the profile may be defined as a 2D (2 dimensional) rendition of geometrical parameters associated with each of the one or more sidewalls **104**, the ground surface **106** and the ceiling **108**. In an alternate embodiment, the profile may be defined as a 3D geometry or 3-dimensional geometrical parameters associated with each of the one or more sidewalls **104**, the ground surface **106** and the ceiling **108**. For example, the one or more sidewalls **104** may include a first sidewall **110** having profile **112** and a second sidewall **114** having profile **116**. As shown, the profiles **112** and **116** may include crest **118**, trough **120** and other geometrical shape(s) **124** being defined on the sidewalls.

Referring to **FIG. 3**, a side view of the machine **130** operating within the worksite **100** is illustrated. The machine **130** may be tasked with altering the geography at the worksite **100**. The machine **130** may be a mobile machine configured to perform operations associated with industries related to mining, construction, farming, or any other industry known in the art. In the embodiment disclosed, the illustrations illustrate an underground mining load-haul-dump (LHD) loader, which may be used to access a load site in the mine site **100** (e.g. from a draw point), haul a load away from the load site, and release the load at a dumping site (e.g. at an ore pass). However, in various other embodiments, the machine **130** may embody different kinds of machine configured to perform operations such as a dozing operation, a grading operation, a leveling operation, a bulk material removal operation, or any other type of operation that results in geographical modifications within the worksite **100**.

Referring to **FIG. 3**, the machine **130** includes a frame **132** and one or more traction assemblies (each traction assembly referred to by the reference numeral **134)**. The frame **132** includes a front end **136** and a rear end **138**, and is configured to support various components/systems of the machine **130** such as, but not limited to, an operator cab **140**, a power producing system **142**, a steering system **144**, an implement assembly **146** and a transmission system (not illustrated). The operator cab **140** may be defined as an enclosure that may include one or more of electronic panels, displays, buttons, joysticks, and various other physically actuable entities. Actuations of such entities, buttons, joysticks, etc. may actuate or move the one or more systems present in the machine **130**.

The power producing system **142** may include a compartment having a power source **148** in the form of an engine or an electric motor that is configured to produce torque/power to operate various systems of the machine **130**. In an embodiment, the power source **148** may be a diesel engine. In various other embodiments, the power source **148** may be any engine running on solid, liquid or gaseous fuel. In the embodiment illustrated, the machine **130** includes one power source **148**. However, it may be contemplated that in various other embodiments, the machine **130** may include more than one power source **148** configured to produce torque/power for operating various systems of the machine **130**.

The steering system **144** may include a steering assembly (direction giving assemblies), a movement system **150** that senses the movement of the machine **130** within the worksite **100** and an orientation sensing device **152**. The steering assembly may be a steering mechanism to facilitate turning of the machine **130**. In the embodiment illustrated, the steering assembly is a hydraulically actuated steering system/assembly. However, in various other embodiments, the steering assembly may include one of an Ackerman steering, Bell-crank steering, rack and pinion steering, and short rack and pinion steering. It may be contemplated that in various other embodiments, the steering assembly may include other known steering assemblies/mechanisms/systems known in the art. The movement system **150** may include distance sensors such as light sensors, proximity sensors and the like. The movement system **150** may be configured to detect the distance traveled by the machine **130** while traversing from one point to another. For example, the machine **130** may travel (as shown in **FIGS. 5** and **6**) and the motion sensors may determine that the distance traveled by machine **130** may be 30 meters. The orientation sensing device **152** may include orientation sensors, accelerometers and gyroscopic mechanisms and maybe configured to determine the orientation of the machine **130** at a specific time instant.

The implement assembly **146** may be configured to engage with the terrain **102** (i.e. one or more sidewalls **104**, ground surface **106** and ceiling **108**) and perform a desired operation. For example, the implement assembly **146** may be configured to perform to one or more operations including digging/extracting, collecting and dumping material present within the worksite **100**, as desired. The implement assembly **146** may include an implement **154**, a linkage assembly **156** and a sensor **158**. The implement **154** may be a bucket or a work tool known in the art that may be configured to engage with the terrain **102**. The linkage assembly **156** may be coupled to the machine **130** and the implement **154**. The linkage assembly **156** may include one or more hydraulic actuators. The actuation/movement of the one or more hydraulic actuators may facilitate movement of the implement **154** relative to the machine **130**. More specifically, the linkage assembly **156** may be configured to control the movement and/or positions (including height parameters) of the implement **154** relative to the machine **130**. The sensor **158** may be disposed on the implement **154** and may be configured to assist in detecting a mass of the material accumulated in the implement **154**. The sensor **158** may be load cells, piezoelectric transducers, or other known weight sensors in the art.

The sensor **158** may be configured to detect the mass of the implement **154** and/or the material accumulated within the implement **154** while operating the machine **130**. The sensor **158** may further be able to retrieve/receive information regarding the implement **154** such as the mass of the implement **154**. Using detected mass of the implement **154** and the material accumulated within the implement **154** and the mass of the implement **154**, the sensor **158** may detect the mass of the material accumulated within the implement **154** as will be readily understood by a person of ordinary skill in the art.

Referring to **FIG. 3** and **FIG. 4**, the machine **130** includes a control system **200**. The control system **200** may be configured to control various components/assemblies of the machine **130** and/or the machine **130** based on suitable logic/instructions (as will be described later in the specification). The control system **200** includes a perception system **160**. The perception system **160** may include at least one perception sensor (not shown). The perception system **160** is configured to generate perception data of the worksite **100**. In accordance with an embodiment, the perception system **160** may include a light detection and ranging (LIDAR) device. In accordance with alternate embodiments, the perception system **160** may include perception sensors such as RADAR (radio detection and ranging) device, a stereo camera, a monocular camera, or another device known in the art. The perception system **160** may be disposed on the machine **130**. In other embodiments, at least one perception system **160** may be located on the machine **130** and at least one perception system similar to the perception system **160** may be remotely located, such as on a one or more vertical structures (pole, tower) within the worksite **100** to generate the perception data. The perception data obtained from the perception system **160** is used to determine the terrain **102** (along with profile of the terrain **102**) and geometrical properties of the worksite **100**. In accordance with an embodiment, the perception data generated by the perception system **160** includes a three dimensional (3D) point cloud representation of the worksite **100**. The three dimensional (3D) point cloud representation of the worksite **100** may include information regarding the profile of the terrain **102** i.e. location where crest **118** exists and location where trough **120** exists, etc. In another embodiment, the perception system **160** may generate 2D images of the worksite **100** or at least a portion of the worksite **100**.

The control system **200** also includes a positioning system **162**. The positioning system **162** may be configured to generate a positional data of the underground loader/machine **130** within the worksite **100**. The positioning system **162** may be any one of a combination of a Global Positioning System (GPS), an Inertial Navigation System, an underground worksite system (equipped with sensors for detecting the position of features and/or machine **130**) or any other known position detection system known in the art.

The control system **200** further includes a controller **170**. The controller **170** is communicably coupled to the steering system **144**, implement assembly **146**, perception system **160** and positioning system **162**. Based on the data/information received from the steering system **144**, implement assembly **146**, perception system **160** and positioning system **162**, the controller **170** may control the actuation of at least one of the one or more actuators within the linkage assembly **156**, which in turn may control the position and movement of the implement **154**. The controller **170** may also be configured to operate the machine **130** within the worksite **100**.

It should be appreciated that the controller **170** may readily embody a general machine microprocessor capable of controlling numerous machine functions. The controller **170** may include a memory, a secondary storage device, a processor, and any other components for running an application. Various other circuits may be associated with the controller **170** such as power supply circuitry, signal conditioning circuitry, solenoid driver circuitry, and other types of circuitry.

In an aspect of the present disclosure, the controller **170**, using the data/information from the positioning system **162** and the perception system **160**, may be configured to detect an initial position of the machine **130** within the worksite **100**. Further, the controller **170** may determine a specific location within the worksite **100** and thereafter determine a route for the machine **130** to move from the initial position of the machine **130** to the specific location. Furthermore, the controller **170** may control a movement of the machine **130** along the route up to the specific location. Concurrently, the controller **170** may be configured to move an implement assembly **146** of the machine **130** based on a profile of the terrain **102** along the route and one or more parameters associated with the terrain proximate to the specific location. A detailed understanding of the controller's **170** capabilities will be described in detail later in the specification.

Industrial Applicability

With reference to **FIGS. 5-10**, an exemplary method **1000** for operating the implement **154** of the machine **130**, by the controller **170** will now be discussed. The method **1000** is discussed by way of a flowchart, as provided in **FIG. 10**, that illustrates exemplary stages/steps (i.e., from **1002** to **1010**) associated with the method **1000**. Furthermore, for the purpose of understanding the ongoing disclosure, **FIGS. 5-10** present a side view of the machine **130** working at the worksite **100**. Accordingly, only one sidewall **104** is visible. However, it may be understood that another sidewall exists, in spite of not being disclosed in the illustrations.

Furthermore, for the purpose of ongoing disclosure, it may be assumed that the machine **130** (i.e. the underground loader) is at a position labeled '**180**' and a dumping pit **198** is at a position labeled '**190**' within the worksite **100** and the controller **170** receives a signal to actuate the method **1000** for operating the machine **130**. More particularly, the controller **170** may receive the signal for starting autonomous dumping of material accumulated within the implement **154** into the dumping pit **198** via input device (joystick, key, button, etc.) present within the operator cab **140**. In an embodiment, the controller **170** may receive the signal for starting autonomous dumping of material accumulated within the implement **154** into the dumping pit **198** via a computer system, located at a remote location, being operated by an operator.

Upon receipt of such an instruction, the controller **170** detects a position **180** (hereinafter referred to as 'first position') of the machine **130** within the worksite **100** (**STEP 1002**). In an embodiment, the controller **170** may determine the first position **180**, based on an input from the operator on the input device. For example, the machine **130** may have an input device in the form of a touch screen **196** provided within the operator cab **140**. The operator inside the operator cab **140** may provide an input via the touch screen **196** to determine the first position **180**. Alternatively, the operator operating the machine **130** from a remote location may communicate with the touch screen **196** via a computer and provide the input to the touch screen **196** to determine the first position **180**.

In another embodiment, the controller **170** may make use of the perception system **160** and the pre-stored terrain map of the worksite **100** (within the memory of the controller **170**) to determine the position of the machine **130** in the worksite **100**. More specifically, the controller **170** may actuate the perception system **160** and determine the terrain **102** surrounding the machine **130**. The determined terrain **102** surrounding the machine **130** may be compared with various portions of the worksite **100** (the terrain map pre-stored within the memory of the controller **170** may include the terrain maps of various portions of the worksite **100**). When the determined terrain surrounding the machine **130** is same as a specific portion of the worksite **100**, the controller **170** may be able to determine the position (i.e. first position **180**) of the machine **130**. More simply, the controller **170** may identify the position **180** of the machine **130** within the worksite **100** from where the perception system **160** (disposed on the machine **130**) can determine the said terrain, as discussed above.

In another embodiment, the worksite **100** may have a plurality of position detecting sensors disposed at specific positions within the worksite **100**.

A map of the worksite **100** and the positions of the plurality of position detecting sensors dispersed within the worksite **100** may be pre-stored within the memory of the controller **170**. The controller **170** may communicate with said plurality of position detecting sensors (may be proximity sensors) dispersed within the worksite **100** to establish the first position **180** of the machine **130** within the worksite **100** i.e. the proximity sensors may detect the distance of the machine **130** from each sensor. Collating the detected distance from each proximity sensor and the position of the proximity sensors on the worksite **100**, the controller **170** may establish the first position **180**, as will be readily understood by a person of ordinary skill in the art.

While only a few exemplary methods of detecting the first position **180** of the machine **130** within the worksite **100** have been disclosed, it may be contemplated that in various other embodiments different techniques/logic/instructions may be employed to detect the first position **180** of the machine **130** within the worksite **100**.

The method **1000** now proceeds to **STEP 1004** where the controller **170** determines the location of the dumping pit **198** to be location '**190**'. In an embodiment, the controller **170** may have pre-stored instructions for identifying a dumping pit **198** within the worksite **100**. For example, the controller **170** may have pre-stored instructions to identify a portion of the worksite **100** as the location of the dumping pit **198** if the location/portion has a bore of a predefined diameter therein. Thus, in an embodiment, the controller **170** may determine the terrain **102** via the use of the perception system **160**. On this determined terrain **102**, the controller **170** may apply the said instructions to identify the dumping pit **198**.

In another example, the controller **170** may display on the touch screen **196** a message, prompting the operator (whether within the operator cab **140** or at a remote location) to input the location **190** of the dumping pit **198**. While two exemplary methods of determining the location **190** of the dumping pit **198** within the worksite **100** have been disclosed, it may be contemplated that in various other embodiments different techniques/logic/instructions may be employed to determine the location **190** of the dumping pit **198** within the worksite **100**.

The method **1000** now moves to **STEP 1006**. Here, the controller **170** determines a route for the machine **130** to tram (move) from the first position **180** to the location **190** of the dumping pit **198**. In an example, the controller **170** may determine a route **192** (as shown in **FIG. 1**) for the machine **130** to tram from the first position **180** to the location **190**. The route **192** may be determined by the controller **170** such that the features of the worksite **100** such as terrain features: crests and troughs are minimized, thereby, providing a smooth traversal of the machine **130** while minimizing/preventing the risk of sudden jerk/impact of the machine **130** and/or implement **154** with surrounding terrain features and/or one or more objects. In an embodiment, the route **192** may be determined by the controller **170** such that a pre-defined distance is maintained between the machine **130** and terrain **102** (such as sidewalls **104** and ceiling **108** and associated crests and troughs) and/or one or more objects present within the worksite **100**. In an embodiment, the one or more objects may include another machine (which may be an underground loader, a hauling truck, longwall shearer systems, and other known mining equipment/systems/machines).

In another embodiment, the controller **170** may determine the route **192** for the machine to tram from the first position **180** to the location **190**, based on an input from the operator on the input device. The operator inside the operator cab **140** may provide an input via the touch screen **196** to determine the route **192**. Alternatively, the operator operating the machine **130** from a remote location may communicate with the touch screen **196** via a computer and provide the input to the touch screen **196** to determine the route **192**. While two exemplary methods of determining the route **192** have been disclosed, it may be contemplated that in various other embodiments different techniques/logic/instructions may be employed to determine the route **192**.

Subsequent to the determination of the route **192** by the controller **170**, the method **1000** moves to **STEP 1008** i.e. the controller **170** now controls the movement of the machine **130** such that the machine **130** trams (moves) from the first position **180** to the location **190** of the dumping pit **198**. More specifically, the controller **170** controls a speed at which the machine **130** moves along the route **192** and controls a direction (via steering system **144**) in which the machine **130** trams.

Subsequent to **STEP 1008**, the method **1000** initiates **STEP 1010**. In said step, the controller **170** controls the movement of the implement assembly **146**. More specifically, the controller **170** controls the movement of the implement assembly **146** based on the profile of the terrain **102** along the route **192**. The controller **170** also controls the movement of the implement assembly **146** based on one or more parameters associated with the dumping pit **198**. The one or more parameters associated with the dumping pit **198** may include a size of the bore defining the dumping pit **198**, a depth of the dumping pit **198**, an embankment **199** defined at an edge of the dumping pit **198** (as shown in **FIGS. 1-8**). The embankment **199** may include a height '**h**', width '**w**' and length (not shown as the length extends into the plane of the illustrations).

A detailed understanding of **STEP 1010** will now be explained using exemplary scenarios. In an embodiment, **STEP 1010** starts as soon as the controller **170** initiates moving the machine **130** along the route **192**. In said step, the controller **170** may determine the profile of the terrain **102** along the route **192**. More specifically, the controller **170** determines the profile of the terrain **102** i.e. a three-dimensional geometry of each of the one or more sidewalls **104**, the ground surface **106** and the ceiling **108** proximate to the machine **130** during traversal of the machine **130** along the route **192**. Using this determined data (profile) along with machine **130**'s dimensions pre-stored within the memory of the controller **170**, the controller **170** may simulate the tramming of the machine **130** from the first position **180** to the location **190** of the dumping pit **198**.

During such simulation, the controller **170** determines that implement assembly **146** may collide with a feature of the terrain **102** while the machine **130** trams along route **192**. For example, referring to **FIG. 6 and FIGS.** 7, the controller **170** may determine that the machine **130** traversing along a portion of the ground surface **106** having an irregular profile is on course to collide with a protrusion **220** defined on the sidewall **104**. The controller **170** may now compute a position of the implement **154** such that the detected simulated collision with the protrusion **220** is avoided. However, the controller **170** may be configured to compute such position of the implement **154** in a manner that collision with the ceiling **108** is prevented. For example, the controller **170** may determine that the implement **154** can be raised to its highest vertical position to avoid collision with protrusion **220**. However, raising the implement **154** to the highest vertical position may cause the implement **154** to collide with the portion **222** of the ceiling **108**. Accordingly, the controller **170** may compute the position of the implement **154** such that collision with the protrusion **220** is avoided while maintaining an implement clearance with the portion **222** of the ceiling **108**. This ensures that collision of the implement **154** with the sidewalls **104** and ceiling is prevented during movement of the machine **130** along this portion of the ground surface **106** having the irregular profile.

In an embodiment, the controller **170** while raising the height of the implement **154** may also steer the machine **130** away from the protrusion **220** to avoid collision of the protrusion **220** with the machine **130**, as will be understood by a person of ordinary skill in the art. It may be contemplated that the movement away from the protrusion **220** is not illustrated in the illustrations as the movement of the machine **130** is along a direction perpendicular to the plane of the illustrations.

In the manner described above, the controller **170** determines all the possible instances where the implement **154** may collide with the one or more sidewalls **104** along the route **192**. Furthermore, the controller **170** may determine all the possible instances where the implement **154** may collide with the ground surface **106** and ceiling **108** along the route **192** (in a similar manner as disclosed above). Concurrently, the controller **170** computes positions of the implement **154** to avoid such collisions.

Let us assume that the controller **170** moves the machine **130** along a portion of the route **192** where the implement **154** may be on course to collide with the terrain **102**. As the controller **170** is equipped with pre-stored instructions/logic to prevent the collisions before the machine **130** passes through portions of the route **192** where collisions are simulated, the controller **170** issues a command signal for actuating the hydraulic actuators of the linkage assembly **156**. Thereby, moving the implement **154** to a position where collision with the terrain **102** is avoided. In an embodiment, the controller **170** may be further configured to move the implement **154** such that at least a predefined safe distance is maintained between the terrain **102** and the implement assembly **146** (specifically, the implement **154**) during traversal of the machine **130** along the route **192**.

It may be noted that the simulation described above is performed after the **STEP 1008** in the embodiment illustrated. However, a person of ordinary skill in the art may be able to contemplate that in various other embodiments the simulation for detecting potential collisions and determination of positions of the implement **154** to avoid such collisions may be performed by the controller **170** before **STEP 1008**.

Also, it may be noted that in the embodiment disclosed, simulation has been discussed in **STEP 1010**. However, in various other embodiments, real-time manipulation of the implement assembly **146** may be performed by the controller **170** i.e. the controller **170** may not detect the collisions prior to the travel along the route **192**. More specifically, the controller **170** may detect a possible collision scenario while the machine **130** traverses along the route **192**. For example, the controller **170** may detect one or more objects such as one or more machines while the machine **130** traverses along the route **192**. In case a distance between the machine **130** and the machine detected by the perception system **160** is such that a collision situation arises, the controller **170** controls the movement of the implement assembly **146** based on the position of the detected machine.

In an aspect of the present disclosure, **STEP 1010** may further include the controller **170** determining a position of the embankment **199** within the worksite **100** and the height '**h**' of the embankment **199** prior to the machine **130** reaching the location **190** of the dumping pit **198**. The controller **170** may have pre-stored instructions/logic in the memory for determining the position of the embankment **199** and the height '**h**' of the embankment **199**. For example, the controller **170** may have pre-stored instructions for actuating the perception system **160** to determine the three-dimensional geometrical parameters of the terrain **102** surrounding the dumping pit **198**. Using these instructions, the controller **170** may determine the embankment **199** and height '**h**' prior to the machine **130** reaching the location **190**. For example, the controller **170** may have instructions (pre-stored) to identify a portion of the terrain **102** at the edge of the dumping pit **198** as an embankment **199** if the height of the portion at the edge of the dumping pit **198** exceeds a predefined threshold value.

Alternatively, the operator may provide an input via the touch screen **196** to determine the position of the embankment **199** and height '**h**'. Alternatively, the operator operating the machine **130** from a remote location may communicate with the touch screen **196** via a computer and provide the input to the touch screen **196** to determine the embankment **199** and height '**h**'. While said exemplary methods of determining the embankment **199** and height '**h**' have been disclosed, it may be contemplated that in various other embodiments different techniques/logic/instructions may be employed.

After detecting embankment **199**, the controller **170** determines a position the implement **154** should undertake (based on the height '**h**') as the machine **130** approaches/reaches the location **190** (to prevent the implement **154** from colliding with the embankment **199**). Using this information, the controller **170** controls the linkage assembly **156** to move the implement **154** to the determined position as the machine **130** approaches the location **190**, thereby, preventing the implement **154** from colliding with the embankment **199**, as shown in **FIGS**. 7.

In an embodiment, the controller **170** may be configured to stop the machine **130** at a predefined clearance from the embankment **199**, as shown in **FIGS**. 7. More specifically, the controller **170** may have pre-stored instructions to communicate with a sensor (such as a proximity sensor disposed on the machine **130**) or the perception system **160** to determine the distance between the embankment **199** and the machine **130**. When the determined distance between the embankment **199** and the machine **130** is equal the predefined clearance (pre-stored within the memory of controller **170**), the controller **170** issues a command to halt the machine **130**.

In another aspect of the present disclosure, the controller **170** may further be configured to control the implement assembly **146** to facilitate dumping of material accumulated within the implement **154** into the dumping pit **198**, as shown in **FIG. 8**. More specifically, the controller **170** may be configured to actuate the linkage assembly **156** such that a pivoting action of the implement **154** takes place. Therefore, leading to dumping of the material within the implement **154** into the dumping pit **198**.

In an aspect of the present disclosure, the dumping of the material within the implement **154** into the dumping pit **198** further includes determining by the sensor **158** (as disclosed above) the mass of the material accumulated within the implement **154** in a first implement position i.e. position of the implement **154** when the machine **130** is halted at predefined clearance from the embankment **199**, as shown in **FIG. 7B**. The controller **170** is then configured to actuate the linkage assembly **156** to move the implement **154** to a dumping position i.e. a position where the material accumulated within the implement **154** exits in view of gravity, as shown in **FIG. 8**. The controller **170** is then further configured to pivot the implement **154** (via the linkage assembly **156**) to the first implement position and back to the dumping position (to facilitate pivoting action of the implement **154**) for dumping the material still accumulated within the implement **154**. This process of pivoting the implement **154** is continued until the mass determined by the sensor **158** is equal to the mass of the implement **154** devoid of any material therein. In an embodiment, the dumping of the material within the implement **154** into the dumping pit **198** may include moving, by the controller **170**, the implement **154** between the dumping position and the first implement position for a predetermined number of times. More specifically, in an embodiment, the pre-determined number of times may be stored in the memory of the controller **170**. Let us assume in an exemplary scenario the pre-determined number of times is 5. The controller **170** may move the implement **154** between the dumping position and the first implement position 5 times (no matter what the volume or mass of material within the implement **154** may be). In another embodiment, different values of predetermined number of times corresponding to different scenarios may be stored within the memory of the controller **170**. For example, the predetermined number of times may be 4 when the sensor **158** detects the mass of material within the implement **154** is 100 Kgs, 5 when the sensor **158** detects the mass of material within the implement **154** is 130 Kgs, 6 when the sensor **158** detects the mass of material within the implement **154** is 170 Kgs and so on. In such a configuration, the controller **170** may determine the mass of the material within the implement **154** and then based on the determined mass, the controller **170** moves the implement **154** between the dumping position and the first implement position the desired number of times. For example, if the mass of material within the implement is detected as **130** Kgs, the controller **170** may move the implement **154** between the dumping position and the first implement position 5 times.

In another aspect of the present disclosure, the controller **170** may further be configured to move the machine **130** away from the embankment **199** after dumping the material into the dumping pit **198**. This can be envisioned by viewing **FIG. 8** as the dumping operation and **FIG. 7** as the machine **130** moving away from the embankment **199**. The controller **170** may further be configured to operate the implement assembly **146** to move the implement **154** of the implement assembly **146** to a tramming position (lowered position), as shown in **FIG. 5**. The controller **170** may further be configured to move the machine **130** back to the first position **180**.

In an aspect of the present disclosure, the controller **170** may be configured to detect any changes to the terrain **102** along route **192** while the machine **130** is tramming from the first position **180** to the location **190** of the dumping pit **198**. For the purpose of better understanding of the ongoing disclosure, let us assume that the machine **130** has a second perception system. In this scenario, while the controller **170** uses the perception system **160** to determine the route **192** and move the implement assembly **146**, the second perception system may be configured to detect the changes to the terrain **102** along the route **192** by a second machine or another system. This information may be relayed to the controller **170** by the second perception system. The simulation may now be performed again based on the updated information from the second perception system. The simulation may determine different collision scenarios. Accordingly, the controller **170** may now be configured to modify the movement of the implement assembly **146** based on the updated simulation results. Alternatively, the machine **130** may be operated in real time based on the updated/modified terrain **102**.

Such method **1000** and control system **200** prevents the operator from performing the same operation over and over again. Thus, obviating a human operator from maintaining a high level of performance and operation of the underground loader/machine **130**. Thereby, reducing operator stress levels. Furthermore, elimination of the human operator for performing the dumping operation and automating the machine **130** results in an improvement in the operational efficiency and allows the operator to focus on planning more effective operations, further incrementing the efficiency.

It will be apparent to those skilled in the art that various modifications and variations can be made to the system of the present disclosure without departing from the scope of the disclosure. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the system disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims and their equivalent.

Claims

1. A method for operating an underground loader, the method comprising:

detecting, by a controller, a first position of the underground loader within a worksite,

determining, by the controller, a location of a dumping pit within the worksite;

determining, by the controller, a route for the underground loader to tram from the first position to the location of the dumping pit,

controlling, by the controller, a movement of the underground loader along the route up to the location of the dumping pit;

moving, by the controller, an implement assembly of the underground loader based on a profile of a terrain along the route and a height of an embankment defined at an edge of the dumping pit.

2. The method as claimed in claim 1, wherein the terrain includes one or more sidewalls, a ceiling, and a ground surface within the worksite.

3. The method as claimed in claim 1 or claim 2, wherein moving the implement assembly includes:

identifying, by the controller, a position of the embankment within the worksite;

determining, by the controller, a profile of the one or more sidewalls, the ceiling and the ground surface;

manipulating, by the controller, the implement assembly based on the position of the embankment and the profile of the one or more sidewalls, the ceiling and the ground surface.

4. The method as claimed in any one of the preceding claims, wherein moving the implement assembly includes maintaining, by the controller, at least a predefined distance between the terrain and the implement assembly while traversal of the underground loader along the route.

5. The method as claimed in any one of the preceding claims, further comprising:

stopping, by the controller, the underground loader at a predefined clearance from the embankment.

6. The method as claimed in claim 5, further comprising:

controlling, by the controller, the implement assembly to facilitate dumping of material from the implement assembly into the dumping pit;

moving, by the controller, the underground loader away from the embankment;

operating, by the controller, the implement assembly to move an implement of the implement assembly to a tramming position; and

moving the underground loader, by the controller, back to the first position.

7. The method as claimed in any one of the preceding claims, further comprising:

moving, by the controller, the implement to a dumping position to dump the material; and

moving the implement between the dumping position and a first implement position a pre-determined number of times.

8. The method as claimed in any one of the preceding claims, further comprising:

identifying, by a perception system, one or more objects along the route while traversal of the underground loader, the one or more objects including one or more machines; and

modifying, by the controller, the movement of the implement assembly based on the one or more objects.

9. The method as claimed in any one of the preceding claims, wherein determining the location of the dumping pit within the worksite includes:

generating, by a perception system, a perception data of the worksite; and

determining, by the controller, based on the perception data, a 2D (2 dimensional) point cloud of the worksite.

10. A control system for operating an underground loader at a worksite, the underground loader having an implement assembly, the worksite having a terrain, a dumping pit, and an embankment defined at an edge of the dumping pit, the control system comprising:

a positioning system configured to generate a positional data of the underground loader within the worksite;

a controller communicably coupled to the positioning system and configured to:

detect a first position of the underground loader based on the positional data of the underground loader;

determine a location of the dumping pit within the worksite;

determine a route for the underground loader to tram from the first position to the location of the dumping pit;

control a movement of the underground loader along the route up to the location of the dumping pit; and move the implement assembly of the underground loader based on a profile of the terrain along the route and a height of the embankment.

11. The control system as claimed in claim 10, wherein the controller is configured to maintain at least a predefined distance between the terrain and the implement assembly while traversal of the underground loader along the route.

12. The control system as claimed in claim 10 or claim 11, wherein the controller is further configured to:

identify a position of the embankment within the worksite; and

manipulate the implement assembly based on the position of the embankment and the profile of the terrain.

13. The control system as claimed in any one of claims 10 to 12 wherein the controller is configured to stop the underground loader at a predefined clearance from the embankment.

14. The control system as claimed in any one of claims 10 to 13 wherein the controller is configured to control the implement assembly to facilitate dumping of a material from the implement assembly into the dumping pit.

15. The control system as claimed in claim 14 wherein the controller is configured to:

move the underground loader away from the embankment,

operate the implement assembly to a tramming position, and

move the underground loader back to the first position.

16. The control system as claimed in claim 15 wherein the controller is configured to:

move the implement to a dumping position to dump the material; and

move the implement between a dumping position and a first implement position a pre-determined number of times.

17. An underground loader operating at a mining site, the mining site having a terrain and including a dumping pit and an embankment, the embankment being defined at an edge of the dumping pit and having a height, the underground loader including:

an implement assembly;

a positioning system configured to generate a positional data of the underground loader within the mining site;

a controller communicably coupled to the positioning system and configured to:

detect a first position of the underground loader based on the positional data of the underground loader;

determine a location of the dumping pit within the mining site;

determine a route for the underground loader to tram from the first position to the location of the dumping pit;

control a movement of the underground loader along the route up to the location of the dumping pit; and

move the implement assembly of the underground loader based on a profile of the terrain along the route and the height of the embankment.

18. The underground loader as claimed in claim 17, wherein the controller is configured to stop the underground loader at a predefined clearance from the embankment.

19. The underground loader as claimed in claim 17 or claim 18 wherein the controller is configured to:

control the implement assembly to facilitate dumping of material from the implement assembly into the dumping pit;

move the underground loader away from the embankment;

operate the implement assembly to a tramming position; and

move the underground loader back to the first position.

20. The underground loader as claimed in any one of claims 17 to 19 wherein the controller is configured to:

move the implement to a dumping position to dump the material; and

move the implement between the dumping position and a first implement position a pre-determined number of times.

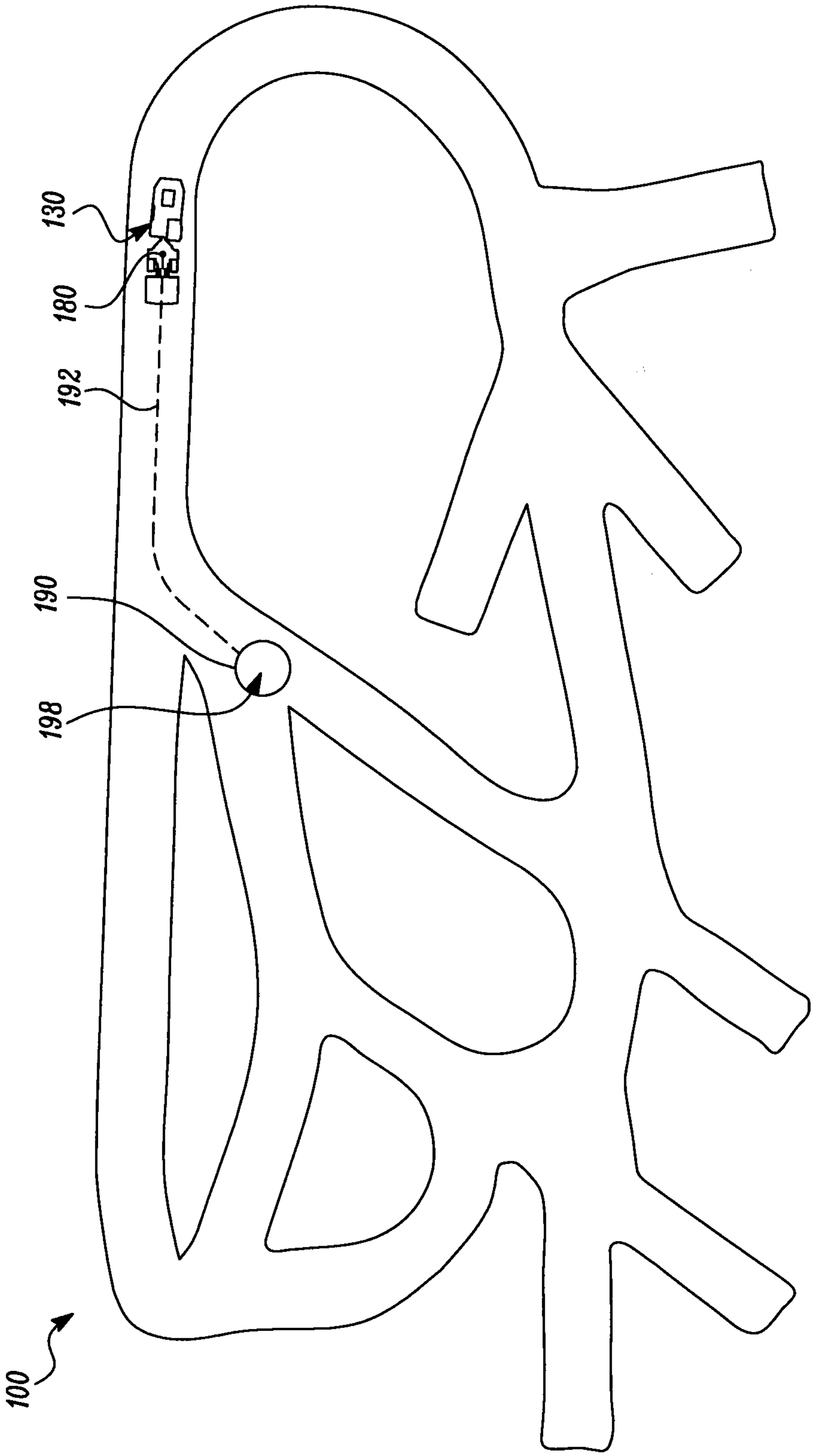

FIG. 1

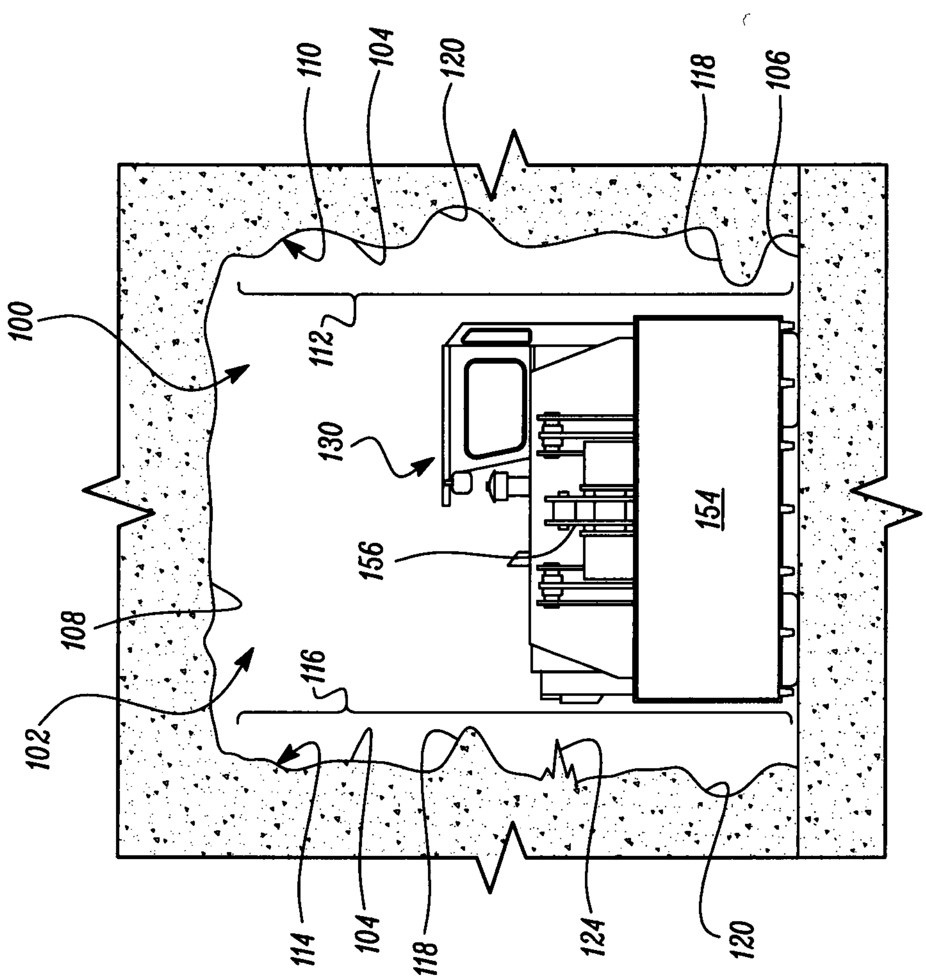

FIG. 2

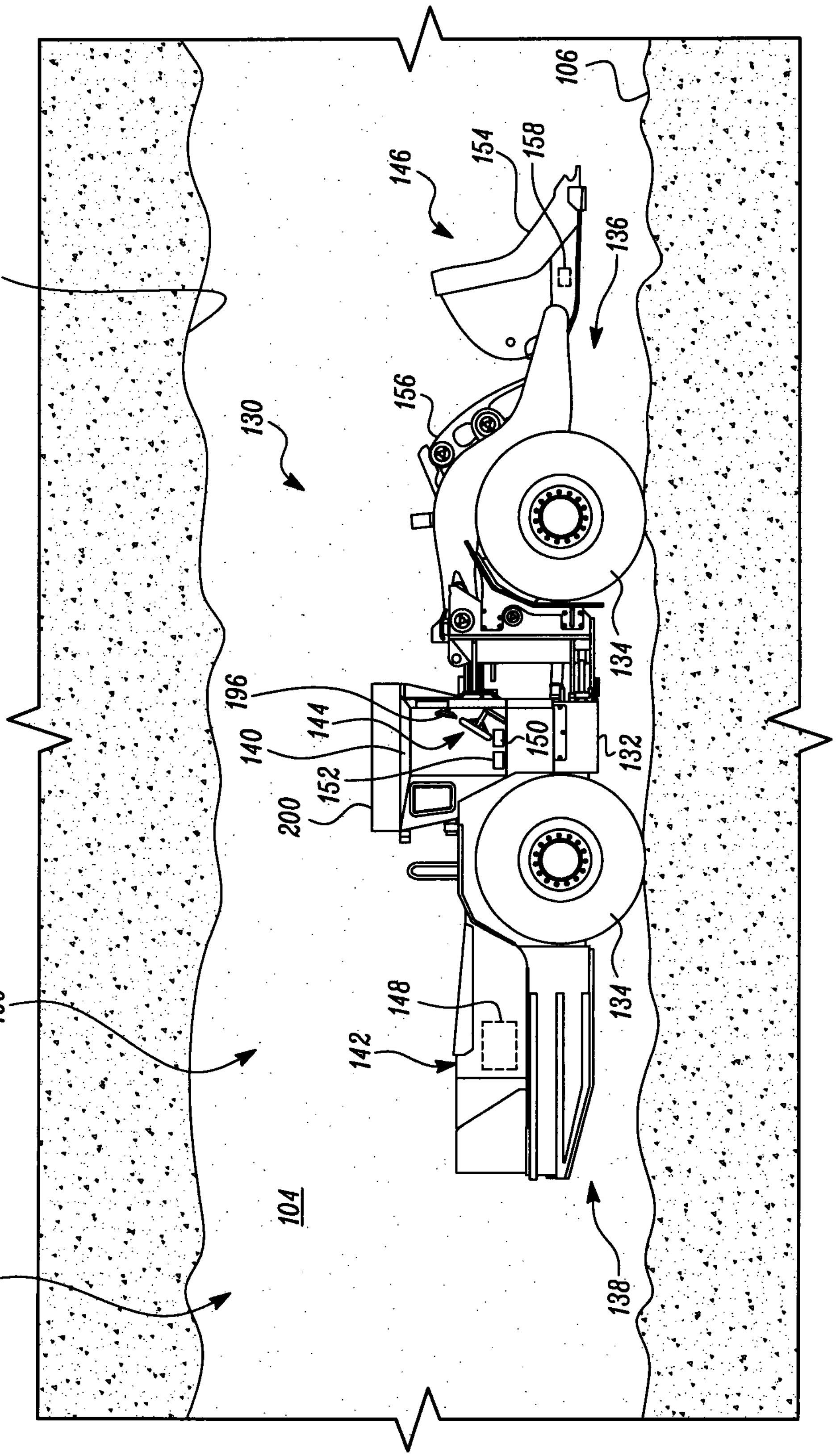
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FIG. 3

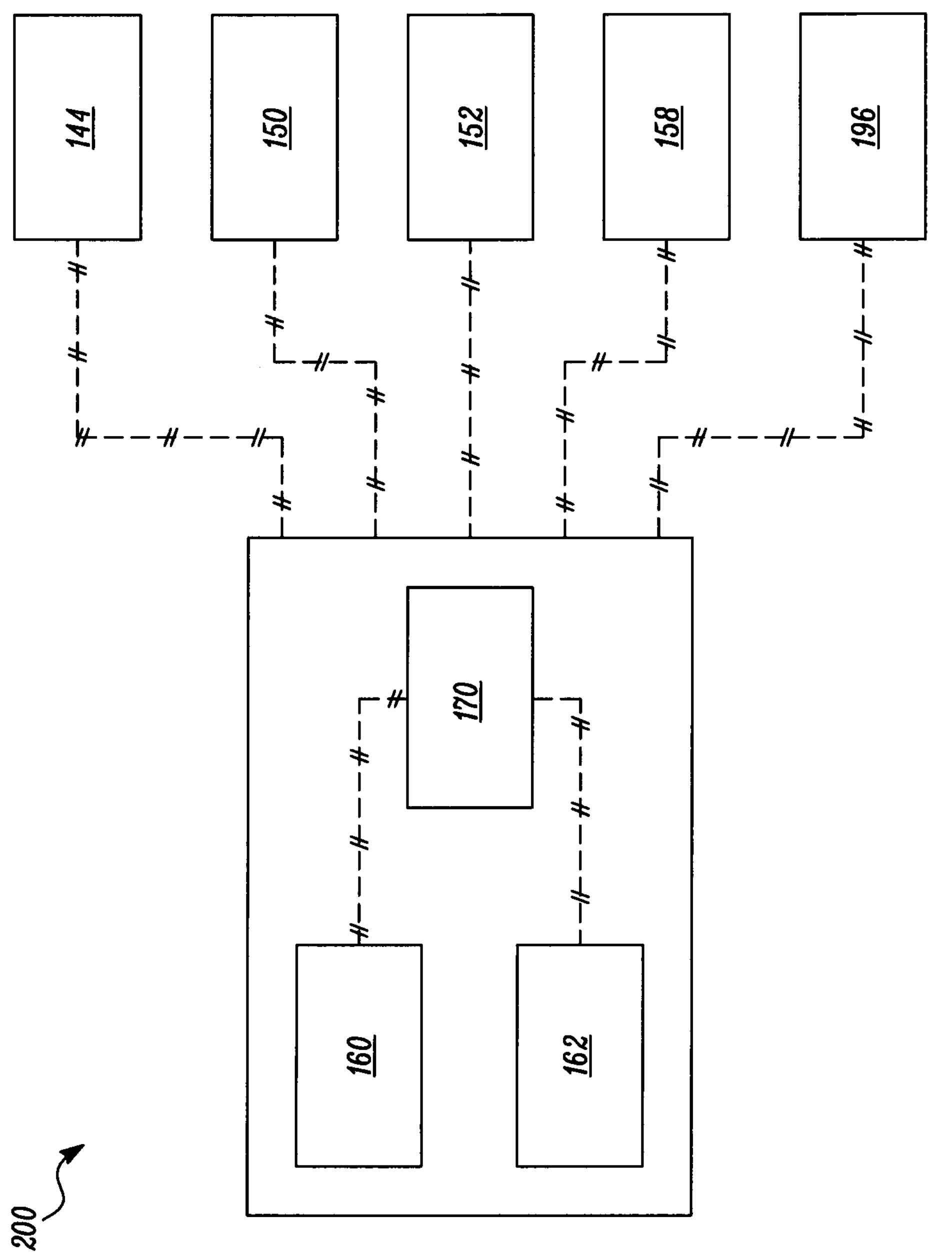

FIG. 4

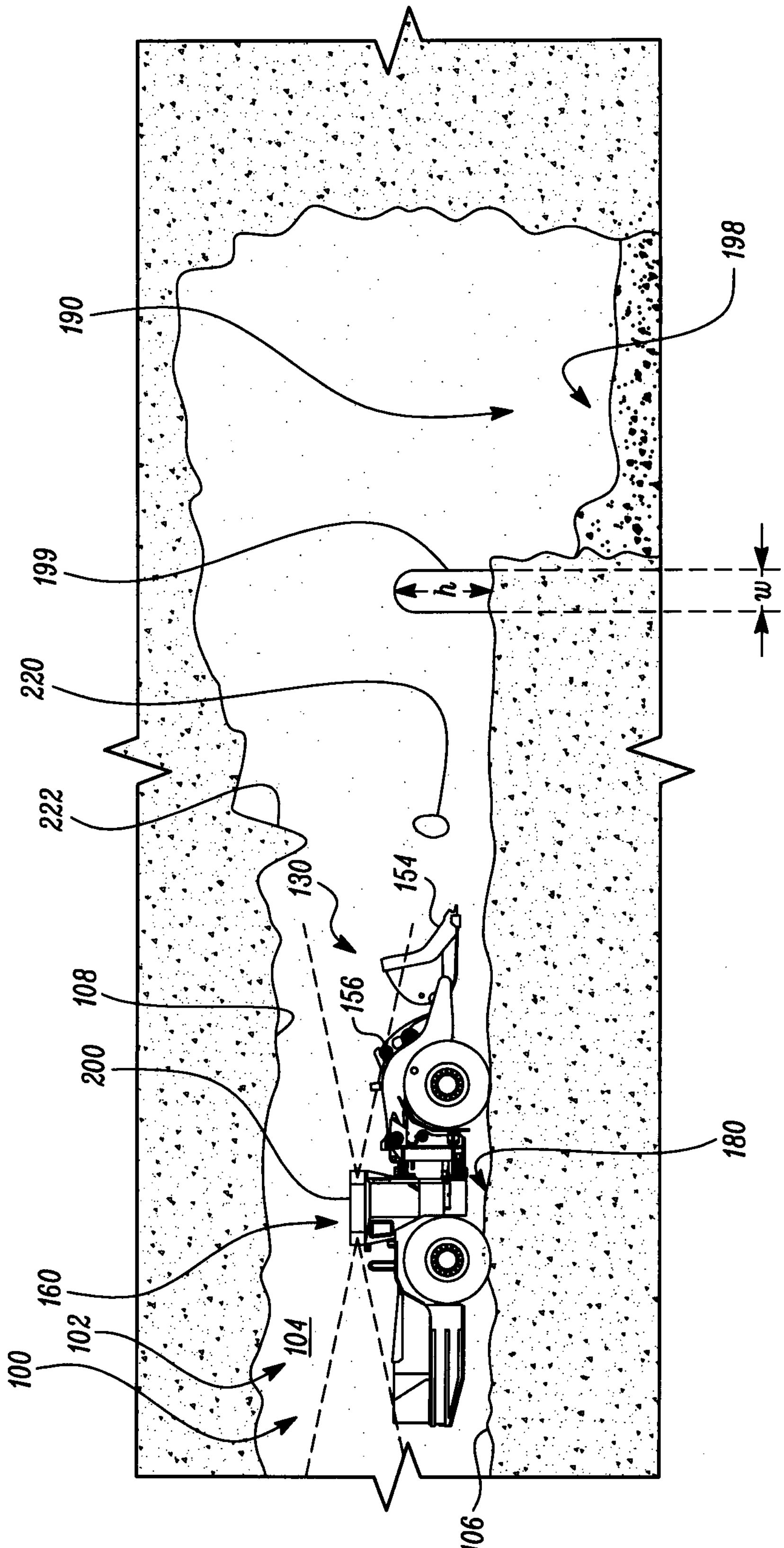
190
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FIG. 5

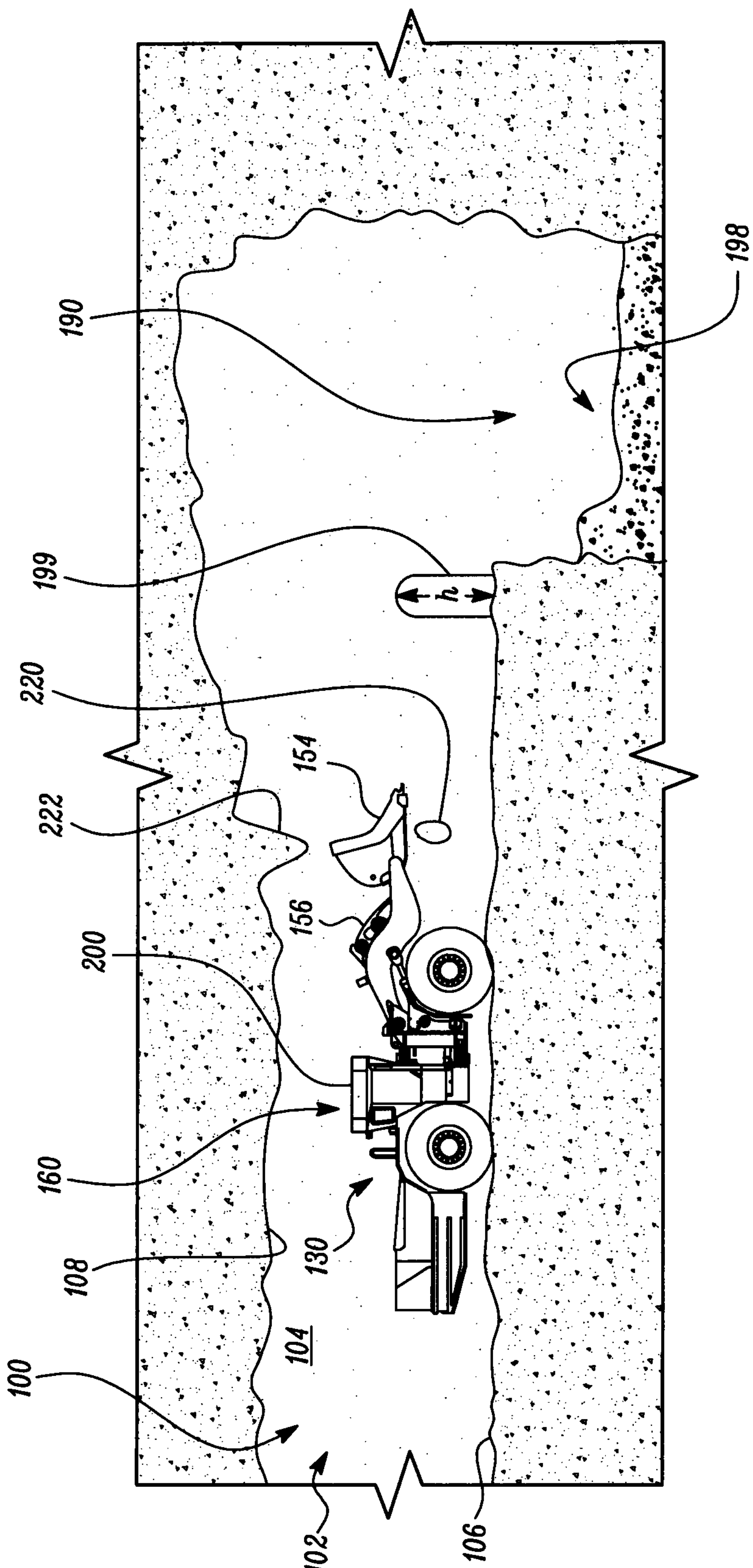

FIG. 6

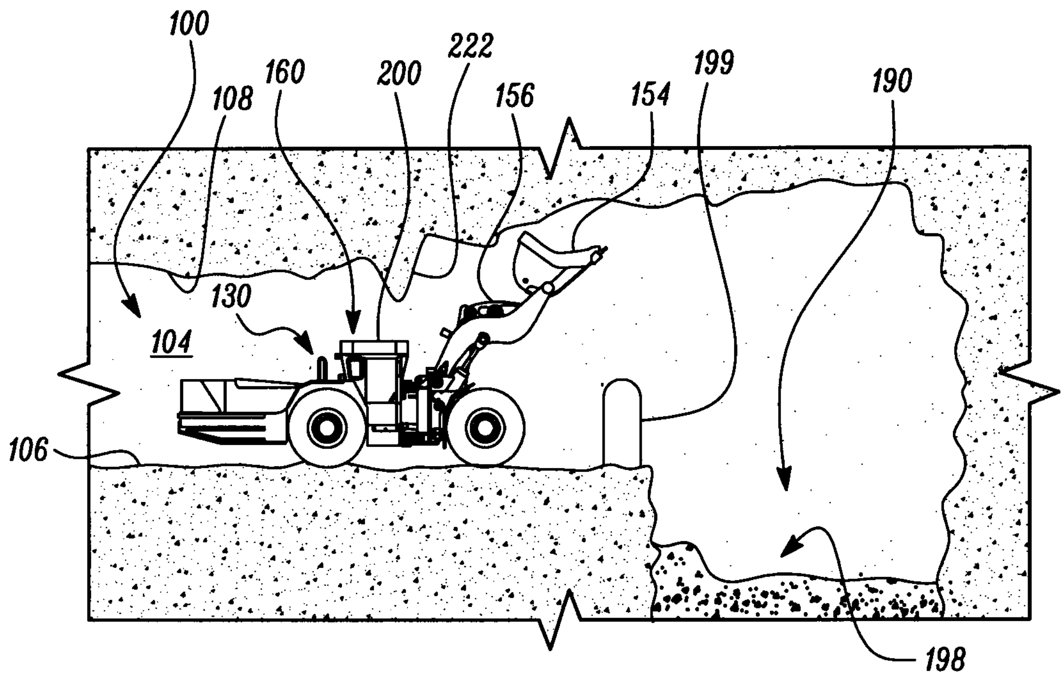
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FIG. 7A

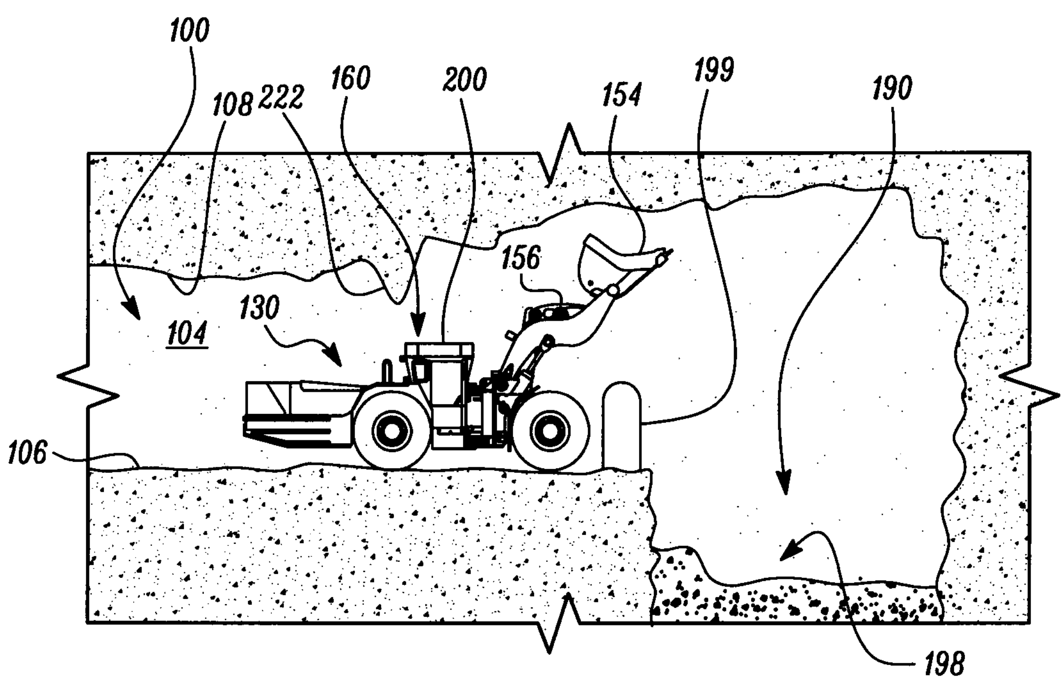
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FIG. 7B

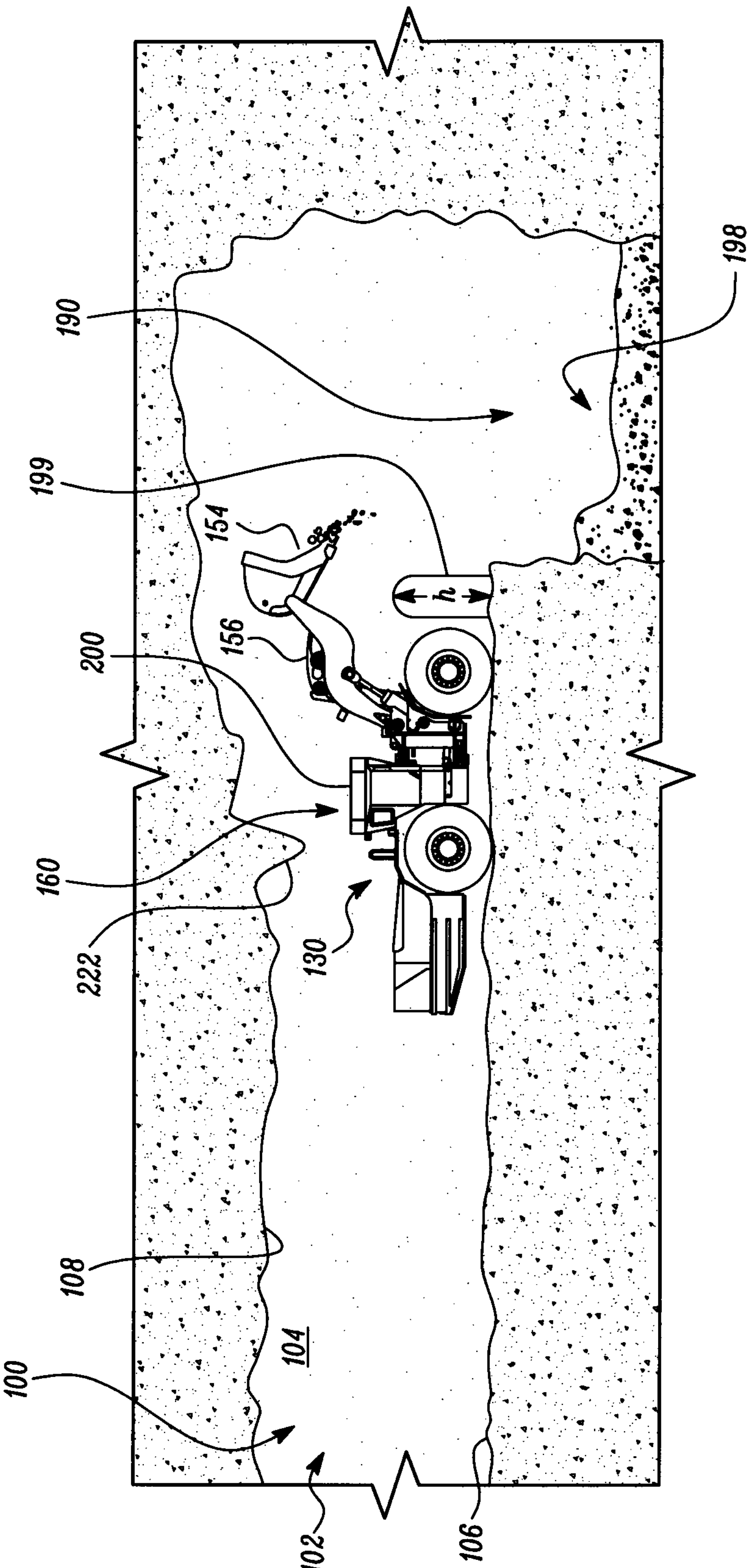


FIG. 8

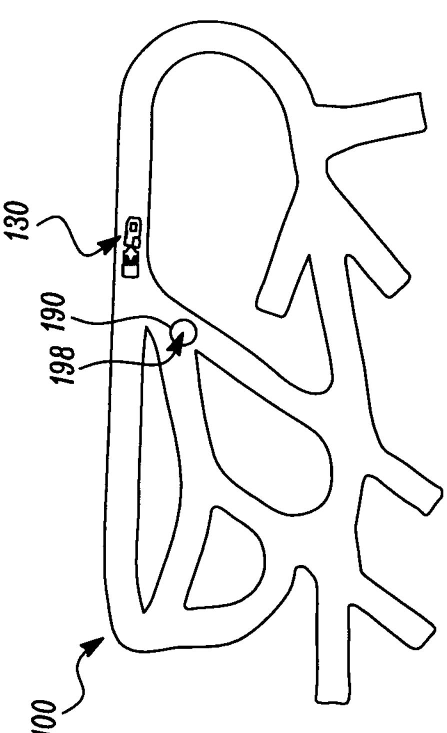


FIG. 9A

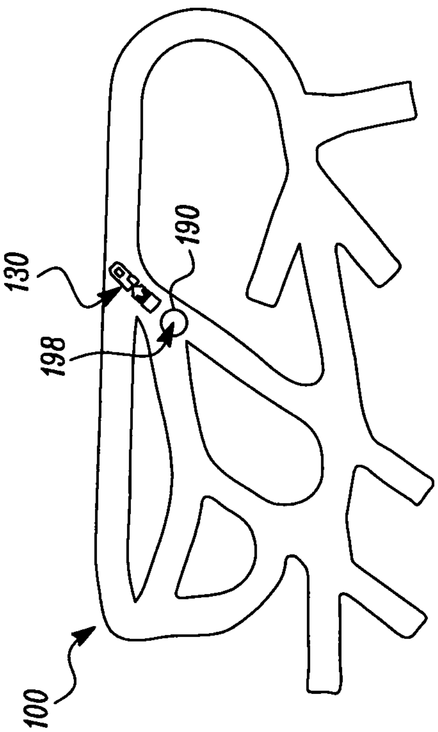


FIG. 9B

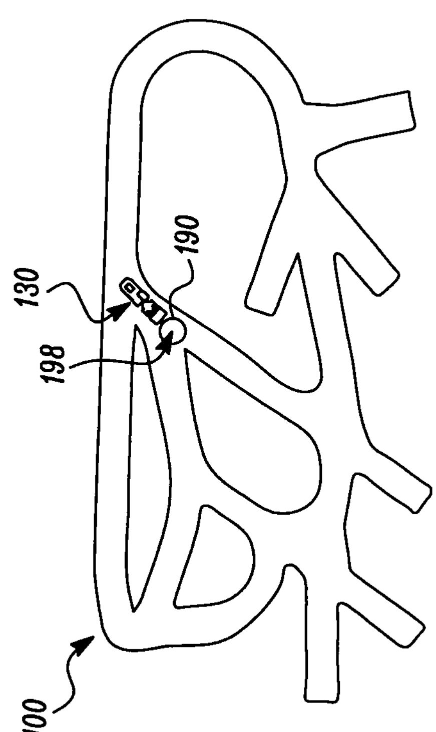


FIG. 9C

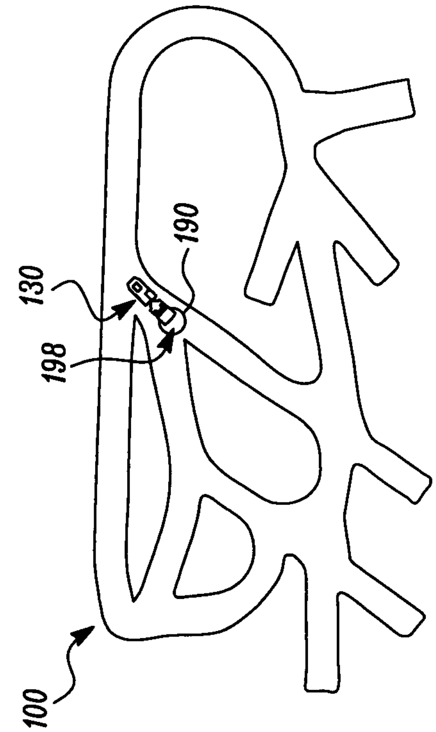


FIG. 9D

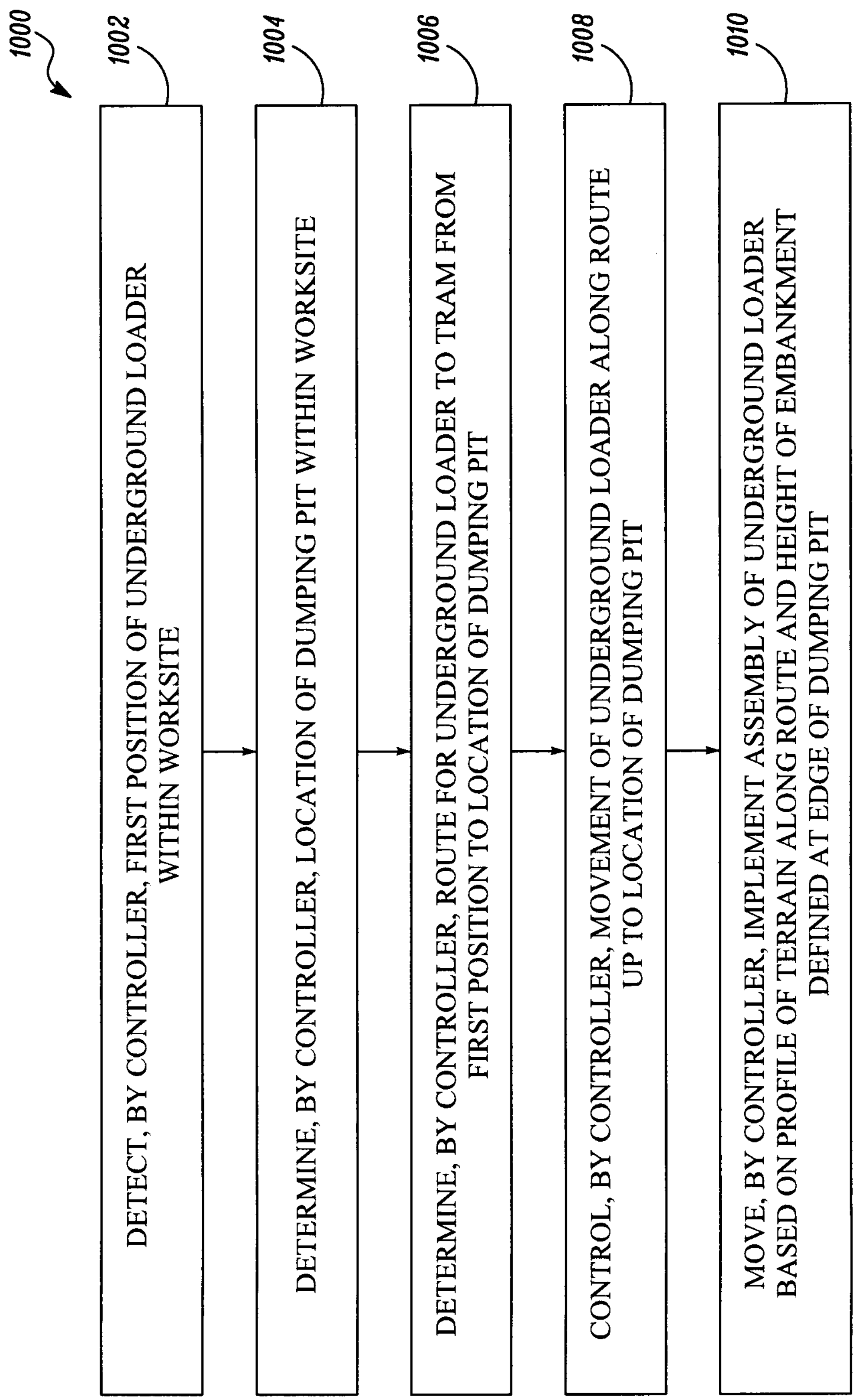
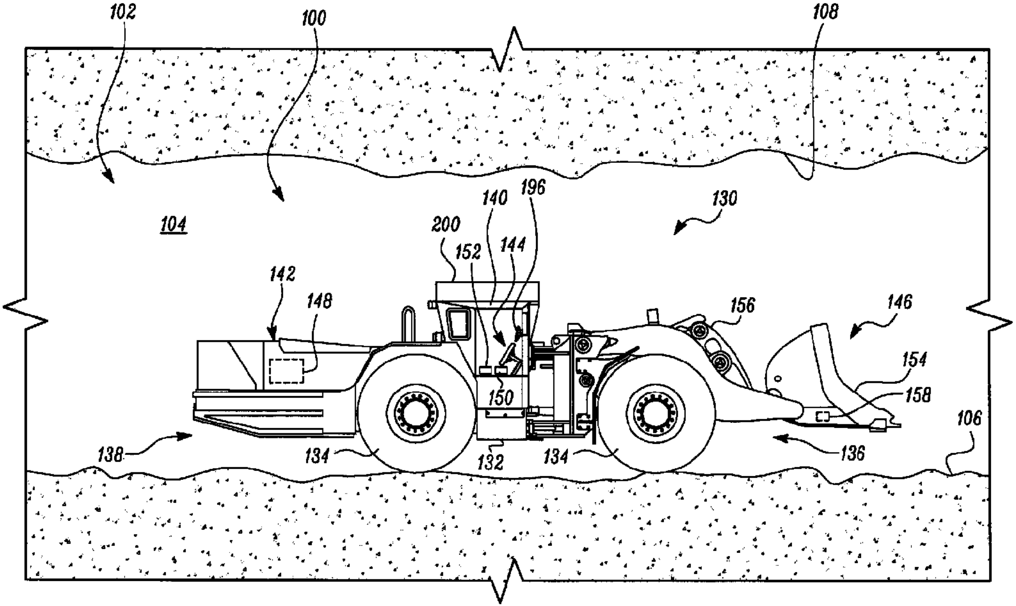

1000
1002
DETECT, BY CONTROLLER, FIRST POSITION OF UNDERGROUND LOADER WITHIN WORKSITE
1004
DETERMINE, BY CONTROLLER, LOCATION OF DUMPING PIT WITHIN WORKSITE
1006
DETERMINE, BY CONTROLLER, ROUTE FOR UNDERGROUND LOADER TO TRAM FROM FIRST POSITION TO LOCATION OF DUMPING PIT
1008
CONTROL, BY CONTROLLER, MOVEMENT OF UNDERGROUND LOADER ALONG ROUTE UP TO LOCATION OF DUMPING PIT
1010
MOVE, BY CONTROLLER, IMPLEMENT ASSEMBLY OF UNDERGROUND LOADER BASED ON PROFILE OF TERRAIN ALONG ROUTE AND HEIGHT OF EMBANKMENT DEFINED AT EDGE OF DUMPING PIT

FIG. 10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