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(72) Inventors:
• **HANSKI, Sami**
33330 Tampere (FI)
• **ANTTILA, Sami**
33330 Tampere (FI)
• **LINDGREN, Jouni**
33330 Tampere (FI)

(71) Applicant: **Sandvik Mining and Construction Oy**
33330 Tampere (FI)

(74) Representative: **Sandvik**
Sandvik Mining and Construction Oy
Patent Department
PL 100
33311 Tampere (FI)

(54) **UNDERGROUND DRILLING RIG TRAMMING CONTROL**

(57) Method for controlling an underground drilling rig, comprising receiving target pose (200) information indicative of at the target pose for the drilling unit (4) in accordance with a drilling plan, detecting, during tramming/driving of the rig, information indicative of the orientation of the carrier (2), defining, during tramming/driving of the drilling rig, orientation of the drilling unit on basis of the detected carrier orientation information, and generating tramming/driving assistance information on basis of the target pose information and the defined orientation of the drilling unit.

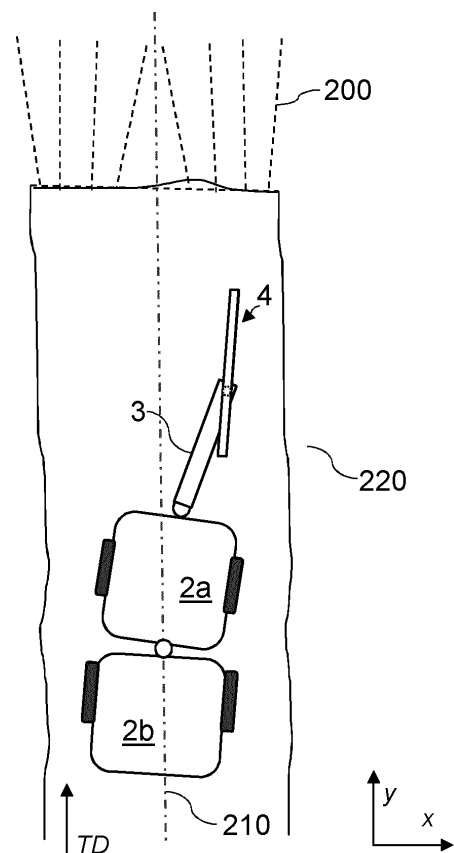


Fig. 2

Description

FIELD

[0001] The present invention relates to controlling tramming of an underground drilling rig.

BACKGROUND

[0002] Drilling rigs are used in underground construction and mining sites. In drilling-blasting based methods rock is excavated in rounds. Several successive rounds produce a tunnel having a tunnel face. At first drill holes are drilled to the tunnel face, where after the drilled holes are charged and blasted. Rock material of the amount of one round is detached at one blasting time. The detached rock material is transported away from the tunnel for further treatments.

[0003] For excavating rock, an excavation plan, which may comprise at least one drilling pattern, or drill hole pattern, is designed in advance and information on the rock type, for example, is determined. Typically, the drilling pattern is designed as office work for each round. The pattern is defining target holes and hence work tasks carried out by the drilling rig. The pattern is provided for the rock drilling rig to drill holes in the rock in such a way that a desired round and tunnel profile can be achieved.

[0004] To perform a drilling round, drilling rig is trammed in proximity of a tunnel face to be drilled in accordance with a target hole pattern defined in the drilling plan. Tramming may generally refer to driving the rig. After tramming the rig to a position in the tunnel for drilling, the rig needs to be stabilized and a drilling unit of a drilling rig, typically comprising a drill (machine) at a feed beam connected to a boom connected to a carrier, needs to be positioned at appropriate position and orientation before starting drilling. If the rig has been stopped at the end of the tramming stage to a pose which does not allow correct positioning of the drilling unit, the rig needs to be driven back and forth to obtain appropriate pose to correctly position the drilling unit. This is a particular challenge in narrow underground tunnels, in which satellite-based positioning data is not available and repositioning of a large drilling rig is substantially more difficult than at surface work sites.

SUMMARY

[0005] The invention is defined by the features of the independent claims. Some specific embodiments are defined in the dependent claims.

[0006] According to a first aspect, there is provided a mobile underground drilling rig, comprising a carrier, at least one boom attached at a first end to the carrier, and a drilling unit attached to a second end of the boom, and control means configured for: receiving target pose information indicative of at least target pose for the drilling unit in accordance with an input plan, detecting, during

tramming of the drilling rig, carrier pose information indicative of orientation of the carrier, defining, during tramming of the drilling rig, orientation of the drilling unit on the basis of the detected carrier pose information, and generating tramming assistance information on the basis of the target pose information and the defined orientation of the drilling unit.

[0007] According to a second aspect, there is provided a method for controlling an underground drilling rig comprising a carrier, at least one boom attached at a first end to the carrier, and a drilling unit attached to a second end of the boom, comprising: receiving target pose information indicative of at least target pose for the drilling unit in accordance with an input plan, detecting, during tramming of the drilling rig, carrier pose information indicative of orientation of the carrier, defining, during tramming of the drilling rig, orientation of the drilling unit on the basis of the detected carrier pose information, and generating tramming assistance information on the basis of the target pose information and the defined orientation of the drilling unit.

[0008] According to a third aspect, there is provided a control apparatus for controlling an underground drilling rig, comprising means for performing the method or an embodiment of the method. The means may comprise at least one processor, at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processor, cause the apparatus at least to perform the method or an embodiment of the method.

[0009] According to a fourth aspect, there is provided a computer program, a computer program product or (a non-tangible) computer-readable medium comprising computer program code for, when executed in a data processing apparatus, to cause the apparatus to perform the method or an embodiment thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIGURE 1 illustrates an example of a drilling rig;

FIGURE 2 illustrates a top view example of a drilling rig and tunnel excavation;

FIGURE 3 illustrates a method according to at least some embodiments;

FIGURE 4 illustrates an example display view; and

FIGURE 5 illustrates an example apparatus capable of supporting at least some embodiments.

EMBODIMENTS

[0011] As an example of an apparatus in which at least some of the embodiments may be employed, Figure 1

illustrates a rock drilling rig 1 comprising a carrier 2, at least one (drilling) boom 3 rotatably attached to the carrier, and a drilling unit 4 rotatably attached to other end of the boom 3. In this example, the carrier comprises two portions, i.e. a first/front portion 2a and a second/rear portion 2b, connected by a joint 8. Instead of a single-part boom, the boom 3 may comprise two or more parts or portions connected by a joint.

[0012] The boom 3 is further connected to a drilling unit 4 by at least one joint. The drilling unit 4 comprises a feed beam 5 on which a rock drilling machine 6 can be moved by means of a feed device. Further, a tool 7 is connectable to the drilling machine 5, by which tool the impact pulses given by the percussion device of the rock drilling machine are transmitted to the rock to be drilled.

[0013] It is to be noted that Figure 1 is simplified and represents one example of a drilling rig, in which the boom is relatively long. It is to be appreciated that the presently disclosed features may be applied for a wide variety of rock drilling rigs, some examples of which include tunnel development, long-hole, support, in-the-hole, and top-hammer drilling rig types. For example, in case of long-hole drills, the boom may refer to (relatively short) support and connecting structure for the drilling unit. Depending on drilling rig type, the rig 1 and the drilling unit 4 may comprise various further units and devices, such as a rod handling cassette, a support rack, cylinder(s), a dust removal unit, further drilling support elements, etc.

[0014] The drilling rig 1 further comprises a motor 9, such as a combustion engine and/or an electric motor. The drilling rig 1 typically comprises a system of pumps for generating hydraulic pressure for operating various parts of the machine, such as actuating the boom 3 and the feed beam 5, etc. The drilling rig 1 may comprise one or more other sources of energy, such as an accumulator, a hydrogen container, a fuel tank, etc.

[0015] The rock drilling rig 1 further comprises at least one control unit 10 arranged to control actuators of the rock drilling rig 1, for example. The control unit 10 may comprise one or more processors executing computer program code stored in a memory. The control unit may comprise or be connected to a user interface with a display device as well as operator input interface for receiving operator commands and information to the control unit 10 and generating display views and other output for an operator of the rig. In some embodiments, the control unit 10 is configured to perform at least tramming control related operations, and there may be one or more other control units in the rig for controlling other operations.

[0016] In a tramming stage of a drilling rig work procedure or cycle, the rig 1 may tram towards direction *TD* to a drilling position at the worksite. It is to be noted that a specific tramming mode or boom and/or drilling unit position may be applied. For example, the drilling unit 4 may be pivoted partially on top of the boom 3.

[0017] Figure 1 also illustrates examples of available movement of rig portions in relation to one another: arrow

a indicates (horizontal/lateral plane or *xy* direction) movement/relation between rig portions 2a, 2b, *b* indicates (horizontal/lateral plane or *xy* direction) movement/relation between front carrier portion 2a and boom 3, *c* indicates (vertical plane or *z* direction) movement between front carrier portion 2a and boom 3, *d* and *e* movement/relation (in horizontal plane and vertical plane, respectively) between the boom 3 and the drilling unit 4. It is to be appreciated that there may be more or less joints and movement directions between rig portions, and the order of joints may be different than illustrated in the example of Figure 1. For example, a bolter rig may comprise a further joint in the drilling unit, and a long-hole drilling rig may be arranged without a joint providing *b* direction movement.

[0018] One or more sensors 11 may be arranged for determining current position and direction of the boom 3, or a portion thereof. One or more sensors may be arranged to determine current position and direction of the drilling unit 4. Figure 1 illustrates only single sensor 11, but it will be appreciated that there may be a plurality of sensors. Such sensors may be positioned in the carrier 2, the boom 3, and/or the drilling unit 4. The sensing data may be provided to the control unit 10 (or another control unit for positioning), which may execute appropriate computations. In an example embodiment, joints are equipped with joint position sensors. Joint position sensor data, of a plurality of joints between the carrier 2 and the drilling unit 4, from such sensors is applied to define the position and orientation of the drilling unit 4 in relation to the carrier 2. The orientation of the drilling unit 4 may define also the orientation of the feed beam 5 and the drilling machine 6 (and the tool 7).

[0019] The drilling rig 1 may comprise at least one scanner 12 for scanning tunnel profile. In an example embodiment, the scanner 12 is a 3D scanner, in which case 3D scanning data, e.g. point cloud data is produced. For example, the rig may comprise a front scanner configured to scan environment towards normal forward driving direction *TD* (and naturally to sides within reach of the scanner). The rig may also comprise a rear scanner configured to scan the environment towards direction opposite to *TD*, i.e. backwards of the vehicle. The scanner 12 may be a laser scanner or another type of sensor device, such as 4D or another type of radar, appropriate for determining obstacles and distances to obstacles for the vehicle.

[0020] The drilling rig 1 may comprise various further units, such as a wireless communications unit 13, configured for data transfer with a base station and/or a user device. The communication device may thus be connected to a communications system of the worksite, e.g. via a wireless access point or base station 14 of a wireless access system comprising a wireless local area network (WLAN) and/or a cellular communications network (e.g. a 4G, 5G or another generation cellular network). For example, the drilling rig may be remotely monitored and controlled based on state data from the drilling rig and

control data from a remote controller unit.

[0021] It is to be appreciated that Figure 1 provides only one example and many other configurations are applicable. For example, instead of one boom, there may be two booms or more than two booms, such as three or even four booms in a single drilling rig. Another type of work machine may be attached to the boom 3, such as a bolting unit, a concrete sprayer, a platform, a scaling unit, or an explosives charger unit, for example. It is to be also noted that the drilling rig may be unmanned. Thus, the user interface may be remote from the rig and the rig may be remotely controlled by an operator in the tunnel, or in control room at the worksite area or even long distance away from the worksite via communications network(s).

[0022] With reference to Figure 2, illustrating a top view of a tunnel and drilling rig 1, a drilling plan (illustrated by broken line) may define positions and orientations of holes 200 to be drilled. The holes to be drilled may be arranged in multiple drill hole rows.

[0023] The plan may define a plurality of target poses for the drilling unit 4, such as hole positions and orientations. The plan may be designed offline and off-site, for example in an office, or on-board the drilling rig. Such plan may be sent via a wired or wireless connection to, or otherwise loaded to a memory of the rock drilling rig 1 for access by the control unit 10.

[0024] The drilling rig 1 may be trammed in proximity of a tunnel face to be drilled according to a target hole pattern defined in the drilling plan. After the tramping stage, a positioning stage may be carried out. Thus, the boom 3 and the drilling unit 4 are controlled to position the drilling unit 4, typically the feed beam 5, at the defined hole/target pose, at appropriate position and alignment based on hole position and orientation information defined in the plan. The drilling rig 1 is also stabilized for drilling, whereby typically a set of ground supports are pushed onto the ground. The drilling unit and/or feed beam may be positioned after the stabilization, or re-position after the stabilization to ensure correct pose to drill the first planned hole according to the drill plan.

[0025] The drilling rig 1 may be configured to operate autonomously at least some operations, such as at least some of operations of a drilling work cycle. The drilling rig 1 may in its autonomous operating mode operate independently without requiring continuous user control but which may be taken under external control in response to an operator alert or automatic operation terminating, for example.

[0026] The boom and/or feed beam positioning, for achieving the target pose for the drilling unit 4, may be automatized. Thus, on the basis of target pose, i.e. hole position and orientation information of the plan and detected information of current position and orientation of the feed beam, the control unit 10 (or another control unit), may compute movement control actions (for the carrier 2, the boom 3, and/or the feed beam 5) required to arrive at the target pose, generate associated control

signals, and send the control signals for associated actuators or control system elements. However, if the parking position of the drilling rig 1 (and the carrier thereof), limited by the tunnel walls, does not allow the instrumentation to achieve the target pose for the drilling unit 4, autonomous positioning fails, requiring operator intervention and causing delay in production.

[0027] In some embodiments, the drilling rig 1 is configured to perform automatic drilling cycle. The drilling plan and pattern may be used as an input for automatic control of the drilling rig 1. Based on hole position data in the drilling plan and position data from the scanner unit, the control unit 10 may generate steering instruction and associated control signal to operate the wheels to tram the drilling rig close to a target hole.

[0028] Particularly for remotely controlled drilling rigs, it may be difficult, especially for a less-experienced operator, to control the drilling rig 1, at a narrow tunnel without colliding to a tunnel wall, on the basis of remote monitoring graphical user interface (GUI) view to a correct parking position, at which the drilling unit 4 can be appropriately positioned and aligned to the target pose. If the rig has been stopped at the end of the tramping stage to a pose which is detected during the positioning stage of the drilling unit to be non-optimal for, or does not allow correct positioning of the drilling unit, there often is not much space around the large rig to drive back and forth at the typically very narrow end portion of the tunnel to obtain appropriate pose to correctly position the drilling unit. There are now provided further improvements for tramping control, further illustrated below.

[0029] Figure 3 illustrates a method according to some embodiments. The method may be performed by an apparatus for controlling a drilling rig, such as the control unit 10 of the drilling rig 1.

[0030] The method comprises receiving 300 target pose information indicative of at least target pose for a drilling unit, such as the drilling unit 4, in accordance with an input plan, in some embodiments a drilling plan.

[0031] The target pose information may be received from an internal or external memory, or from another apparatus, such as the remote controller unit or a worksite control system apparatus. The target pose information may be received as part of a received drilling plan or another type of tunnel system or mine plan or model, such as a tunnel plan file comprising data indicative at least a tunnel line and/or other tunnel parameters. Appropriate data of the plan may be (automatically) selectively obtained in block 300 for the target pose. In an example embodiment this is based on next drilling task to be performed by the rig, and the target pose information may comprise or be based on hole sequence data of a next round to be drilled. Reception/retrieval of the target pose information may be based on received positioning data indicative of current location of the rig 1.

[0032] Carrier pose information indicative of orientation of a carrier of the drilling rig is detected 310 during tramping of the drilling rig. This information may be re-

ceived from a carrier pose information source, such as a gyroscope or a magnetometer.

[0033] Block 320 comprises defining, during tramming of the drilling rig, orientation of the drilling unit on the basis of the detected carrier pose information. This may comprise computing the orientation of the drilling unit on the basis of current orientation relation between the drilling unit and the carrier, in an embodiment computed based on current positions of a plurality of joints between the carrier and the drilling unit. Block 330 comprises generating tramming assistance information on the basis of the target pose information and the orientation of the drilling unit.

[0034] Tramming assistance information refers generally to information applied during tramming of the drilling rig, for assisting the tramming of the rig. Depending on applied implementation, if the drilling rig is manually operated or tramming autonomously, the tramming assistance information may be generated 330 to assist an operator to control the tramming and steering the rig, or for use by a control unit to autonomously steer the drilling rig. Block 320 may also comprise (or there may be a further block) of defining position of the drilling unit, and the tramming assistance information in block 330 may comprise or be based on position of the drilling unit in relation to the position of the target pose for the drilling unit (based on the drilling plan).

[0035] With the tramming assistance information, the underground drilling rig 1 may be further steered to be positioned and oriented such as to allow appropriate pose of the drilling unit 4 for upcoming drilling task already during the tramming stage. That is, the tramming assistance information may be applied during driving when approaching a parking position for drilling, which may also be referred to as drilling position for the carrier, at the typically very narrow tunnel conditions, i.e. before stopping the rig and starting (fine-)positioning of the boom and/or feed beam to a hole to be drilled. In case of manual operation, when tramming assistance information is displayed for the operator, the operator may be assisted already during the tramming stage, when steering the carrier 2 to the drilling position. The operator may be provided with tramming assistance information indicating how the typically large drilling rig should be steered to approach the drilling position optimally for the upcoming drilling task at the narrow tunnel face area. The tramming assistance information, or a GUI based on the assistance information, may indicate current pose of drilling unit relative to the target pose. The operator may thus instantly detect how the drilling unit currently positions in respect to the hole profile (or pattern).

[0036] The present features enable to reduce or avoid movement or re-parking of the carrier after stopping at the drilling position, during the drilling unit positioning stage, or having to re-enter the tramming stage due positioning of the drilling unit failing. The tramming assistance information may indicate for the operator if, and in a further embodiment what, corrective steering and/or

other rig actuator actions may need to be performed to have the drilling unit at the target pose or close to the target pose already at end of the tramming stage. Since orientation of the drilling unit is defined based on the orientation of the carrier, orientation sensors may be avoided at the drilling unit (or boom), where they would be much more vulnerable to be damaged. Some further example embodiments are illustrated below, also with references to example drilling rig 1 of Figure 1 and applying a drilling plan as the input plan.

[0037] Deviations between position and/or orientation information in the input plan, in particular the target pose information, and current position and/or orientation of one or more drilling rig portions may be defined and applied for generating the tramming assistance information.

[0038] Between blocks 320 and 330, there may be an additional block of defining deviation of the (current) orientation of the drilling unit 4 from the at least one target pose, on the basis of the defined (320) orientation of the drilling unit and the detected (300) target pose information. The tramming assistance information may be generated 330 on the basis of the defined deviation of the orientation of the drilling unit from the target pose in accordance with the drilling plan. The deviation may be defined based on angular difference between the current orientation of the drilling unit 4 and the target orientation for the drilling unit (in the same reference system). The deviation may further be based on positional deviation, and defined based on computed difference/distance between the current position of the drilling unit and target position for the drilling unit for initiating the upcoming drilling task and defined (in the target pose) based on the drilling plan.

[0039] The method may comprise, during or after block 330, generating a GUI view indicative of at least the current orientation and/or position of the drilling unit 4 and the at least one target pose. The GUI view may thus indicate how the drilling unit is currently positioned in view of the approaching work task and hole to be drilled. For example, a GUI view comprising at least elements illustrated in Figure 2 may be generated. The GUI view may be or comprise the tramming assistance information provided for the operator. When the operator perceives this relation already during the tramming stage, (s)he may take proactive corrective control actions already before stopping the rig and starting positioning of the drilling unit to the hole to be drilled.

[0040] Position and orientation of other rig portions, in particular the carrier 2 and/or the boom 3, in relation to the target pose(s) may also be defined and displayed. This enables to further perceive how the rig 1 is posed in relation to the hole to be drilled and to assist in controlling the rig to approach the drilling position in optimal pose.

[0041] One or more portions of the drilling plan, in an embodiment a profile of at least one hole of a next round to be drilled, may be selectively displayed during the tramming stage. Various display effects may be utilized.

For example, if drilling order is defined in the drilling plan, a first hole to be drilled is selected for display or highlighted e.g. with a particular color from other holes being displayed.

[0042] GUI element(s) modelling or indicative of at least some portions of the drilling rig, such as the carrier 2, the boom 3, and the drilling unit 4, may thus be positioned in the GUI view in accordance with the current position and orientation of the respective portion, and together with and in relation to at least some information of the drilling plan. The target pose(s) may be visualized in the display, e.g. by applying a form similar to that of drilling unit, positioned and oriented in the display in accordance with the position and orientation of a hole to be drilled.

[0043] On the basis of the defined deviation, a GUI element may be generated, indicative of the deviation of the current orientation of the drilling unit 4 from the at least one target pose in accordance with the input plan. The (deviation) GUI element may serve as the tramming assistance information provided for the operator and may be included in the GUI view indicating position and orientation of at least some portions 2, 3, 4 of the drilling rig in relation to at least portion of the drilling plan. The deviation may be visualized in various ways. In a simple example, deviation is defined based on position and orientation of at least some portions of the drilling rig in relation to the target pose for the drilling unit (based on the drilling plan).

[0044] The target pose (of the drilling unit) may be indicated or defined based on target tunnel line defined in the input plan. For example, line 210 in Figure 2 may illustrate middle (target) tunnel line, in respect to which the target pose may be defined. The target tunnel line may be visualized in the GUI displayed during the tramming. Position and orientation of at least some portions of the rig 1, such as the carrier 2, and/or the drilling unit 4, may be displayed in relation to the tunnel line 210.

[0045] In another example, a reference is made to example GUI view of Figure 4, illustrating a top view of a front carrier portion 2a and a drilling unit 4, e.g. of a long-hole rig at a tramming position. The GUI view may comprise a (middle) tunnel line 210, which may represent current target pose for the drilling unit 4, according to the input plan. The GUI view may comprise tunnel walls 220a, 220b, which may be displayed e.g. based on a portion of a tunnel model relevant for the current position of the drilling rig 1. Further, an assisting indicator 400 of the current orientation of the drilling unit is generated and displayed in the GUI view during the tramming. The operator may thus be prompted to perform a steering action to further align the lines 210, 400.

[0046] The GUI view may also comprise further information assisting the operator in tramming the drilling rig 1 towards the drilling position. For example, distance of a rig portion to wall may be indicated, a warning indicator may be displayed, and/or a steering guidance indicator may be displayed. In addition to visual tramming assist-

ance, the associated drilling rig or remote control UI system may be configured to generate audible and/or haptic output based on block 330 to assist the operator.

[0047] The GUI view and various tramming assistance elements/indicator thereof may be displayed and continuously updated during tramming of the drilling rig 1, for assisting (an on-board or remote) operator to control tramming and positioning of the drilling rig to the drilling position for carrying out a drilling operation according to the drilling plan.

[0048] Block 330 may thus comprise generating assistance information for guiding the operator. The assistance information may indicate how the operator should control the rig 1, in particular the carrier 2, during the tramming to approach the position in optimal way (and pose). In a simple example, the view displayed for the operator and/or a UI element (e.g. joystick) may indicate at least one control action for approaching the target pose, such as a direction, in which associated rig portion, such as the carrier 2, should be controlled.

[0049] In an example embodiment, the tramming assistance information is generated and displayed during the tramming stage on the basis of input parameter data of (currently) available movement range or reach of a rig portion 3, 4, 5. The control unit 10 may compute, on the basis of available ranges of joints between the carrier 2 and the drilling unit 4, which is the current maximum reach of the drilling unit 4. On the basis of current position and orientation of the carrier, information indicative of the available reach may be generated as the tramming assistance information. Hence, block 320 may comprise defining available orientation, e.g. as an available orientation range, based on the detected orientation of the carrier. The available reach information and the target pose may be processed to define if the target pose can be achieved with the current carrier orientation. The available reach information may be displayed in the GUI view and/or used for automatized tramming control. This assists the operator to instantly detect if it possible, with the current pose of the carrier, to position the drilling unit appropriately to the position and orientation of the hole to be drilled. The display view is continuously updated, and when the operator correctively steers the carrier, (s)he may instantly notice, based on updated reach indication, if the steering action was enough to reach the hole with the drilling unit 2. In another example, the GUI view indicates if the target pose cannot be reached with the current pose of the carrier.

[0050] Such reach indication is particularly useful for last meters of tramming before the drilling position. Such reach indication may be activated based on rig position information, e.g. when the rig is less than 5 meters from the drilling position.

[0051] The tramming assistance information may comprise an indication of upcoming path of the rig 1 in relation to at least a portion of the drilling plan. The indication may be defined on the basis of current status of a drilling rig portion, such as current position, orientation, and

steering or articulation angle of the carrier 2. This enables to illustrate where, in relation to the drilling plan, the rig will move if the tramming is continued without further control actions. The GUI view may indicate future path for the carrier and drilling unit 4, e.g. by specific splines or other type of GUI element to visualize future occupancy area of the respective rig portion.

[0052] Block 330 may comprise generating rig steering control instruction during the tramming for autonomously controlling at least some portions of the drilling rig 1 during the tramming. Additionally or alternatively, block 330 may comprise generating steering control assistance information for guiding an operator to control the drilling rig. Such control instruction(s) may be generated based on the difference between current position and orientation of the drilling unit 4 and that of the target pose. Such control instruction(s) may be steering operation control instructions for controlling steering system of the carrier 2. Block 330 may be performed by an autonomous tramming or driving control module, which generates steering control instructions to tram the rig to the drilling position. The control module may apply predefined route for the rig and steer the rig to route points of the route, for example.

[0053] The rig control instruction may comprise defining required movement path, i.e. trajectory, of the carrier to (enable to) reach the target pose for the drilling unit 4, or at least to reduce the deviation defined in block 330. Thus, the autonomous tramming or driving control module may apply the target pose, carrier orientation and the available reach information to define steering action(s) control orientation of the carrier (or carrier portion) to facilitate aligning the drilling unit to the target pose. On the basis of the rig control instruction, control signal(s) may be generated in or after block 330 for associated actuator(s), such as steering control system actuators. The control signals may then be sent for the associated actuators or control system elements. For example, a control signal is sent from the control unit 10 to actuator of the joint 8 to change articulation angle and driving direction of the rig to facilitate aligning the drilling unit to the target pose.

[0054] Further, the apparatus or control unit performing the method of Fig. 3 may be configured to inform and/or guide the operator during the autonomous tramming, in response to meeting a predefined trigger condition requiring operator attention being met. This may be based on the information based on block 320. For example, in response to the control module detecting that the target pose cannot be reached (with the autonomous driving mode), the control unit 10 may cause an indication for the operator to manually control the drilling rig. In another example, the control unit 10 is configured to determine a corrective control action for one or more components of the drilling rig, after which a trajectory for positioning the drilling unit to the target pose can be generated.

[0055] The target pose may be indicative of, or defined

based on a target orientation for the feed beam 5 for drilling a hole in a set or pattern of holes defined in the drilling plan. The computation (in or for block 310, 320 and/or 330) may require conversion between (positioning) reference systems, such local drilling rig reference system and worksite or global reference system. Hence, one or more conversions between coordinate systems may be performed.

[0056] The target pose may define the position and the orientation of the hole in a worksite/mine reference system, which may be a mine or tunnel coordinate system, which may be based on a global coordinate system. The target pose may need to be converted into a machine/drilling rig reference system, which may be a rig coordinate system, in relation to which position and orientation of rig portions, such as the carrier (portion), boom, and drilling unit 4 may be defined. Another embodiment, the orientation (and position) of the drilling unit in worksite/mine reference system is computed based on local drilling rig reference system, based on angular relations between associated rig portions and dimensional data of the rig portions.

[0057] The carrier 2 may comprise a gyroscope. The orientation of the drilling unit 4 may be defined in block 320 on the basis of the received orientation of the carrier 2 as obtained from the gyroscope and joint position information of a plurality of joints between the carrier 2b and the drilling unit 4. For example, the rear portion 2b may comprise a gyroscope 15. Thus, position of the carrier joint 8 is used as an input for defining the orientation of the drilling unit 4. For example, the orientation may be defined as azimuth, and in the example of Figure 1, computed on the basis of current joint positions of movement ranges indicated by a-e. In case of drilling rigs with non-articulated carriers, the orientation may naturally be computed on the basis of positions of joints between the carrier and the drilling unit.

[0058] It is to be appreciated that various further features may be complement or differentiate at least some of the above-illustrated embodiments. For example, there may be further user interaction and/or automation functionality further assisting the tramming stage, e.g. facilitating the operator to detect how to approach the target pose, select appropriate action to overcome an issue during the tramming, and control the drilling rig and the various portions 2, 3, 4 thereof.

[0059] An electronic device comprising electronic circuitries may be an apparatus for realizing at least some embodiments illustrated above, such as the method illustrated in connection with Figure 3. The apparatus may be comprised in at least one computing device connected to or integrated into a control system of the rock drilling rig. Such control system may be an intelligent on-board control system controlling operation of various sub-systems of the rock drilling rig, such as a hydraulic system, a motor, a rock drill, etc. Such control systems are often distributed and include many independent modules connected by a bus system of controller area network (CAN)

nodes, for example.

[0060] Figure 5 illustrates a simplified example apparatus capable of supporting at least some embodiments of the present invention. Illustrated is a device 50, which may be configured to carry out at least some of the embodiments relating to the drilling rig tramming related operations illustrated above. The device 50 may comprise or implement the control unit 10.

[0061] Comprised in the device 50 is a processor 51, which may comprise, for example, a single- or multi-core processor. The processor 51 may comprise more than one processor. The processor may comprise at least one application-specific integrated circuit, ASIC. The processor may comprise at least one field-programmable gate array, FPGA. The processor may be configured, at least in part by computer instructions, to perform actions.

[0062] The device 50 may comprise memory 52. The memory may comprise random-access memory and/or permanent memory. The memory may be at least in part accessible to the processor 51. The memory may be at least in part comprised in the processor 51. The memory may be at least in part external to the device 50 but accessible to the device. The memory 52 may be means for storing information, such as parameters 54 affecting operations of the device. The parameter information in particular may comprise parameter information affecting e.g. the operations in Figure 3, such as threshold values.

[0063] The memory 52 may be a non-transitory computer readable medium comprising computer program code 53 including computer instructions that the processor 51 is configured to execute. When computer instructions configured to cause the processor to perform certain actions are stored in the memory, and the device in overall is configured to run under the direction of the processor using computer instructions from the memory, the processor and/or its at least one processing core may be considered to be configured to perform said certain actions. The processor may, together with the memory and computer program code, form means for performing at least some of the above-illustrated method steps in the device.

[0064] The device 50 may comprise a communications unit 55 comprising a transmitter and/or a receiver. The transmitter and the receiver may be configured to transmit and receive, respectively, i.a. data and control commands within or outside the drilling rig 1. The transmitter and/or receiver may be configured to operate in accordance with global system for mobile communication, GSM, wideband code division multiple access, WCDMA, long term evolution, LTE, 3GPP new radio access technology (N-RAT), wireless local area network, WLAN, and/or Ethernet standards, for example. The device 50 may comprise a near-field communication, NFC, transceiver. The NFC transceiver may support at least one NFC technology, such as NFC, Bluetooth, or similar technologies.

[0065] The device 50 may comprise or be connected to a UI component(s). The UI may comprise at least one of a display 56, a speaker, an input device 57 such as a

keyboard, a joystick, a touchscreen, and/or a microphone. The UI may be configured to display views on the basis of above illustrated embodiments. A user may operate the device and control at least some of above illustrated features. In some embodiments, the user may control the apparatus 30 or the rig 1 via the UI, for example to manually operate a boom, input steering control actions for the carrier 2, change operation mode of the drilling rig e.g. from tramming mode to automatic positioning at the drilling position, change display views, modify parameters 54, in response to user authentication and adequate rights associated with the user, etc.

[0066] The device 50 may further comprise and/or be connected to further units, devices and systems, such as one or more sensor devices 58 sensing environment of the device 50 and/or joint position detection sensor device(s).

[0067] The processor 51, the memory 52, the communications unit 55 and the UI may be interconnected by electrical leads internal to the device 50 in a multitude of different ways. For example, each of the aforementioned devices may be separately connected to a master bus internal to the device, to allow for the devices to exchange information. However, as the skilled person will appreciate, this is only one example and depending on the embodiment various ways of interconnecting at least two of the aforementioned devices may be selected without departing from the scope of the present invention.

[0068] It is to be understood that the embodiments of the invention disclosed are not limited to the particular structures, process steps, or materials disclosed herein, but are extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

[0069] Reference throughout this specification to one embodiment or an embodiment means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Where reference is made to a numerical value using a term such as, for example, about or substantially, the exact numerical value is also disclosed.

[0070] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the preceding description, numerous specific details are provided, such as examples of lengths, widths, shapes, etc., to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that the invention can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or de-

scribed in detail to avoid obscuring aspects of the invention.

[0071] The verbs "to comprise" and "to include" are used in this document as open limitations that neither exclude nor require the existence of also un-recited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated. Furthermore, it is to be understood that the use of "a" or "an", that is, a singular form, throughout this document does not exclude a plurality.

[0072] While the forgoing examples are illustrative of the principles of the present invention in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications can be made without departing from the principles and concepts of the invention as defined by the claims set forth below.

Claims

1. A mobile underground drilling rig (1), comprising a carrier (2), at least one boom (3) attached at a first end to the carrier, and a drilling unit (4) attached to a second end of the boom, and control means configured for:

- receiving (300) target pose information indicative of at least target pose for the drilling unit in accordance with an input plan, **characterized in that** the control means are further configured for:
- detecting (310), during tramming of the drilling rig, carrier pose information indicative of orientation of the carrier,
- defining (320), during tramming of the drilling rig, orientation of the drilling unit on the basis of the detected carrier pose information, and
- generating (330) tramming assistance information on the basis of the target pose information and the defined orientation of the drilling unit.

2. The drilling rig of claim 1, wherein the drilling unit (4) comprises a rock drill (6) attached to a feed beam (5) rotatably connected to the boom (3), the input plan comprises a drilling plan comprising target positions and orientations for each hole in a set of holes to be drilled, and the target pose information is indicative of, or defined based on, a target orientation for the feed beam for drilling a hole in the set of holes.

3. The drilling rig of claim 1 or 2, wherein control means are configured to define deviation of the drilling unit (4) from the at least one target pose on the basis of the defined orientation of the drilling unit and the target pose information, and generate the tramming assistance information on the basis of the defined deviation of the orientation of the drilling unit from the at least one target pose.

4. The drilling rig of any preceding claim, wherein control means are configured for receiving information on orientation of the carrier (2) from a gyroscope comprised by the carrier and defining the orientation of the drilling unit (4) on the basis of the received information on orientation of the carrier and joint position information of a plurality of joints between the carrier and the drilling unit.

5. The drilling rig of any preceding claim, wherein the carrier (2) comprises a first carrier portion (2a) and a second carrier portion (2b) interconnected by a carrier joint (8), the carrier pose information is indicative of orientation of the first carrier portion, and the control means are configured to use information on position of the carrier joint as an input for defining the orientation of the drilling unit.

6. The drilling rig of any preceding claim, wherein the control means are configured for generating a graphical user interface view indicative of at least the orientation of the drilling unit and the at least one target pose, and displaying the graphical user interface view during the tramming of the drilling rig for assisting an operator to control the tramming of the drilling rig to a drilling position for carrying out a drilling operation according to a drilling plan.

7. The drilling rig of any preceding claim, wherein the generating (330) the tramming assistance information comprises defining a steering control instruction for autonomous steering operation or for guiding an operator to control steering of the drilling rig.

8. A method for controlling an underground drilling (1) rig comprising a carrier (2), at least one boom (3) attached at a first end to the carrier, and a drilling unit (4) attached to a second end of the boom, comprising:

- receiving (300) target pose information indicative of at least target pose for the drilling unit in accordance with an input plan, **characterized by** further comprising:

- detecting (310), during tramming of the drilling rig, carrier pose information indicative of orientation of the carrier,
- defining (320), during tramming of the drilling rig, orientation of the drilling unit on the basis of the detected carrier pose information, and
- generating (330) tramming assistance information on the basis of the target pose information and the defined orientation of the drilling unit.

9. The method of claim 8, wherein the drilling unit comprises a rock drill (6) attached to a feed beam (5) rotatably connected to the boom (3), the input plan comprises a drilling plan comprising target positions and orientations for each hole in a set of holes to be drilled, and the target pose information is indicative of, or defined based on, a target orientation for the feed beam for drilling a hole in the set of holes. 5

10. The method of any preceding claim, comprising defining deviation of the drilling unit (4) from the at least one target pose on the basis of the defined orientation of the drilling unit and the target pose information, and generating the tramming assistance information on the basis of the defined deviation of the orientation of the drilling unit from the at least one target pose. 10
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11. The method of any preceding claim, comprising receiving orientation of the carrier from a gyroscope comprised by the carrier (2) and defining the orientation of the drilling unit (4) on the basis of the received orientation of the carrier and joint position information of a plurality of joints between the carrier and the drilling unit. 20
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12. The method of any preceding claim, wherein the carrier (2) comprises a first carrier portion (2a) and a second carrier portion (2b) interconnected by a carrier joint (8), the carrier pose information is indicative of orientation of the first carrier portion, and information on position of the carrier joint is used as an input for defining the orientation of the drilling unit. 30

13. The method of any preceding claim, comprising: 35
generating a graphical user interface view indicative of at least the orientation of the drilling unit and the at least one target pose, and
displaying the graphical user interface view during the tramming of the drilling rig for assisting an operator to control the tramming of the drilling rig to a drilling position for carrying out a drilling operation according to a drilling plan. 40

14. The method of any preceding claim, wherein the generating the tramming assistance information comprises defining a steering control instruction for autonomous steering operation or for guiding an operator to control steering of the drilling rig. 45
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15. A computer program comprising code for, when executed in a data processing apparatus (50), to cause a method in accordance with any preceding claim 8 to 14 to be performed. 55

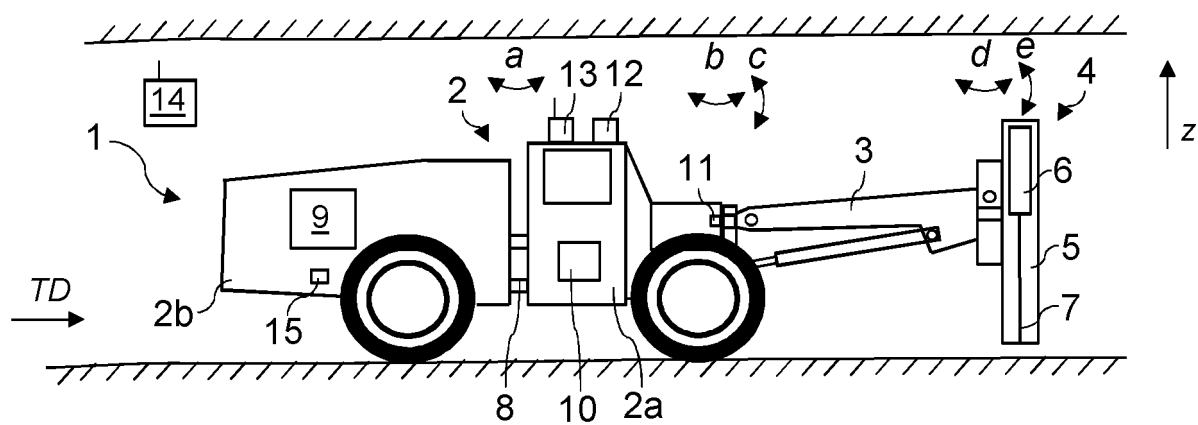


Fig. 1

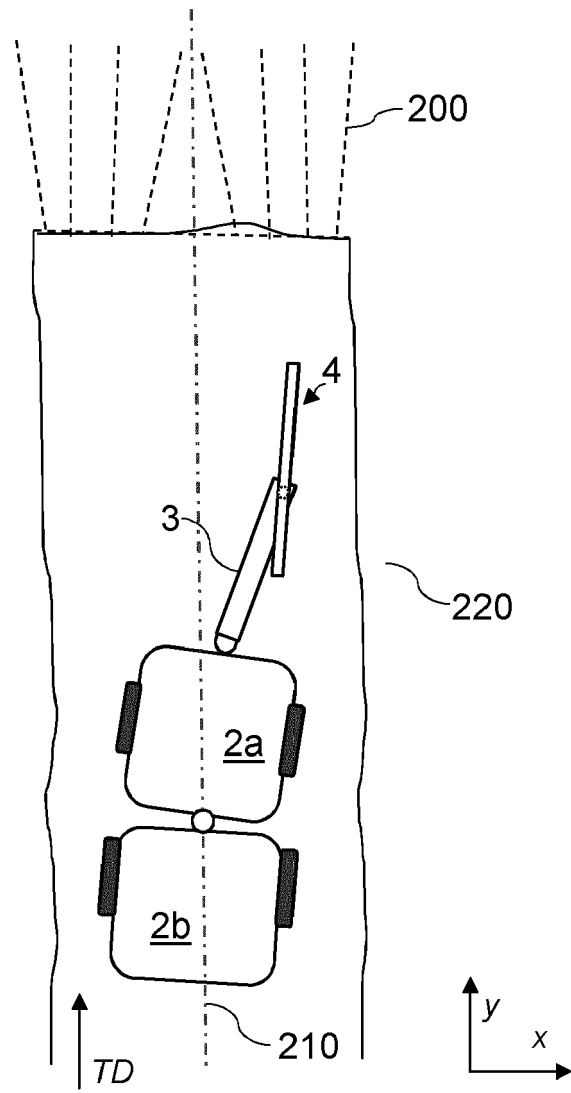


Fig. 2

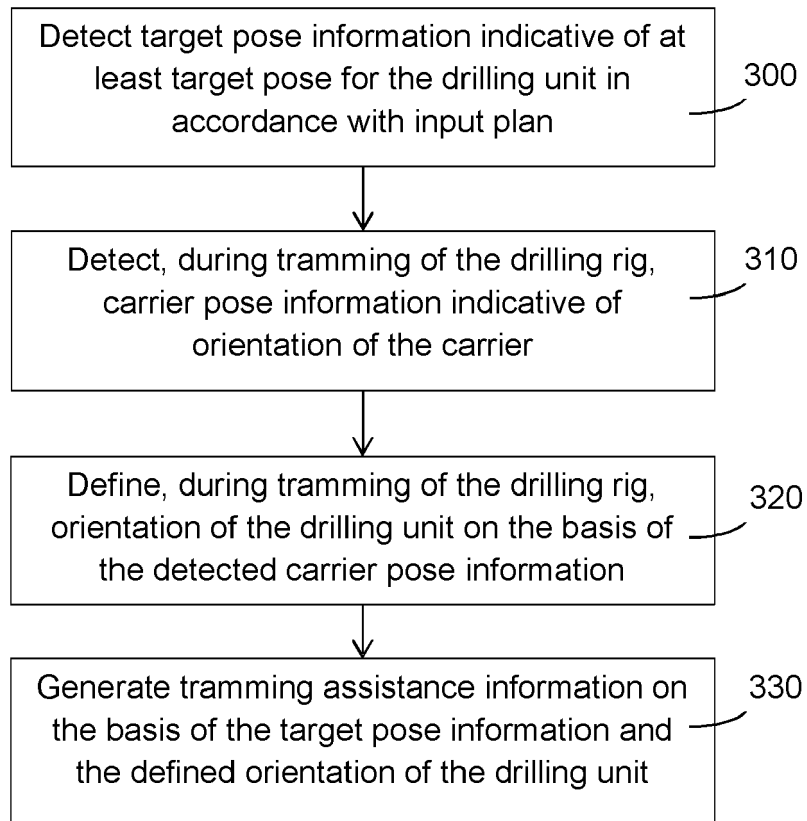


Fig. 3

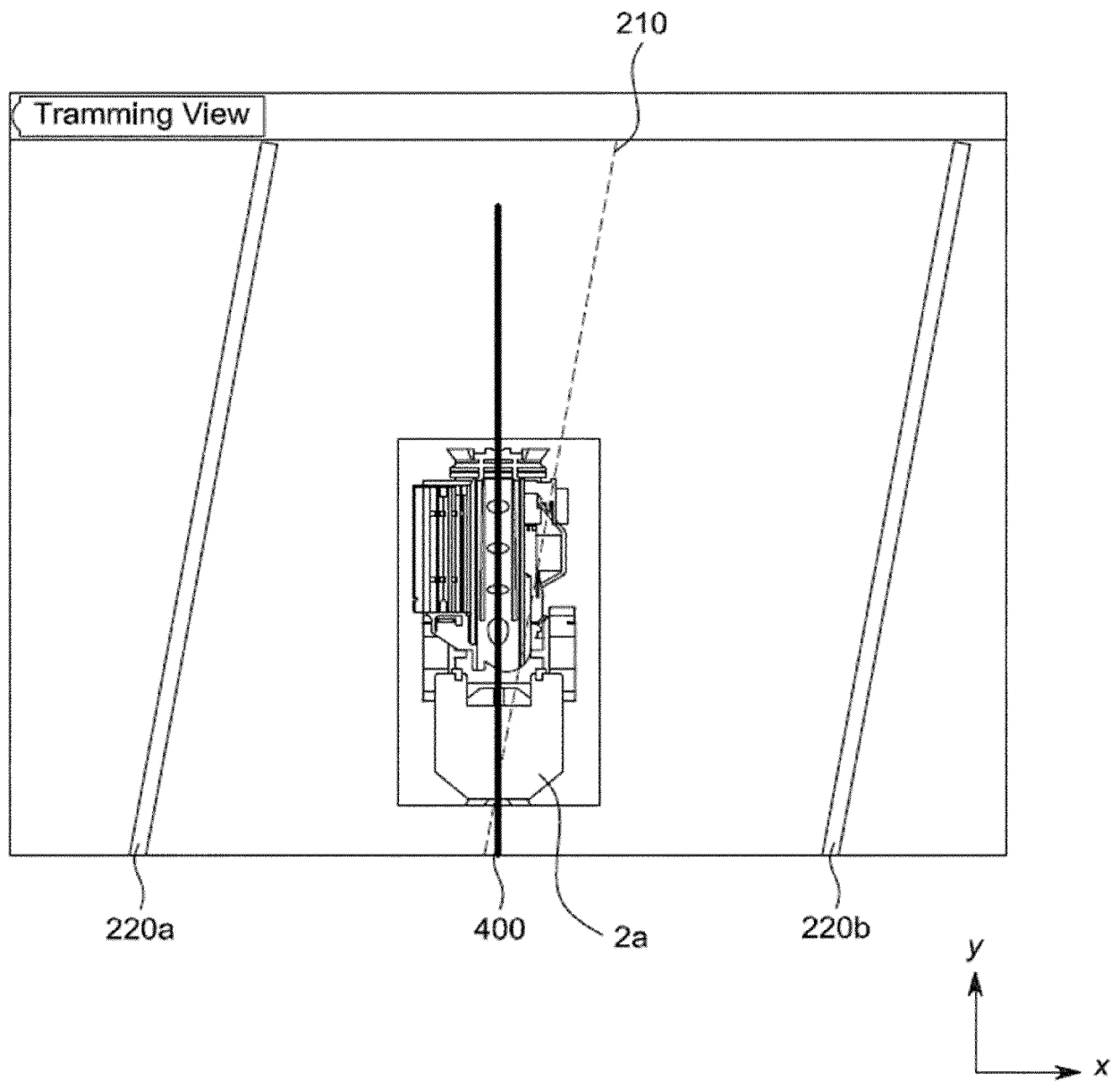


Fig. 4

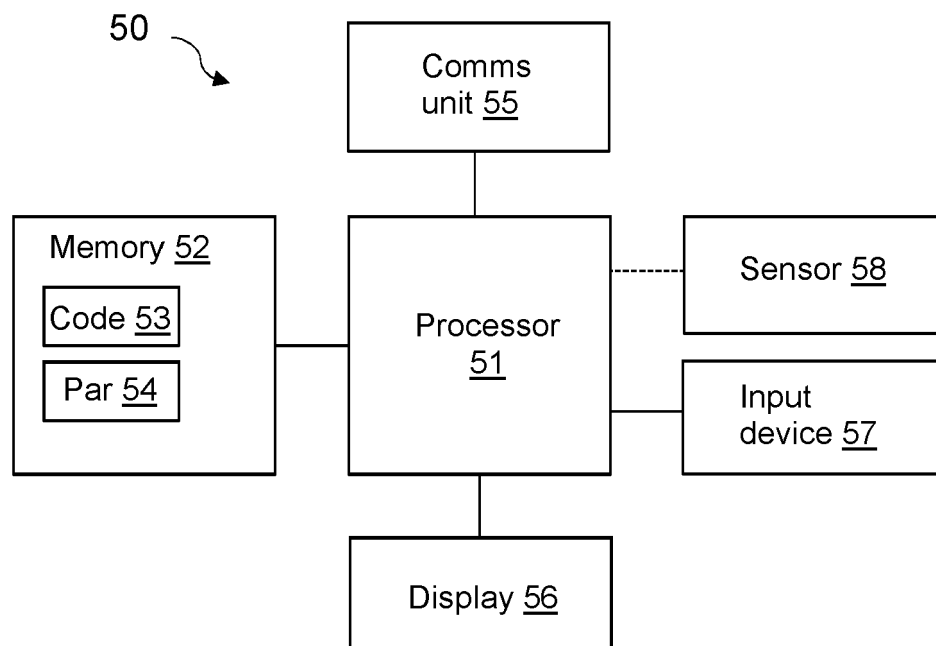


Fig. 5



EUROPEAN SEARCH REPORT

 Application Number
 EP 21 17 6165

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 25 November 2021	Examiner Rampelmann, Klaus
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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