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(54) DETERMINING POSITION FOR A BOLT OF A BOLT FAN

(57) Example embodiments related to controlling of a mobile bolter machine. An apparatus may comprise: at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to: obtain

scanning data of a rock surface; determine, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and determine a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

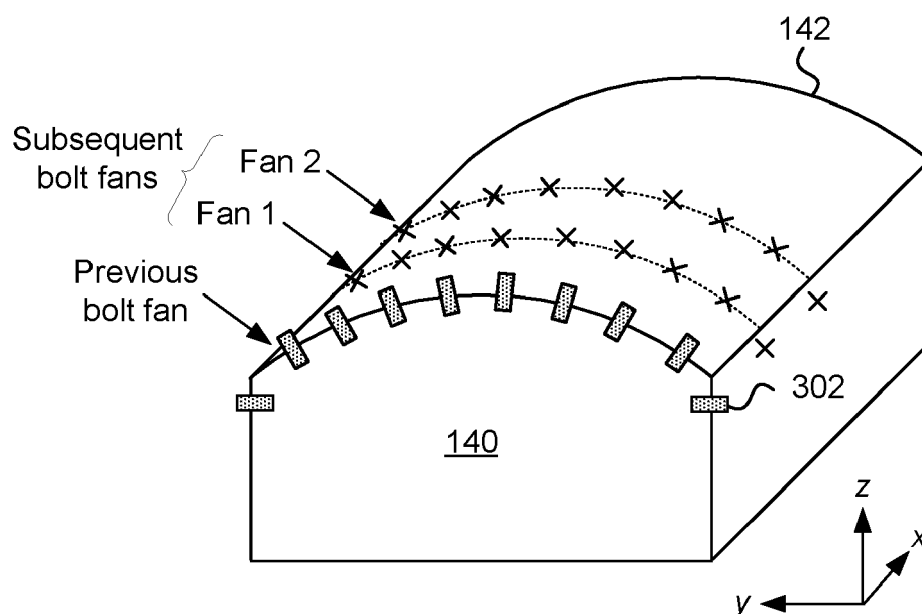


FIG. 3

Description

TECHNICAL FIELD

[0001] Various example embodiments generally relate to the field of bolting a rock surface. Some example embodiments relate to determining a position for installing a bolt based on position of at least one bolt of a previously installed bolt fan.

BACKGROUND

[0002] In various applications, such as for example underground mining, it may be desired to install bolts on a rock surface. A mobile bolter machine may comprise one or more booms with appropriate tools for drilling holes and installing bolts to the rock surface. Positions of the bolts may be determined on-site by a human operator sitting in the cabin of the mobile bolter machine.

SUMMARY

[0003] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

[0004] According to a first aspect, an apparatus for controlling a mobile bolter machine is disclosed. The apparatus may comprise: at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to: obtain scanning data of a rock surface; determine, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and determine a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

[0005] According to a second aspect, a mobile bolter machine is disclosed. The mobile bolter machine may comprise: at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the mobile bolter machine at least to: obtain scanning data of a rock surface; determine, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and determine a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

[0006] According to a third aspect, a method for controlling a mobile bolter machine is disclosed. The method may comprise: obtaining scanning data of a rock surface; determining, based on the scanning data, a position of at

least one bolt of a previous bolt fan on the rock surface; and determining a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

[0007] According to a fourth aspect, an apparatus for controlling a mobile bolter machine is disclosed. The apparatus may comprise: means for obtaining scanning data of a rock surface; means for determining, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and means for determining a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

[0008] According to a fifth aspect, a computer program, a computer program product, or a (non-transitory) computer-readable medium is disclosed. The computer program, computer program product, or (non-transitory) computer-readable medium may comprise program instructions which, when executed by an apparatus, cause the apparatus at least to: obtain scanning data of a rock surface; determine, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and determine a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

[0009] According to some aspects, there is provided the subject matter of the independent claims. Some further aspects are defined in the dependent claims. Many of the attendant features will be more readily appreciated as they become better understood by reference to the following description considered in connection with the accompanying drawings.

LIST OF DRAWINGS

[0010] The accompanying drawings, which are included to provide a further understanding of the example embodiments and constitute a part of this specification, illustrate example embodiments and, together with the description, help to explain the example embodiments. In the drawings:

FIG. 1 illustrates an example of a mobile bolter machine;

FIG. 2 illustrates an example of a mobile bolter machine communicatively coupled to a remote control device;

FIG. 3 illustrates an example of installed and planned bolt fans on a rock surface;

FIG. 4 illustrates an example of a top view of installed and planned bolt fans on a rock surface;

FIG. 5 illustrates an example of a method for determining bolt locations for subsequent bolt fan(s) based on a previous bolt fan;

FIG. 6 illustrates an example of bolt positions relative

to individual bolts of a previous bolt fan;

FIG. 7 illustrates an example of bolt positions relative to a line of a previous bolt fan;

FIG. 8 illustrates an example of an apparatus configured to practise one or more example embodiments; and

FIG. 9 illustrates an example of a method for controlling a mobile bolter machine.

[0011] Like references are used to designate like parts in the accompanying drawings.

DESCRIPTION

[0012] Reference will now be made to embodiments, examples of which are illustrated in the accompanying drawings. The description provided below in connection with the appended drawings is intended as a description of the present examples and is not intended to represent the only forms in which the present example may be constructed or utilized. The description sets forth the functions of the example and the sequence of steps for constructing and operating the example. However, the same or equivalent functions and sequences may be accomplished by different examples.

[0013] Bolting of a rock surface may be configured based on a reference bolting scheme comprising determination of bolt positions based on positions of previously installed bolts, or a systematic bolting scheme following a predetermined bolting plan. In either case, desired dimensions between bolts or bolt fans may be defined to ensure properly dense bolting of the rock surface. A bolting scheme may be also called a bolting plan. Examples of such dimensions include the distance between adjacent bolt fans and the distance between middle points or other points of adjacent bolts. Positions of previously installed bolts may be configured to be manually pointed by a boom, a drill bit, a normal laser, or other device. During navigation of a mobile bolter machine, positions of the next bolt fan may be shown on a user interface.

[0014] Example embodiments of the present disclosure improve accuracy and speed of bolting a rock surface. An apparatus may be configured to obtain scanning data of the rock surface and determine position(s) of bolt(s) of a previously installed bolt fan on the rock surface. The scanning data may be representative of the rock surface. Based on the determined bolt position(s), the apparatus may be configured to determine position(s) of bolt(s) of subsequent bolt fan(s) on the rock surface.

[0015] FIG. 1 illustrates an example of a mobile bolter machine. Even though mobile bolter machine 100 is illustrated as an underground mobile bolter machine, example embodiments of the present disclosure may be applied also to other type of mobile bolter machines, for example rigs configured for installing bolts on rock cuttings along roads or railways. Mobile bolter machine 100 may for example comprise a bolting drill rig, a rock

bolter drill rig, a roof bolter, a rock bolter, a mining bolter, a multifunction drill rig, a cable bolter, or the like.

[0016] Mobile bolter machine 100 may be an automated mobile bolter machine, for example an automated vehicle, e.g., a mining vehicle, equipped with tools configured for bolting. An automated vehicle, for example an automated mobile bolter machine, operating in an automatic mode may be configured to, for example, receive a task to be performed, perceive the environment of the automated vehicle, and autonomously perform the task while taking the environment into account. An automated vehicle operating in an automatic mode may be configured to operate independently but may be taken under external control at certain operation areas or conditions, such as during states of emergencies. Example embodiments of the present disclosure may be however applied also in non-autonomous or semiautonomous mobile bolter machines, for example remote-controlled mobile bolter machines.

[0017] In the example of FIG. 1, axis x represents the forward driving direction of mobile bolter machine 100. Axis z represents the vertical direction, in this example towards the roof of tunnel 140. Note that axis z may or may not be parallel to the vector of gravity depending on whether mobile bolter machine 100 is ascending or descending in tunnel 140. Mobile bolter machine 100 may comprise a movable carrier 110 and at least one boom 120 connected to movable carrier 110. Movable carrier 110 may comprise equipment for moving or stabilising mobile bolter machine 100, such as for example a motor, wheels, or stabilizer jacks (ground support). Movable carrier 110 may be configured to move autonomously or it may be configured to be controlled by a human operator, either remotely or locally at mobile bolter machine 100. Even though one boom 120 has been illustrated in FIG. 1, mobile bolter machine 100 may generally comprise one or a plurality (e.g., two, three, four,...) of booms 120. A bolter 124 may be coupled to a distal end portion of boom 120. Bolter 124 may be alternatively called a bolting head. Bolter 124 may be configured to drill holes and/or to install bolts at rock surface 142. Rock surface 142 may comprise the roof of tunnel 140 and/or at least some of the walls of tunnel 140. It is however noted that rock surface 142 may comprise any rock surface to be bolted. For example, rock surface 142 may be located outside tunnel 142.

[0018] Mobile bolter machine 100 may comprise at least one sensor(s) 112 for scanning environment of mobile bolter machine 100, for example, rock surface 142 and any bolts or bolt fans previously installed thereon. Sensor(s) 112 may include for example one or more of the following scanning devices: one or more cameras, one or more radio detection and ranging (radar) sensors, or one or more light detection and ranging (lidar) sensors. Sensor(s) 112 may therefore comprise a single sensor or group of two or more sensors. Sensor(s) 112 may be configured to scan rock surface 142, for example to detect particular features of rock surface 142 or asso-

ciated with rock surface 142, such as bolts. Scanning rock surface 142 may comprise scanning with sensor(s) 112 such that its sensing direction is towards rock surface 142. Scanning rock surface 142 does not necessarily include detecting features of rock surface 142. For example, scanning rock surface 142 may comprise pointing sensor(s) 112 towards rock surface 142 and detecting positions of bolts installed on rock surface 142.

[0019] A camera may be used to extract depth information of objects such as for example a bolt, for example by comparing two images taken at slightly different positions (e.g., by two camera units). Alternatively, sensor(s) 112 may comprise a time-of-flight (ToF) camera, which may be configured to determine a distance between the camera and an object, e.g., rock surface 142 or a bolt of a bolt fan, by measuring a round-trip time of an artificial light signal provided by a laser or a lightemitting diode (LED). A lidar sensor may be configured to determine a distance to an object by targeting the object with a laser and measuring the time for the reflected light to return to a receiver of the lidar sensor. A radar sensor may be configured to transmit electromagnetic energy towards rock surface 142 and to observe the echoes returned from the rock surface, or bolts installed thereon, to determine distances to rock surface 142 or the bolts. Based on the scanning, mobile bolter machine 100 may be configured to obtain point cloud data that represents the scanned environment. The point cloud data may for example comprise a three-dimensional (3D) model of rock surface 142, and/or a bolt fan or bolts installed thereon. Position of the bolt fan, e.g., individual bolts of the bolt fan, may be determined based on the scanning data, as will be further described below. The position of the bolt fan may be therefore fixed to, or known in relation to, a coordinate system of mobile bolter machine 100 (F_{machine}). The coordinate system of mobile bolter machine 100 may be stationary with respect to mobile bolter machine 100.

[0020] Mobile bolter machine 100 may be configured to scan rock surface 142 during movement or while being stationary with respect to rock surface 142. Scanning rock surface 142 during movement may speed up the bolting process, because bolting may be initiated soon after mobile bolter machine 100 has reached the planned position for installing the next bolts (bolting position), as will be further described below. Scanning of rock surface 142 may be implemented for example with a simultaneous localization and mapping (SLAM) system, which may be configured to scan environment of mobile bolter machine 100 to obtain the point cloud data of surrounding surfaces or objects. The obtained point cloud data may be used for object detection, but also for determining position of mobile bolter machine 100 based on comparing the scanning data to reference data, such as for example a 3D model of tunnel 140.

[0021] Mobile bolter machine 100 may comprise a controller (C) 114. Controller 114 may be communicatively coupled to sensor(s) 112, for example to receive

scanned sensor data from sensor(s) 112, or, to request sensor(s) 112 to initiate scanning of rock surface 142. Controller 114 may be for example provided as a software application residing on a memory and being executable by a processor. An example of an apparatus suitable for implementing controller 114 is provided in FIG. 8. Controller 114 may comprise, or be communicatively coupled to, various functions, blocks, or applications for implementing functionality of controller 114. For example, controller 114 may comprise or be communicatively coupled to a data management server, which may be configured to store information on a digital bolting plan, tunnel lines or profiles, a mine map point cloud, or the like. The digital bolting plan may comprise planned bolt positions or planned bolt fan positions. Controller 114 may comprise a navigation application configured to control, or enable a human operator to control, navigation of mobile bolter machine 100, for example to move it to the planned bolting position and/or to determine planned positions of bolts or bolt fans of the digital bolting plan relative to a current position of mobile bolter machine 100. Position of mobile bolter machine 100 may be referred to as a navigation position. A bolting position may be therefore a navigation position, which has been planned or determined for mobile bolter machine 100 to install bolt(s) at rock surface 142.

[0022] Controller 114 may be configured to determine and/or maintain the digital bolting plan, a 3D model of at least one component of mobile bolter machine 100 (e.g., a 3D model of boom(s) 120 or bolter 124), and/or a kinematic model of mobile bolter machine 100, or component(s) thereof. A 3D model of a component of mobile bolter machine 100 may comprise 3D geometry data of the component, obtained for example from a computer aided design (CAD) model of the respective physical component.

[0023] A kinematic model of mobile bolter machine 100, or component(s) thereof, may comprise a mathematical description of at least a part of mobile bolter machine 100. A kinematic model may describe motion of mobile bolter machine 100 or component(s) of mobile bolter machine 100 without taking into account the forces that cause the motion. The kinematic model may be used for estimating a position of mobile bolter machine 100 or component(s) of mobile bolter machine 100, for example based on measurement data from one or more sensors associated with mobile bolter machine 100 or motion of mobile bolter machine 100 caused by given control inputs. The kinematic model of mobile bolter machine 100 may comprise at least dimensions of mobile bolter machine 100 and/or reach of mobile bolter machine 100 such as a movement range of at least one boom 120 or bolter 124 of mobile bolter machine 100. The kinematic model may comprise information on dimensions of boom(s) 120, or parts thereof, for example bolter 124, characteristics of joint(s) 122 (e.g., their degrees of freedom), constraints between moving parts of mobile bolter machine 100, or the like. The kinematic model may thus

enable modelling movement of the component(s) of mobile bolter machine 100, for example to determine possible bolt positions for bolting from a particular bolting position. The kinematic model may for example enable determining a maximum distance reachable by bolter 124. The 3D model(s) of the component(s) may be provided as point cloud data indicative of the surface of the component(s). Point cloud data may comprise a plurality of data points representing, for example, distances between mobile bolter machine 100 and its component(s) or other objects in the environment of mobile bolter machine 100, for example at a particular time instance. An individual point included in a point cloud may be presented by, for example, x and y coordinates, or x, y, and z coordinates with respect to a particular coordinate frame.

[0024] Mobile bolter machine 100 may be controlled by a remote control device 200, which may be external to mobile bolter machine 100, as illustrated in FIG. 2. Remote control device 200 may be for example a server located remote from mobile bolter machine 100, for example outside tunnel 140. Functionality of controller 114 may be distributed between mobile bolter machine 100, for example a local controller of mobile bolter machine 100, and remote control device 200. Information may be exchanged between remote control device 200 and mobile bolter machine 100 over a communication interface including any suitable wireless or wired connection. Examples of suitable communication interfaces are described with reference to FIG. 8.

[0025] Controller 114 may be configured to determine and/or maintain the digital bolting plan. The digital bolting plan, the 3D model(s), or the kinematic model(s) of mobile bolter machine 100 may be stored at controller 114, for example based on pre-configuration of the models. Alternatively, controller 114 may be configured to receive the digital bolting plan or one or more of the models from mobile bolter machine 100 or the data management server. Controller 114 may also be configured to receive, for example from mobile bolter machine 100, the scanned sensor data of sensor(s) 112, which controller 114 may be configured to use for detecting bolt(s) installed on rock surface 142. Example embodiments of the present disclosure may be thus implemented locally by mobile bolter machine 100, by remote control device 200, or by a system comprising mobile bolter machine 100 and remote control device 200.

[0026] FIG. 3 illustrates an example of installed and planned bolt fans on a rock surface. A previous bolt fan may comprise bolts 302 installed on rock surface 142. The previous bolt fan may be located substantially on a plane perpendicular to driving direction (x) of mobile bolter machine 100. Controller 114 may be configured to determine position(s) for bolt(s) of subsequent bolt fan(s), for example a first subsequent bolt fan (Fan 1) and a second subsequent bolt fan (Fan 2). Each bolt fan may be associated with a position along the longitudinal direction of tunnel 140, in this example axis x.

[0027] Considering bolting at a particular point of axis

x, the bolt fans may be configured to be installed starting from the roof of tunnel 140, for example from the highest point of the roof, and moving down along rock surface 142 such that bolts located on walls of tunnel 140 are installed after bolts the roof of tunnel 140, or vice versa. A wall of tunnel 140 may comprise a portion of rock surface 142 for which the inclination with respect to axis z is below a threshold, for example less than 45°. A roof of tunnel 140 may comprise a portion of rock surface 142 for which the inclination with respect to axis z is above the threshold, for example greater than 45°.

[0028] The first subsequent bolt fan may be adjacent to the previous bolt fan in the driving direction (x) of mobile bolter machine 100. The second subsequent bolt fan may be adjacent to the first subsequent bolt fan in the driving direction (x) of mobile bolter machine 100. The first subsequent bolt fan may be therefore between the previous bolt fan and the second subsequent bolt fan. The first subsequent bolt fan may be adjacent to both the previous bolt fan and the second subsequent bolt fan. An adjacent bolt fan may refer to a bolt fan that is next to a particular bolt fan, either in the driving direction of mobile bolter machine, or the direction opposite to the driving direction.

[0029] Positions of subsequent bolt fan(s) may be initially defined in the digital bolting plan. Alternatively, controller 114 may be configured to determine positions for bolts of subsequent bolt fan(s) without the digital bolting plan indicating any initial positions for them. Controller 114 may be configured to determine, e.g., adjust, position(s) of bolt(s) of the subsequent bolt fan(s) based on the previous bolt fan. Even though two subsequent bolt fans are illustrated in FIG. 3, controller 114 may be configured to determine bolt positions for one or a plurality (e.g., two, three, four,...) of subsequent bolt fans.

[0030] An example of a top view of the previous ('o') and subsequent ('x') bolt fans is illustrated in FIG. 4. Controller 114 may be configured to determine the positions of the bolts of the previous bolt fan. Controller 114 may be further configured to determine a line of the previous bolt fan, as will be further described with reference to FIG. 5. It is noted that due to the potentially curved profile of the roof and/or walls of tunnel 140, the line may be a curved line on a plane, e.g., the plane perpendicular to the driving direction of mobile bolter machine 100 (yz-plane). Optionally, controller 114 may be configured to project positions of the bolts of the previous bolt fan to a plane, e.g., the xy-plane, and to determine the line of the previous bolt fan on this plane, resulting in a straight line.

[0031] FIG. 5 illustrates an example of a method for determining bolt locations for subsequent bolt fan(s) based on a previous bolt fan.

[0032] At operation 501, controller 114 may be configured to obtain a bolting plan, for example a digital bolting plan. Controller 114 may be configured to retrieve the bolting plan from a memory associated with controller 114, for example a memory of mobile control machine 100. Alternatively, controller 114 may be configured to receive the bolting plan, for example via a communication

interface (e.g., from a remote server) or user interface 810. The bolting plan may be configured to indicate planned relative positions of bolts and/or bolt fans, for example a planned distance between bolts of bolt fans adjacent to each other or a planned distance between bolt fans adjacent to each other. Adjacent bolts or adjacent bolt fans may refer to bolts or bolt fans that are adjacent to each other, for example in the driving direction of mobile bolter machine 100. The bolting plan may comprise any suitable format of digital data configured to indicate planned positions of bolts or bolt fans, for example in a coordinate frame stationary with respect to rock surface 142 (e.g., F_{tunnel}). Controller 114 may be configured to map the planned positions of the bolts or bolt fan(s) to its own coordinate system (F_{machine}). The bolting plan may be further configured to indicate a planned distance for adjacent bolts of the same bolt fan.

[0033] At operation 502, controller 114 may be configured to obtain scanning data of rock surface 142. The scanning data may comprise 3D scanning data of rock surface 142, obtained for example by sensor(s) 112. Controller 114 may be configured to control scanning of rock surface 142 to obtain the scanning data. Controller 114 may be configured to cause scanning of rock surface 142, for example by transmitting to sensor(s) 112 a request to initiate scanning.

[0034] Sensor(s) 112 may be positioned such that their sensor signal(s) are configured to be directed to rock surface 142, when mobile bolter machine 100 is operated near rock surface 142. Scanning data may comprise data captured by sensor(s) 112 during scanning of rock surface 142. Controller 114 may be configured to obtain the scanning data of rock surface 142, for example by receiving the scanning data from sensor(s) 112. Controller 114 may be however configured to process, for example select or filter, raw sensor data provided by sensor(s) 112 to obtain the scanning data.

[0035] It is noted that controller 114 may be configured to cause scanning of rock surface 142 when mobile bolter machine 100 is not located at the planned bolting position for installing the next bolt fan. For example, controller 114 may be configured to cause scanning of rock surface 142 before mobile bolter machine 100 arrives at the planned bolting position for installing the next bolt fan. Controller 114 may be configured to control scanning of rock surface 142 such that the scanning data is obtained while mobile bolter machine 100 is moving away from a previous bolting position. Controller 114 may be configured to determine the planned bolting position based on the scanning data, for example such that mobile bolter machine 100 is enabled to install one or more subsequent bolt fans, for example based on the kinematic model of mobile bolter machine 100.

[0036] For example, controller 114 may be configured to cause scanning of rock surface 142 to obtain the scanning data, in response to determining that mobile bolter machine 100 is located within a predetermined range from a planned bolting position, which may com-

prise a planned position for mobile bolter machine 100 (e.g., carrier 110) for bolting bolt(s) of subsequent bolt fan(s). This provides the benefit of faster bolting, because the scanning may be initiated already before arriving at the planned bolting location of mobile bolter machine 100. Note that controller 114 may be configured to post-process the scanning data to compensate for movement of mobile bolter machine 100 during or after scanning of rock surface 142.

[0037] At operation 503, controller 114 may be configured to detect a previous bolt fan installed on rock surface 142. Controller 114 may be configured to determine, based on the scanning data, position(s) of bolt(s) of the previous bolt fan on rock surface 142. Detecting bolt(s) of the previous fan may comprise detecting distinctive features of the bolt(s) in the scanning data (e.g., the point cloud data) such as for example protuberance of the bolt(s) from rock surface 142. Controller 114 may be configured to detect the bolt(s) of the previous bolt fan, for example based on applying any suitable computer vision or pattern recognition algorithm(s) on the scanning data. The position of the bolt(s) of the previous bolt fan may be determined in the coordinate frame of mobile bolter machine 100 (F_{machine}), which may be stationary with respect to mobile bolter machine 100 (e.g., carrier 110). Optionally, controller 114 may be configured to map the determined bolt position(s) to an external coordinate frame, for example to a coordinate frame stationary with respect to rock surface 142 (e.g., F_{tunnel}).

[0038] For example, controller 114 may be configured to initially provide information on the position of the bolts of the previous bolt fan with respect to the coordinate frame of mobile bolter machine 100 (F_{machine}). Controller 114 may be therefore configured to provide information on the position of the bolts of the previous bolt fan with respect to the position of mobile bolter machine 100 during the scanning by sensor(s) 112. Subsequently, after movement of mobile bolter machine 100, the positions of the bolts of the previous bolt fan may be updated at the coordinate frame of mobile bolter machine 100 such that their positions with respect to rock surface 142 remain stationary. It is also possible to perform the scanning at multiple positions of mobile bolter machine 100. As noted above, movement of mobile bolter machine 100 during or after the scanning may be compensated by controller 114.

[0039] At operation 504, controller 114 may be configured to determine position(s) for bolt(s) of subsequent bolt fan(s) on rock surface 142. Controller 114 may be configured to determine position(s) for bolt(s) of subsequent bolt fan(s) based on the position(s) of the bolt(s) of the previous bolt fan, as determined at operation 503.

[0040] As a first option, controller 114 may be configured to determine the position(s) for bolt(s) of the subsequent bolt fan(s) such that bolt(s) of the subsequent bolt fan(s) is/are configured to be positioned at a planned distance from respective adjacent bolt(s) of an adjacent

fan in a direction substantially perpendicular to the adjacent bolt fan. An example of this approach is provided in FIG. 6. Both FIG. 6 and FIG. 7 illustrate top views (towards floor of tunnel 140) of positions of already installed bolts of the previous bolt fan and planned bolt positions of two subsequent bolt fans.

[0041] For example, bolt 612 of the first subsequent bolt fan (Fan 1) may be configured to be positioned at the planned distance (d_x) from respective adjacent bolt 602 of the previous bolt fan. Bolt 624 of the second subsequent bolt fan (Fan 2) may be configured to be positioned at the planned distance (d_x) from respective adjacent bolt 614 of the first subsequent bolt fan, which is an adjacent bolt fan for the second subsequent bolt fan (Fan 2). Note that the planned distance may comprise the x-component of the distance between respective bolts of the adjacent bolt fans, e.g., the distance in the driving direction of mobile bolter machine 100. This distance may be substantially perpendicular to the previous bolt fan, or a plane defined by the previous bolt fan. For example, controller 114 may be configured to determine position of bolt 616 of the first subsequent bolt fan (Fan 1) such that the distance between a line passing through the planned location of bolt 616 in a direction (y) perpendicular to the driving direction (x) and a respective bolt 606 of the previous bolt fan is equal to the planned distance (d_x). This provides freedom in selecting positions for bolts of the subsequent bolt fans along the y-axis, while ensuring that bolts are installed at appropriate distances in the driving direction of mobile bolter machine 100.

[0042] As a second option, controller 114 may be configured to determine, based on the scanning data, a position of a line of the previous bolt fan. For example, controller 114 may be configured to fit a line to a set of points representing bolt positions of the previous bolt fan. Fitting the line may comprise averaging positions of the bolts of the previous bolt fan along the x-axis, or any other suitable line fitting method. The line of the previous bolt fan may be substantially perpendicular to the longitudinal direction of tunnel 140. During bolting the driving direction (x) of mobile bolter machine 100 may be substantially the same as the longitudinal direction of tunnel 140. Controller 114 may be further configured to determine, based on the position of the line of the previous bolt fan, locations for bolts of the subsequent bolt fan(s). An example of this approach is illustrated in FIG. 7. Note that the line may be a straight line or a curved line on a plane, in this example the yz-plane.

[0043] For example, bolt 712 of the first subsequent bolt fan (Fan 1) may be configured to be positioned at the planned distance (d_x) from the line of the previous bolt fan. An indication of the planned distance may be included in the bolting plan and it may be configured to indicate the planned distance between adjacent bolt fans. Bolt 724 of the second subsequent bolt fan (Fan 2) may be configured to be positioned at twice the planned distance ($2d_x$) from the line of the previous bolt fan, i.e., the previously installed bolt fan. In general,

controller 114 may be configured to determine positions of the bolts of subsequent bolt fans such that the bolts are at an integer multiple (e.g., $2d_x$, $3d_x$, $4d_x$) of the planned distance between from the previous bolt fan. In case of N subsequent bolt fans, controller 114 may be configured to determine positions of the bolts of the N subsequent bolt fans such that bolts of an n -th bolt fan are located at distance nd_x from the line of the previous bolt fan, where integer $n = 1 \dots N$. Determining positions of subsequent bolt fans based on the line of the previous bolt fan provides the benefit of more consistent bolting pattern, because drifting of bolt locations, e.g., due to deviations in individual bolt locations from the planned locations, may be avoided. Deviations in individual bolt locations might occur due to errors in installation or due to adjustment of bolt positions during the installation, for example to avoid installing a bolt in a steep recess of rock surface 142.

[0044] The planned distance to the line of the previous bolt fan may be again the x-component of the distance to the line, or in case of a curved line to the plane on which the line resides. Again, this provides freedom in selecting positions for bolts of the subsequent bolt fans along the y-axis, while ensuring that bolts are installed at appropriate distances in the driving direction of mobile bolter machine 100.

[0045] In case of both FIG. 6 and FIG. 7, controller 114 may be configured to determine the positions of the bolts of the subsequent bolt fans such that there's a predetermined distance (d_y), or at most this distance, between adjacent bolts of the same bolt fan. One or both of distances d_x and d_y may be indicated in the bolting plan.

[0046] Referring back to FIG. 5, at operation 505 controller 114 may be configured to output an indication of the determined positions of the bolt(s) of the subsequent bolt fan(s). When controller 114 is located at mobile bolter machine 100, controller 114 may be configured to provide the indication over an internal communication interface (e.g., a data bus) of mobile bolter machine 100, for example to another subsystem of mobile bolter machine 100. Alternatively, or additionally, controller 114 may be configured to transmit the indication, or cause transmission of the indication, over an external communication interface of mobile bolter machine 100, for example to remote control device 200. When controller 114 is located external to mobile bolter machine 100, e.g., at remote control device 200, controller 114 may be configured to transmit the indication to mobile bolter machine 100. Transmission of the indication over an internal or external communication interface is provided as an example of outputting the indication. Alternatively, controller 114 may be configured to output the indication within a computer to a software component of mobile bolter machine 100.

[0047] At operation 506, controller 114 may be configured to cause visualization of the determined position(s) of bolt(s) of the subsequent bolt fan(s). For example, controller 114 may be configured to transmit control instructions to a display of mobile bolter machine 100 to

visualize the determined bolt position(s), for example as an overlay on top of a 3D visualization of rock surface 142. This provides the benefit of enabling a human operator of mobile bolter machine 100, either remotely or at the cabin of mobile bolter machine 100, to control installation of the bolts in accordance with their determined positions.

[0048] At operation 507, controller 114 may be configured to control installation of bolts of the subsequent bolt fan(s) to rock surface 142. For example, controller 114 may be configured to control movement of boom 120, and operations of bolter 124, to cause installation of the subsequent bolt fan(s) at the determined bolt positions. Controller 114 may be configured to transmit control instructions to devices(s), e.g., actuators, configured to cause movement of boom 120 or operation(s) of bolter 124 (e.g., drilling or bolting).

[0049] Some operations of FIG. 5 may be optional and the operations may be also performed in different order, where appropriate. For example, controller 114 may be configured to obtain the bolting plan at any suitable time before determining the bolt position(s) for the subsequent bolt fan(s) (cf. operation 504). Controller 114 may be configured to perform one or more of operations 505 to 507, or terminate the method after operation 504.

[0050] FIG. 8 illustrates an example of an apparatus configured to practise one or more example embodiments. Apparatus 800 may be or comprise a control apparatus, such as for example a server, communicatively coupled to mobile bolter machine 100, a control apparatus located at mobile bolter machine 100, controller 114, mobile bolter machine 100 itself, or in general any apparatus or system configured to implement the functionality described herein. Although apparatus 800 is illustrated as a single device, it is appreciated that, where applicable, functions of apparatus 800 may be distributed to a plurality of physically separate apparatuses, for example mobile bolter machine 100 and remote control device 200.

[0051] Apparatus 800 may comprise at least one processor 802. The at least one processor 802 may comprise, for example, one or more of various processing devices, such as for example a co-processor, a micro-processor, a controller, a digital signal processor (DSP), a processing circuitry with or without an accompanying DSP, or various other processing devices including integrated circuits such as, for example, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a microcontroller unit (MCU), a hardware accelerator, a specialpurpose computer chip, or the like.

[0052] Apparatus 800 may further comprise at least one memory 804. The at least one memory 804 may be configured to store, for example, computer program code or the like, for example operating system software and application software. The at least one memory 804 may comprise one or more volatile memory devices, one or more non-volatile memory devices, and/or a combination

thereof. For example, the memory may be embodied as magnetic storage devices (such as hard disk drives, etc.), optical magnetic storage devices, or semiconductor memories (such as mask ROM, PROM (programmable ROM), EPROM (erasable PROM), flash ROM, RAM (random access memory), etc.). Memory 804 is provided as an example of a (non-transitory) computer readable medium. The term "non-transitory," as used herein, is a limitation of the medium itself (i.e., tangible, not a signal) as opposed to a limitation on data storage persistency (e.g., RAM vs. ROM). The at least one memory 804 may be also embodied separate from apparatus 800, for example as a computer readable (storage) medium, examples of which include memory sticks, compact discs (CD), or the like.

[0053] When apparatus 800 is configured to implement some functionality, some component and/or components of apparatus 800, such as for example the at least one processor 802 and/or the at least one memory 804, may be configured to implement this functionality. Furthermore, when the at least one processor 802 is configured to implement some functionality, this functionality may be implemented using program code 806 comprised, for example, in the at least one memory 804.

[0054] The functionality described herein may be performed, at least in part, by one or more computer program product components such as software components. According to an example embodiment, apparatus 800 comprises a processor or processor circuitry, such as for example a microcontroller, configured by the program code 806, when executed, to execute the embodiments of the operations and functionality described herein. Program code 806 is provided as an example of instructions which, when executed by the at least one processor 802, cause performance of apparatus 800.

[0055] For example, controller 114 may be at least partially implemented as program code 806 configured to cause apparatus 800 to perform functionality of controller 114. Similarly, transmission or reception of data (e.g., the bolting plan, indications of bolt positions, or control instructions) over an internal or external communication interface of mobile bolter machine 100 may be controlled by software.

[0056] Alternatively, or in addition, the functionality described herein can be performed, at least in part, by one or more hardware logic components. For example, and without limitation, illustrative types of hardware logic components that can be used include field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), application-specific standard products (ASSPs), system-on-a-chip systems (SOCs), complex programmable logic devices (CPLDs), graphics processing units (GPUs), neural processing unit (NPU), tensor processing unit (TPU), or the like.

[0057] Apparatus 800 may comprise a communication interface 808 configured to enable apparatus 800 to transmit and/or receive information. Communication interface 808 may comprise an internal or external com-

munication interface, such as for example a radio interface between mobile bolter machine 100 and remote control device 200. Apparatus 800 may further comprise other components and/or functions such as for example user interface 810 comprising at least one input device and/or at least one output device. The input device may take various forms such as a keyboard, a touch screen, or one or more embedded control buttons. The output device may for example comprise a display, a speaker, or the like. User interface 810 may enable a human operator to monitor various functions and data, such as for example determined bolt positions, positions of already installed bolts, or the like.

[0058] Apparatus 800 may be configured to perform or cause performance of any aspect of the method(s) described herein. Further, a computer program or a computer program product may comprise instructions for causing, when executed by apparatus 800, apparatus 800 to perform any aspect of the method(s) described herein. Further, apparatus 800 may comprise means for performing any aspect of the method(s) described herein. In one example, the means comprises the at least one processor 802, the at least one memory 804 including program code 806 (instructions) configured to, when executed by the at least one processor 802, cause apparatus 800 to perform the method(s). In general, computer program instructions may be executed on means providing generic processing functions. Such means may be embedded for example in a computer, a server, or the like. The method(s) may be thus computer-implemented, for example based algorithm(s) executable by the generic processing functions, an example of which is the at least one processor 802. Apparatus 800 may comprise means for transmitting or receiving information, for example one or more wired or wireless (e.g. radio) transmitters or receivers, which may be coupled or be configured to be coupled to one or more antennas, or transmitter(s) or receiver(s) of a wired communication interface.

[0059] According to a first aspect, apparatus 800 may be configured to control a mobile bolter machine. The apparatus may comprise: at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to: obtain scanning data of a rock surface; determine, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and determine a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

[0060] According to an example embodiment of the first aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to perform at least one of the following: outputting an indication of the determined position of the at least one bolt of the at least one subsequent bolt fan, causing visuali-

zation of the determined position of the at least one bolt of the at least one subsequent bolt fan on a display, or controlling bolting of the at least one bolt of the at least one subsequent bolt fan on the rock surface based on the determined position for the at least one bolt of the at least one subsequent bolt fan.

[0061] According to an example embodiment of the first aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: obtain a bolting plan indicative of a planned distance between bolts of adjacent bolt fans; and determine the position for the at least one bolt of the at least one subsequent bolt fan such that the at least one bolt of the at least one subsequent bolt fan is configured to be positioned at the planned distance from an adjacent bolt of an adjacent fan in a direction substantially perpendicular to the adjacent bolt fan.

[0062] According to an example embodiment of the first aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: determine, based on the scanning data, a position of a line of the previous bolt fan; and determine, based on the position of the line of the previous bolt fan, locations for bolts of the at least one subsequent bolt fan.

[0063] According to an example embodiment of the first aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: determine the line of the previous bolt fan based on line fitting of positions of bolts of the previous bolt fan on the rock surface.

[0064] According to an example embodiment of the first aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: obtain a bolting plan indicative of a planned distance between adjacent bolt fans; and determine positions for bolts of the at least one subsequent bolt fan such that the bolts of the at least one subsequent bolt fan are configured to be positioned at the planned distance or an integer multiple of the planned distance from the line of the previous bolt fan towards a direction substantially perpendicular to the previous bolt fan.

[0065] According to an example embodiment of the first aspect, the line of the previous bolt fan is substantially perpendicular to a longitudinal direction of a tunnel defining the rock surface.

[0066] According to an example embodiment of the first aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: cause scanning of the rock surface to obtain the scanning data, in response to determining that the mobile bolter machine is located within a predetermined range from a planned position for bolting the at least one subsequent bolt fan.

[0067] According to an example embodiment of the first aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: transmit, to at least one scanning device of the mobile bolter machine, a request to initiate scanning of the rock

surface to cause the scanning of the rock surface.

[0068] According to an example embodiment of the first aspect, the at least one scanning device of the mobile bolter machine comprises at least one camera, at least one radio detection and ranging sensor, or at least one light detection and ranging sensor.

[0069] According to an example embodiment of the first aspect, the scanning data comprises three-dimensional scanning data of the rock surface.

[0070] According to a second aspect, a mobile bolter machine comprises the apparatus according to any example embodiment of the first aspect. For example, the mobile bolter machine may comprise: at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the mobile bolter machine at least to: obtain scanning data of a rock surface; determine, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and determine a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

[0071] FIG. 9 illustrates an example of a method for controlling a mobile bolter machine, according to a third aspect of the present disclosure. The method may comprise a computer-implemented method performed by, for example, apparatus 800 such as controller 114.

[0072] At 901, the method may comprise obtaining scanning data of a rock surface.

[0073] At 902, the method may comprise determining, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface.

[0074] At 903, the method may comprise determining a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

[0075] According to an example embodiment of the third aspect, the method comprises at least one of the following: outputting an indication of the determined position of the at least one bolt of the at least one subsequent bolt fan, causing visualization of the determined position of the at least one bolt of the at least one subsequent bolt fan on a display, or controlling bolting of the at least one bolt of the at least one subsequent bolt fan on the rock surface based on the determined position for the at least one bolt of the at least one subsequent bolt fan.

[0076] According to an example embodiment of the third aspect, the method comprises: obtaining a bolting plan indicative of a planned distance between bolts of adjacent bolt fans; and determining the position for the at least one bolt of the at least one subsequent bolt fan such that the at least one bolt of the at least one subsequent bolt fan is configured to be positioned at the planned distance from an adjacent bolt of an adjacent fan in a direction substantially perpendicular to the adjacent bolt fan.

[0077] According to an example embodiment of the

third aspect, the method comprises: determining, based on the scanning data, a position of a line of the previous bolt fan; and determining, based on the position of the line of the previous bolt fan, locations for bolts of the at least one subsequent bolt fan.

[0078] According to an example embodiment of the third aspect, the method comprises: determining the line of the previous bolt fan based on line fitting of positions of bolts of the previous bolt fan on the rock surface.

[0079] According to an example embodiment of the third aspect, the method comprises: obtaining a bolting plan indicative of a planned distance between adjacent bolt fans; and determining positions for bolts of the at least one subsequent bolt fan such that the bolts of the at least one subsequent bolt fan are configured to be positioned at the planned distance or an integer multiple of the planned distance from the line of the previous bolt fan towards a direction substantially perpendicular to the previous bolt fan.

[0080] According to an example embodiment of the third aspect, the line of the previous bolt fan is substantially perpendicular to a longitudinal direction of a tunnel defining the rock surface.

[0081] According to an example embodiment of the third aspect, the method comprises: causing scanning of the rock surface to obtain the scanning data, in response to determining that the mobile bolter machine is located within a predetermined range from a planned position for bolting the at least one subsequent bolt fan.

[0082] According to an example embodiment of the third aspect, the method comprises: transmitting, to at least one scanning device of the mobile bolter machine, a request to initiate scanning of the rock surface to cause the scanning of the rock surface.

[0083] According to an example embodiment of the third aspect, the at least one scanning device of the mobile bolter machine comprises at least one camera, at least one radio detection and ranging sensor, or at least one light detection and ranging sensor.

[0084] According to an example embodiment of the third aspect, the scanning data comprises three-dimensional scanning data of the rock surface.

[0085] The method may be performed by controller 114, mobile bolter machine 100, or remote control device 200, for example based on program code 806, when executed by processor 802. Various examples of the methods are explained above with regard to functionalities of controller 114, mobile bolter machine 100, and/or remote control device 200, and are therefore not repeated here. It should be understood that example embodiments described may be combined in different ways unless explicitly disallowed.

[0086] According to a fourth aspect, an apparatus may comprise means for obtaining scanning data of a rock surface; means for determining, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and means for determining a position for at least one bolt of at least one subsequent bolt fan on the

rock surface based on the determined position of the at least one bolt of the previous bolt fan. The apparatus may comprise means for performing any example embodiment of the method of the third aspect.

[0087] According to a fifth aspect, a computer program, a computer program product, or a (non-transitory) computer-readable medium is disclosed. The computer program, computer program product, or (non-transitory) computer-readable medium may comprise program instructions which, when executed by an apparatus, cause the apparatus at least to: obtain scanning data of a rock surface; determine, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and determine a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan. The computer program, the computer program product, or the (non-transitory) computer-readable medium may comprise program instructions which, when executed by an apparatus, cause the apparatus to perform any example embodiment of the method of the third aspect.

[0088] Although the subject matter has been described in language specific to structural features and/or acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as examples of implementing the claims and other equivalent features and acts are intended to be within the scope of the claims.

[0089] It will be understood that the benefits and advantages described above may relate to one embodiment or may relate to several embodiments. The embodiments are not limited to those that solve any or all of the stated problems or those that have any or all of the stated benefits and advantages. It will further be understood that reference to 'an' item may refer to one or more of those items.

[0090] The steps or operations of the methods described herein may be carried out in any suitable order, or simultaneously where appropriate. Additionally, individual blocks may be deleted from any of the methods without departing from the scope of the subject matter described herein. Aspects of any of the example embodiments described above may be combined with aspects of any of the other example embodiments described to form further example embodiments without losing the effect sought.

[0091] The term 'comprising' is used herein to mean including the method, blocks, or elements identified, but that such blocks or elements do not comprise an exclusive list and a method or apparatus may contain additional blocks or elements.

[0092] As used herein, "at least one of the following: <a list of two or more elements>" and "at least one of <a list of two or more elements>" and similar wording, where the list of two or more elements are joined by "and" or "or",

mean at least any one of the elements, or at least any two or more of the elements, or at least all the elements. Term "or" may be understood to also cover a case where both of the items separated by "or" are included. Hence, "or" may be understood as an inclusive "or" rather than an exclusive "or".

[0093] Although subjects may be referred to as 'first' or 'second' subjects, this does not necessarily indicate any order or importance of the subjects. Instead, such attributes may be used solely for the purpose of making a difference between subjects.

[0094] It will be understood that the above description is given by way of example only and that various modifications may be made by those skilled in the art. The above specification, examples and data provide a complete description of the structure and use of exemplary embodiments. Although various embodiments have been described above with a certain degree of particularity, or with reference to one or more individual embodiments, those skilled in the art could make numerous alterations to the disclosed embodiments without departing from scope of this specification.

Claims

1. An apparatus for controlling a mobile bolter machine, the apparatus comprising:

at least one processor; and
at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to:

obtain scanning data of a rock surface;
determine, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and
determine a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.

2. The apparatus according to claim 1, wherein the at least one memory and the computer program are code further configured to, with the at least one processor, cause the apparatus to perform at least one of the following:

outputting an indication of the determined position of the at least one bolt of the at least one subsequent bolt fan,
causing visualization of the determined position of the at least one bolt of the at least one subsequent bolt fan on a display, or
controlling bolting of the at least one bolt of the at

- least one subsequent bolt fan on the rock surface based on the determined position for the at least one bolt of the at least one subsequent bolt fan.
3. The apparatus according to claim 1 or 2, wherein the at least one memory and the computer program are code further configured to, with the at least one processor, cause the apparatus to:
 - obtain a bolting plan indicative of a planned distance between bolts of adjacent bolt fans; and
 - determine the position for the at least one bolt of the at least one subsequent bolt fan such that the at least one bolt of the at least one subsequent bolt fan is configured to be positioned at the planned distance from an adjacent bolt of an adjacent bolt fan in a direction substantially perpendicular to the adjacent bolt fan.
 4. The apparatus according to claim 1 or 2, wherein the at least one memory and the computer program are code further configured to, with the at least one processor, cause the apparatus to:
 - determine, based on the scanning data, a position of a line of the previous bolt fan; and
 - determine, based on the position of the line of the previous bolt fan, locations for bolts of the at least one subsequent bolt fan.
 5. The apparatus according to claim 4, wherein the at least one memory and the computer program are code further configured to, with the at least one processor, cause the apparatus to:
 - determine the line of the previous bolt fan based on line fitting of positions of bolts of the previous bolt fan on the rock surface.
 6. The apparatus according to claim 4 or 5, wherein the at least one memory and the computer program are code further configured to, with the at least one processor, cause the apparatus to:
 - obtain a bolting plan indicative of a planned distance between adjacent bolt fans; and
 - determine positions for bolts of the at least one subsequent bolt fan such that the bolts of the at least one subsequent bolt fan are configured to be positioned at the planned distance or an integer multiple of the planned distance from the line of the previous bolt fan towards a direction substantially perpendicular to the previous bolt fan.
 7. The apparatus according to any of claims 4 to 6, wherein the line of the previous bolt fan is substantially perpendicular to a longitudinal direction of a tunnel defining the rock surface.
 8. The apparatus according to any of claims 1 to 7, wherein the at least one memory and the computer program are code further configured to, with the at least one processor, cause the apparatus to:
 - cause scanning of the rock surface to obtain the scanning data, in response to determining that the mobile bolter machine is located within a predetermined range from a planned position for bolting the at least one subsequent bolt fan.
 9. The apparatus according to claim 8, wherein the at least one memory and the computer program are code further configured to, with the at least one processor, cause the apparatus to:
 - transmit, to at least one scanning device of the mobile bolter machine, a request to initiate scanning of the rock surface to cause the scanning of the rock surface.
 10. The apparatus according to claim 9, wherein the at least one scanning device of the mobile bolter machine comprises at least one camera, at least one radio detection and ranging sensor, or at least one light detection and ranging sensor.
 11. The apparatus according to any of claims 1 to 10, wherein the scanning data comprises three-dimensional scanning data of the rock surface.
 12. A mobile bolter machine comprising the apparatus according to any of claims 1 to 11.
 13. A method for controlling a mobile bolter machine, the method comprising:
 - obtaining scanning data of a rock surface;
 - determining, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and
 - determining a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at least one bolt of the previous bolt fan.
 14. A computer program comprising instructions which, when executed by an apparatus, cause the apparatus at least to:
 - obtain scanning data of a rock surface;
 - determine, based on the scanning data, a position of at least one bolt of a previous bolt fan on the rock surface; and
 - determine a position for at least one bolt of at least one subsequent bolt fan on the rock surface based on the determined position of the at

least one bolt of the previous bolt fan.

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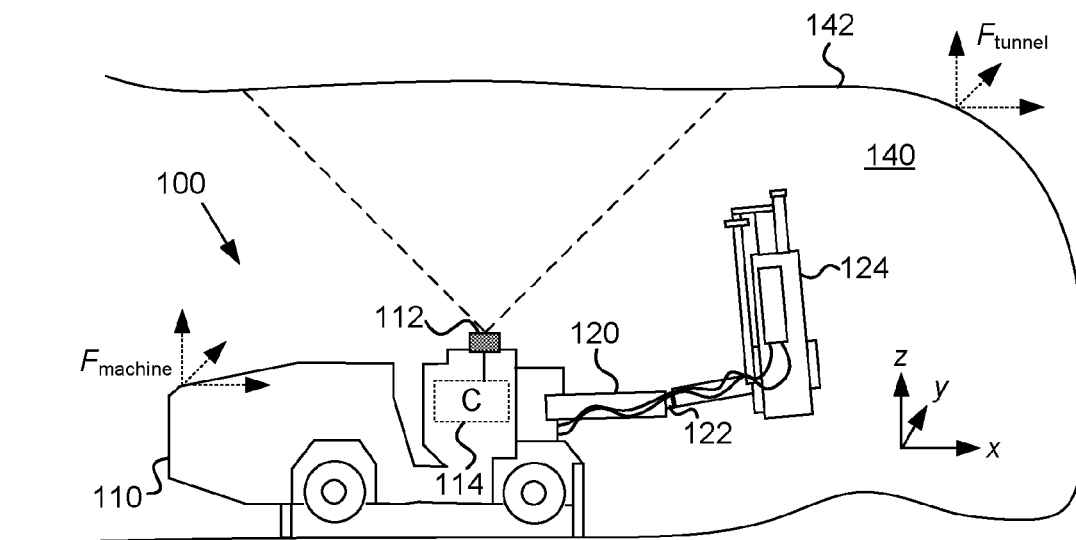


FIG. 1

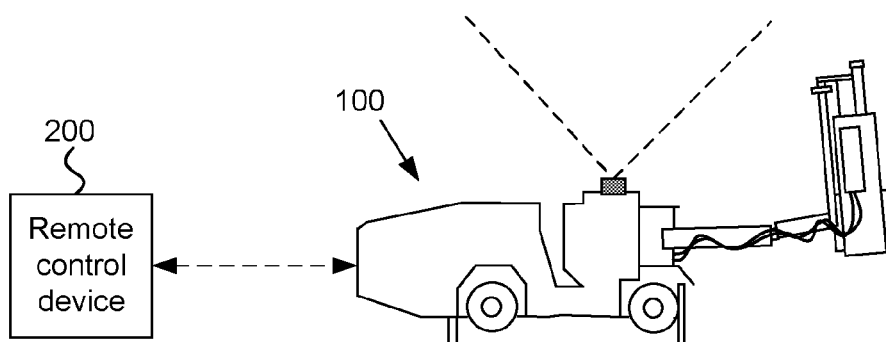


FIG. 2

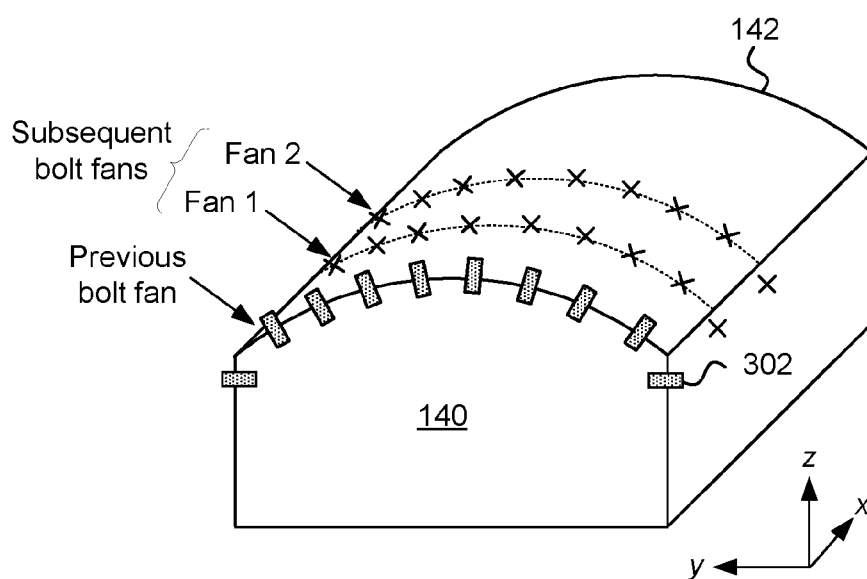


FIG. 3

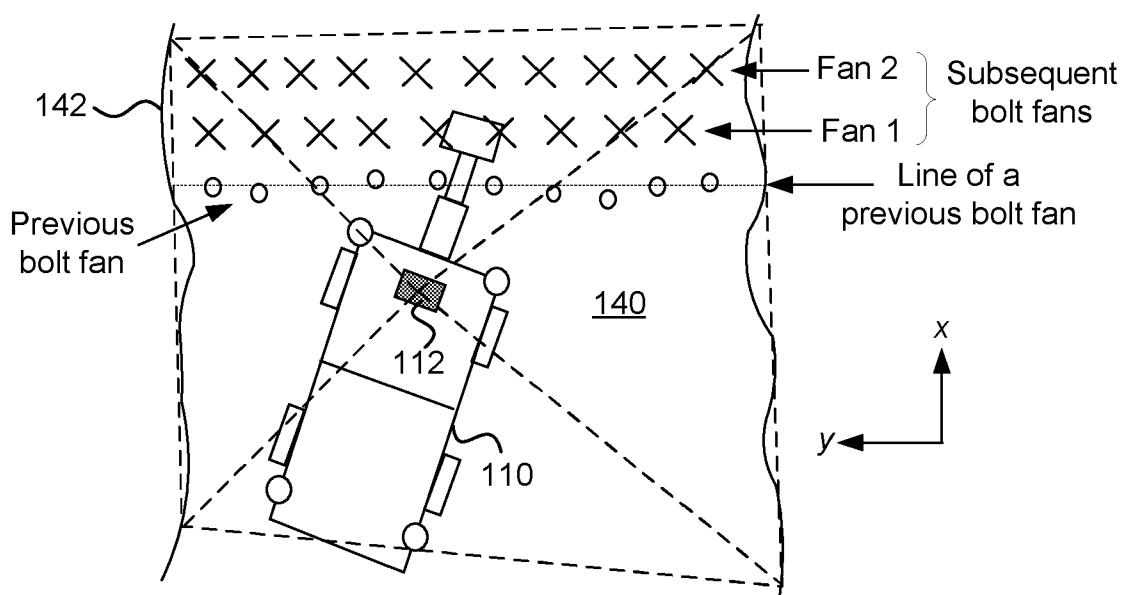


FIG. 4

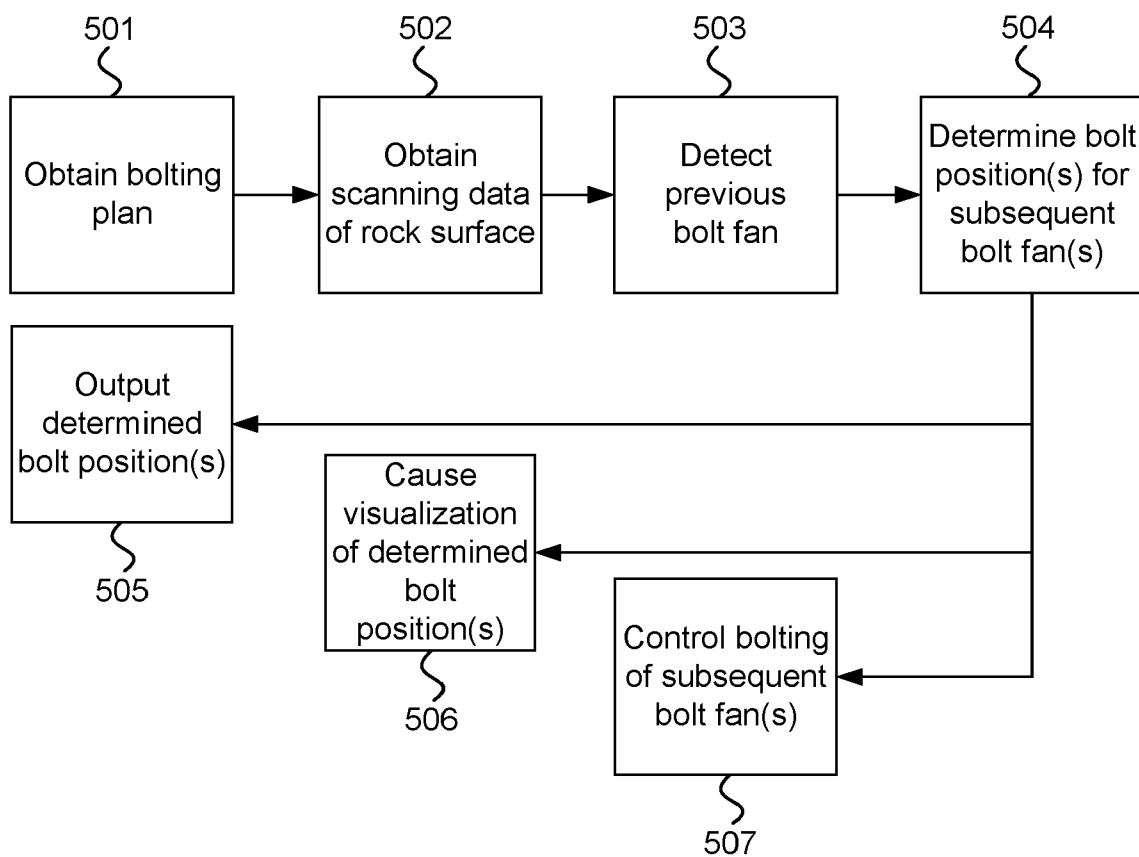


FIG. 5

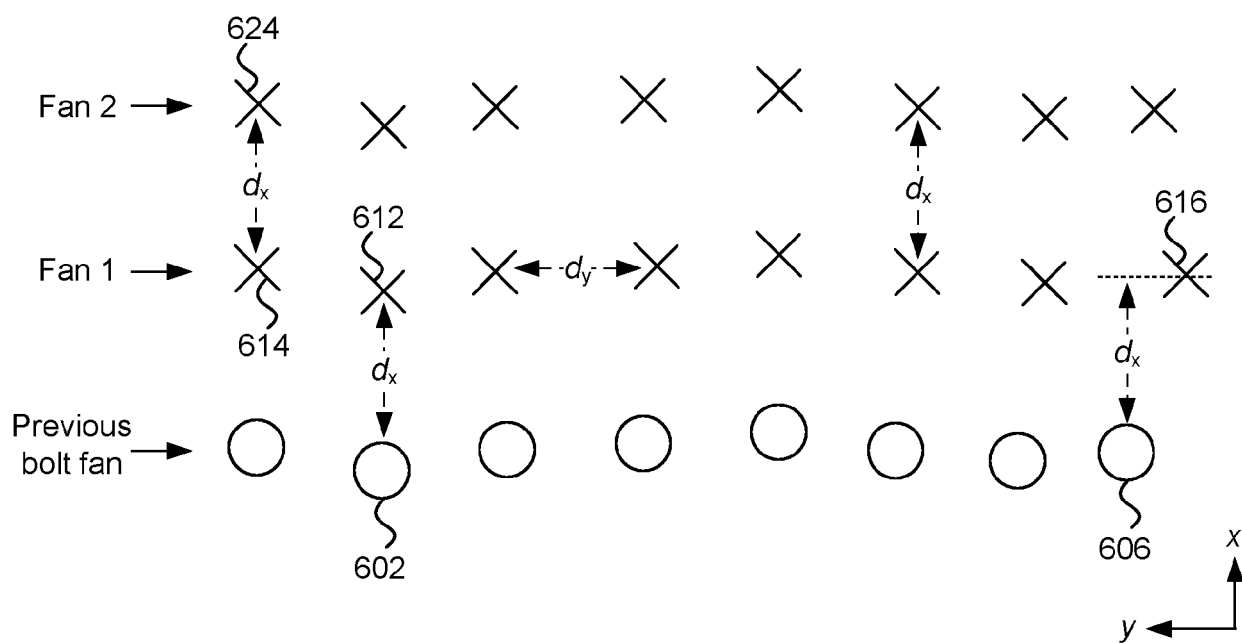


FIG. 6

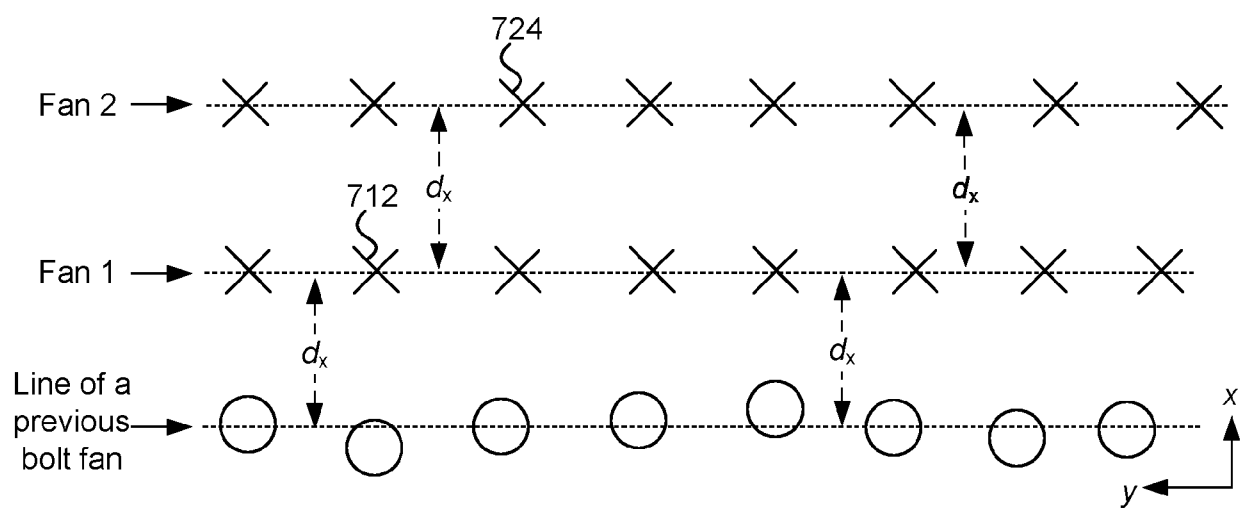


FIG. 7

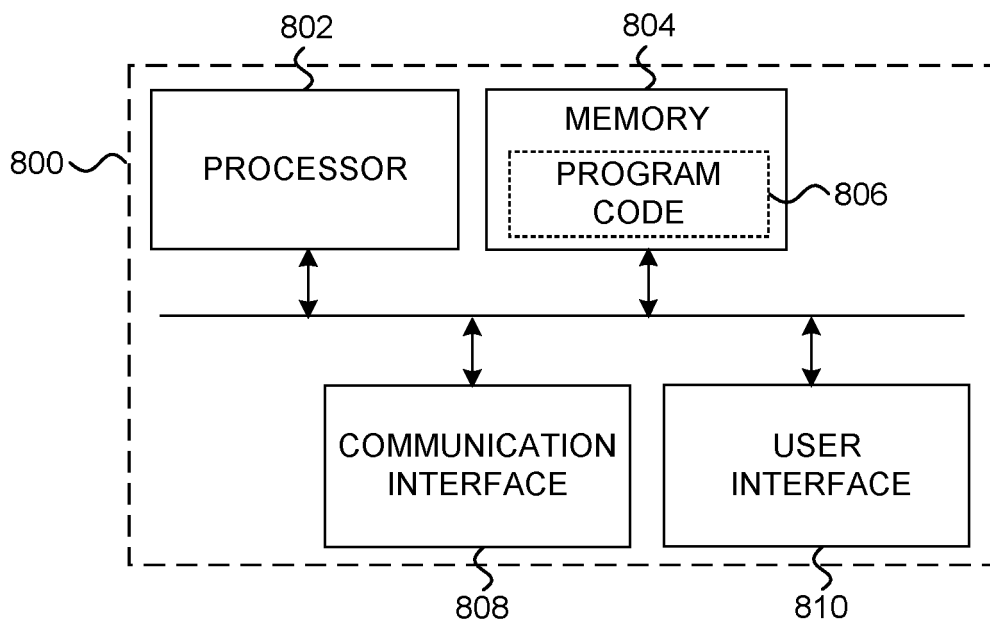


FIG. 8

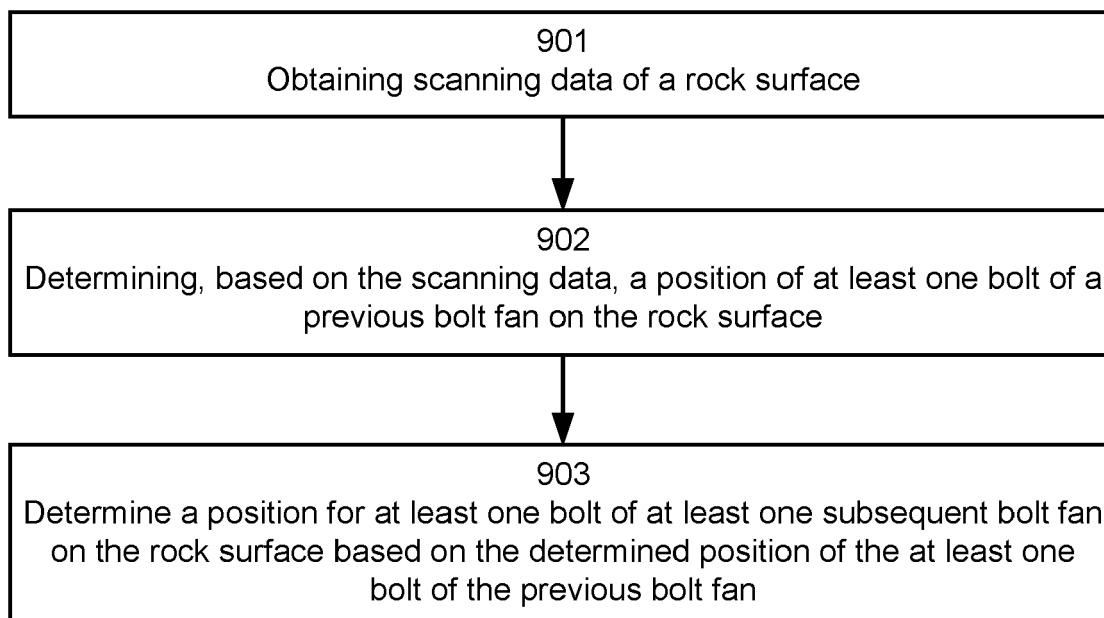


FIG. 9



EUROPEAN SEARCH REPORT

Application Number

EP 23 20 2167

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	US 2016/333690 A1 (PUURA JUSSI [FI] ET AL) 17 November 2016 (2016-11-17) * paragraph [0108] - paragraph [0110]; figures 2, 4-6, 12, 13 * * paragraph [0021]; claim 10 * -----	1-14	TECHNICAL FIELDS SEARCHED (IPC) E21D
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 20 March 2024	Examiner Dantinne, Patrick
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	

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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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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