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(54) CONTROLLING MESH INSTALLATION

(57) Example embodiments generally relate to the field of mesh installation on a rock surface. An apparatus may obtain scanning data of a rock surface (140) to detect at least one first mesh (404) installed on the rock surface and a second mesh (401, 402) positioned for being installed on the rock surface; determine, based on the scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap; and control mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

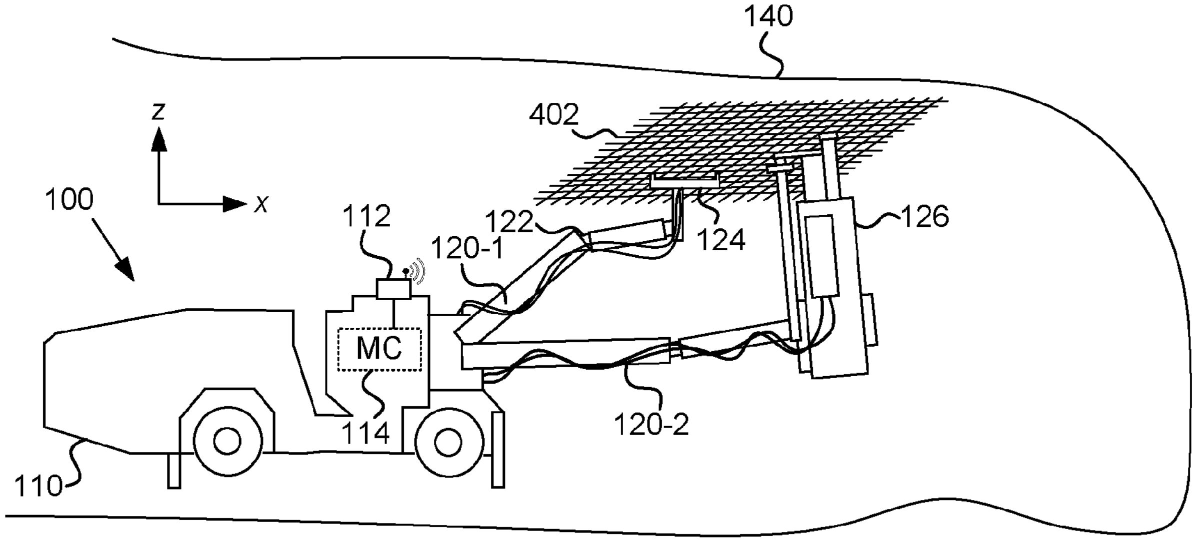

FIG. 1

EP 4 403 744 A1

Description

TECHNICAL FIELD

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

BACKGROUND

[0002] In various applications, such as for example underground mining, it may be desired to protect equipment or people from rocks falling from a rock surface. This may be done for example by installing protective meshes on the rock surface. A mesh installation rig may comprise one or more booms with appropriate tools for installing meshes to the rock surface. Positions of the meshes may be determined on-site by a human operator sitting in the cabin of the mesh installation rig.

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 mesh installation 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 to detect at least one first mesh installed on the rock surface; determine, based on the scanning data, a first position of the at least one first mesh; determine, a second position for installing a second mesh on the rock surface, wherein the at least one first mesh and the second mesh are configured to overlap at an edge of the at least one first mesh, when the second mesh has been installed on the rock surface at the second position; and control installation of the second mesh on the rock surface at the second position.

[0005] 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: control at least one boom to place the second mesh at the second position and to mount the second mesh to the rock surface at the second position.

[0006] 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: control a first boom to place the second mesh at the second position; and control a second boom to mount the second mesh to the rock surface at the second position.

[0007] According to an example embodiment of the first aspect, mounting of the second mesh to the rock surface comprises bolting the second mesh to the rock surface.

[0008] 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 first position of the at least one first mesh and a kinematic model of a mesh installation rig, an installation position for the mesh installation rig for installing the second mesh on the rock surface at the second position; control movement of the mesh installation rig to the installation position; update the first position of the at least one first mesh and the second position of the second mesh in a coordinate system of the mesh installation rig based on the movement to the installation position.

[0009] According to an example embodiment of the first aspect, the apparatus comprises the mesh installation rig.

[0010] According to an example embodiment of the first aspect, the apparatus is configured to obtain the scanning data from at least one of the following: a camera, a radio detection and ranging sensor, or a light detection and ranging sensor laser.

[0011] According to an example embodiment of the first aspect, at least two openings of the at least one first mesh and the second mesh are configured to overlap in a direction perpendicular to the edge of the at least one first mesh, when the second mesh has been installed on the rock surface at the second position.

[0012] According to an example embodiment of the first aspect, the first position comprises a position on a roof of a tunnel and the second position comprises a position on a wall on the tunnel.

[0013] According to a second aspect, a method for controlling mesh installation is disclosed. The method may comprise: obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock surface; determining, based on the scanning data, a first position of the at least one first mesh; determining, a second position for installing a second mesh on the rock surface, wherein the at least one first mesh and the second mesh are configured to overlap at an edge of the at least one first mesh, when the second mesh has been installed on the rock surface at the second position; and controlling installation of the second mesh on the rock surface at the second position.

[0014] According to an example embodiment of the second aspect, the method comprises: controlling at least one boom to place the second mesh at the second position and to mount the second mesh to the rock surface at the second position.

[0015] According to an example embodiment of the second aspect, the method comprises: controlling a first boom to place the second mesh at the second position; and controlling a second boom to mount the second mesh to the rock surface at the second position.

[0016] According to an example embodiment of the second aspect, mounting of the second mesh to the rock surface comprises bolting the second mesh to the rock surface.

[0017] According to an example embodiment of the second aspect, the method comprises: determining, based on the first position of the at least one first mesh and a kinematic model of a mesh installation rig, an installation position for the mesh installation rig for installing the second mesh on the rock surface at the second position; controlling movement of the mesh installation rig to the installation position; updating the first position of the at least one first mesh and the second position of the second mesh in a coordinate system of the mesh installation rig based on the movement to the installation position.

[0018] According to an example embodiment of the second aspect, the method is performed by the mesh installation rig.

[0019] According to an example embodiment of the second aspect, the method comprises: obtaining the scanning data from at least one of the following: a camera, a radio detection and ranging sensor, or a light detection and ranging sensor laser.

[0020] According to an example embodiment of the second aspect, at least two openings of the at least one first mesh and the second mesh are configured to overlap in a direction perpendicular to the edge of the at least one first mesh, when the second mesh has been installed on the rock surface at the second position.

[0021] According to an example embodiment of the second aspect, the first position comprises a position on a roof of a tunnel and the second position comprises a position on a wall on the tunnel.

[0022] According to a third aspect, an apparatus is disclosed. The apparatus may comprise means for performing a method according to the second aspect, or any example embodiment thereof.

[0023] According to a fourth aspect, a computer program or a computer program product is disclosed. The computer program or computer program product may comprise instructions, which when executed by an apparatus, cause the apparatus perform a method according to the second aspect, or any example embodiment thereof.

[0024] According to a fifth aspect, an apparatus for controlling mesh installation 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 to detect at least one first mesh installed on the rock surface and a second mesh positioned for being installed on the rock surface; determine, based on the scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap; and control mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

[0025] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: control adjustment of a position of the second mesh, in response to determining not to find a predetermined number of overlapping openings of the at least one first mesh and the second mesh.

[0026] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: obtain re-scanning data of the rock surface to detect the overlapping openings of the at least one first mesh and the second mesh, in response to the adjustment the position of the second mesh.

[0027] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: control at least one boom to position the second mesh for installing the second mesh to the rock surface and to mount the second mesh to the rock surface.

[0028] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: determine the at least one position where the openings of the at least one first mesh and the second mesh overlap based on searching for the overlapping openings of the at least one first mesh and the second mesh in proximity of at least one gripping position of a first boom configured to position the second mesh for installing the second mesh to the rock surface.

[0029] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: determine a plurality of positions where the openings of the at least one first mesh and the second mesh overlap; and control mounting of the second mesh to the rock surface at the plurality of positions via the overlapping openings of the at least one first mesh and the second mesh in an order of increasing distance from the at least one gripping position of the first boom configured to position the second mesh for being installed to the rock surface.

[0030] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: control a second boom to mount the second mesh to the rock surface.

[0031] According to an example embodiment of the fifth aspect, mounting of the second mesh to the rock surface comprises bolting the second mesh to the rock surface.

[0032] According to an example embodiment of the fifth aspect, the apparatus comprises a mesh installation rig.

[0033] According to an example embodiment of the fifth aspect, the apparatus is configured to obtain the scanning data or the re-scanning data from at least one of the following: a camera, a radio detection and ranging sensor, or a light detection and ranging sensor laser of the mesh installation rig.

[0034] According to an example embodiment of the fifth aspect, the first position comprises a position on a roof of a tunnel and the second position comprises a position on a wall on the tunnel.

[0035] According to a sixth aspect, a method for controlling mesh installation is disclosed. The method may comprise: obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock surface and a second mesh positioned for being installed on the rock surface; determining, based on the scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap; and controlling mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

[0036] According to an example embodiment of the sixth aspect, the method comprises: controlling adjustment of a position of the second mesh, in response to determining not to find a predetermined number of overlapping openings of the at least one first mesh and the second mesh.

[0037] According to an example embodiment of the sixth aspect, the method comprises: obtaining re-scanning data of the rock surface to detect the overlapping openings of the at least one first mesh and the second mesh, in response to the adjustment the position of the second mesh.

[0038] According to an example embodiment of the sixth aspect, the method comprises: controlling at least one boom to position the second mesh for installing the second mesh to the rock surface and to mount the second mesh to the rock surface.

[0039] According to an example embodiment of the sixth aspect, the method comprises: determining the at least one position where the openings of the at least one first mesh and the second mesh overlap based on searching for the overlapping openings of the at least one first mesh and the second mesh in proximity of at least one gripping position of a first boom configured to position the second mesh for installing the second mesh to the rock surface.

[0040] According to an example embodiment of the sixth aspect, the method comprises: determining a plurality of positions where the openings of the at least one first mesh and the second mesh overlap; and controlling mounting of the second mesh to the rock surface at the plurality of positions via the overlapping openings of the at least one first mesh and the second mesh in an order of increasing distance from the at least one gripping position of the first boom configured to position the second mesh for being installed to the rock surface.

[0041] According to an example embodiment of the sixth aspect, the method comprises: controlling a second boom to mount the second mesh to the rock surface.

[0042] According to an example embodiment of the sixth aspect, mounting of the second mesh to the rock surface comprises bolting the second mesh to the rock surface.

[0043] According to an example embodiment of the sixth aspect, the method is performed by a mesh installation rig.

[0044] According to an example embodiment of the sixth aspect, the method comprises: obtaining the scanning data or the re-scanning data from at least one of the following: a camera, a radio detection and ranging sensor, or a light detection and ranging sensor laser.

[0045] According to an example embodiment of the sixth aspect, the first position comprises a position on a roof of a tunnel and the second position comprises a position on a wall on the tunnel.

[0046] According to a seventh aspect, an apparatus is disclosed. The apparatus may comprise means for performing a method according to the sixth aspect, or any example embodiment thereof.

[0047] According to an eighth aspect, a computer program or a computer program product is disclosed. The computer program or computer program product may comprise instructions, which when executed by an apparatus, cause the apparatus perform a method according to the sixth aspect, or any example embodiment thereof.

[0048] According to a ninth aspect, an apparatus for controlling mesh installation 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 to detect at least one first mesh installed on the rock surface; determine, based on the scanning data, a first position of the at least one first mesh; determine, a second position for installing a second mesh on the rock surface, wherein the at least one first mesh and the second mesh are configured to overlap at an edge of the at least one first mesh, when the second mesh has been installed on the tunnel rock surface at the second position; obtain further scanning data of the rock surface to detect the at least one first mesh and the second mesh, when the second mesh is positioned for being installed on the rock surface; determine, based on the further scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap; and control mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

[0049] According to an example embodiment of the ninth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to perform any example embodiment of the method of the second aspect or the sixth aspect.

[0050] According to a tenth aspect, a method for controlling mesh installation is disclosed. The method may comprise: obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock surface; determining, based on the scanning data, a first position of the at least one first mesh; determining, a second position for installing a second mesh on the rock surface, wherein the at least one first mesh and the second mesh are configured to overlap at an edge of the at least one first mesh, when the second mesh has been installed on the tunnel rock surface at the second position; obtaining further scanning data of the rock surface to detect the at least one first mesh and the second mesh, when the second mesh is positioned for being installed on the rock surface; determining, based on the further scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap; and controlling mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

[0051] According to an example embodiment of the tenth aspect, the method may comprise features of any example embodiment of the method of the second aspect or the sixth aspect.

[0052] According to an eleventh aspect, an apparatus is disclosed. The apparatus may comprise means for performing a method according to the ninth aspect, or any example embodiment thereof.

[0053] According to a twelfth aspect, a computer program or a computer program product is disclosed. The computer program or computer program product may comprise instructions, which when executed by an apparatus, cause the apparatus perform a method according to the ninth aspect, or any example embodiment thereof.

[0054] According to a thirteenth aspect, a (non-transitory) computer readable medium is disclosed. The (non-transitory) computer readable medium may comprise program code that, when executed by an apparatus, cause the apparatus to perform a method according to the second, sixth, or ninth aspect, or any example thereof.

[0055] 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

[0056] 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 mesh installation rig;

FIG. 2 illustrates an example of a mesh installation rig communicatively coupled to a remote mesh control device;

FIG. 3 illustrates an example of a flow chart for controlling mesh installation;

FIG. 4 illustrates an example of overlapping meshes;

FIG. 5 illustrates an example of meshes installed on a tunnel surface based on a digital meshing plan;

FIG. 6 illustrates an example of a flow chart for controlling mesh installation via overlapping openings of first and second meshes;

FIG. 7 illustrates an example of first and second meshes with overlapping openings;

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

FIG. 9 illustrates an example of a method for controlling mesh installation;

FIG. 10 illustrates another example of a method for controlling mesh installation; and

FIG. 11 illustrates yet another example of a method for controlling mesh installation.

[0057] Like references are used to designate like parts in the accompanying drawings.

DESCRIPTION

[0058] 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.

[0059] FIG. 1 illustrates an example of mesh installation rig. Even though mesh installation rig 100 is illustrated as an underground mesh installation rig, example embodiments of the present disclosure may be applied also to other type of mesh installation machines, for example rigs configured for installing meshes on rock cuttings along roads or railways.

[0060] Mesh installation rig 100 may be an automated mesh installation rig, for example an automated mining vehicle equipped with tools configured for mesh installation. An automated mining vehicle, for example an automated mesh installation rig, operating in an automatic mode may be configured to, for example, receive a task to be performed, perceive the environment of the automated mining vehicle, and autonomously perform the task while taking the environment into account. An automated mining 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 may be however applied also in non-autonomous or semiautonomous mining vehicles, for example remote-controlled mining vehicles.

[0061] In the example of FIG. 1, axis x represents the forward driving direction of mesh installation rig 100. Axis z represents the vertical direction, in this example towards the roof of the tunnel. Mesh installation rig 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 mesh installation rig 100, such as for example a motor, wheels, or stabilizer jacks. Movable carrier 110 may be configured to move autonomously or it may be controlled by a human operator, either remotely or locally at mesh installation rig 100. Even though two booms 120-1, 120-2 have been illustrated in FIG. 1, mesh installation rig 100 may generally comprise one or a plurality (e.g., two, three, four,...) of booms 120. Boom 120-1 may be referred to as a first boom. Boom 120-2 may be referred to as a second boom.

[0062] A gripper 124 may be coupled to a distal end portion of boom 120-1. Gripper 124 may be configured to grab and hold mesh 402, for example to enable boom 120-1 to position mesh 402 at rock surface 140. Rock surface 140 may comprise the roof of the tunnel or at least some of the walls of the tunnel. A bolter 126 may be coupled to a distal end portion of boom 120-2. Bolter 126 may be configured to mount mesh 402 at rock surface 140. Bolting is provided as one example of mounting mesh 402 to rock surface 140, but other means for mounting, such as for example riveting, may be also used.

[0063] Mesh installation rig 100 may comprise at least one sensor 112 for scanning environment of mesh installation rig 100, for example, rock surface 140 and any meshes already installed thereon or positioned for being installed. Sensor 112 may include for example one or more of the following: a camera, a radio detection and ranging (radar) sensor, or a light detection and ranging (lidar) sensor. Sensor 112 may therefore comprise a group of two or more sensors. Sensor 112 may be configured to scan rock surface 140, for example to detect particular features, such as edge(s), of meshes. Scanning rock surface 140 may comprise scanning with sensor 112 such that its sensing direction is towards rock surface 140. Scanning rock surface 140 does not necessarily include detecting features of rock surface 140. For example, scanning rock surface 140 may comprise pointing sensor 112 towards rock surface 140 and detecting meshes installed on rock surface 140 or positioned close rock surface 140.

[0064] A camera may be used to extract depth information of objects such as for example a mesh, for example by comparing two images taken at slightly different positions (e.g., by two camera units). Alternatively, sensor 112 may comprise a time-of-flight (ToF) camera, which may be configured to determine a distance between the camera and points of the mesh by measuring a round-trip time of an artificial light signal provided by a laser or a light-emitting diode (LED). A lidar sensor may be configured to determine a distance to different points of the mesh by targeting the mesh 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 face and to observe the echoes returned from the mesh to determine distances to different points of the mesh. Based on scanning, mesh installation rig 100 may obtain point cloud data that represents the scanned environment. The point cloud data may for example comprise three-dimensional (3D) model of a detected mesh, or at least certain features such as edge(s) of the mesh. A position of the mesh, or certain points such as corners or edges of the mesh, may be determined based on the scanning data. The position of the mesh may be therefore fixed to, or known in relation to, a coordinate system of mesh installation rig 100. The coordinate system of mesh installation rig 100 may be stationary with respect to mesh installation rig 100.

[0065] Mesh installation rig 100 may be configured to scan rock surface 140 during movement or while being stationary. Scanning rock surface 140 during movement may speed up the mesh installation process, because mesh installation may be initiated soon after mesh installation rig has reached the planned position (installation position) for installing the next mesh, as will be further described below. Scanning of rock surface 140 may be implemented for example with a simultaneous localization and mapping (SLAM) system, which may be configured to scan environment of mesh installation rig 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 mesh installation rig 100 based on comparing the scanning data to reference data, such as for example a 3D model of a tunnel.

[0066] Mesh installation rig 100 may comprise a mesh controller (MC) 114. Mesh controller 114 may be communicatively coupled to sensor 112, for example to receive scanned sensor data from sensor 112, or, to request sensor 112 to initiate scanning of rock surface 140. Mesh 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 mesh controller 114 is provided in FIG. 8. Mesh controller 114 may comprise, or be communicatively coupled to, various functions, blocks, or applications for implementing functionality of mesh controller 114. For example, mesh controller 114 may comprise or be communicatively coupled to a data management server, which may be configured to store information on a digital meshing plan, tunnel lines, point cloud or mesh presentations of tunnel lines or profiles, a mine map point cloud, or the like. The digital meshing plan may comprise planned mesh positions and optionally also planned mounting positions. A mounting position may comprise a position at which a mesh is mounted on rock surface 140 by mounting means such as for example a bolt or a rivet. A planned mounting position may comprise a planned position for the mounting means at rock surface 140. Mesh controller 114 may comprise a navigation application configured to control, or enable a human operator to control, navigation of mesh installation rig 100, for example to move it to the planned installation position and/or to determine positions of planned mounting points of the digital meshing plan relative to a current position of mesh installation rig 100. Position of mesh installation rig 100 may be referred to as a navigation position. An installation position may be therefore a navigation position, which has been planned or determined for mesh installation rig 100 to install a mesh at rock surface 140.

[0067] Mesh controller 114 may be configured to determine and/or maintain the digital meshing plan, a 3D model of at least one component of mesh installation rig 100 (e.g., a 3D model of boom(s) 120, gripper 124 or bolter 126), and/or a kinematic model of mesh installation rig 100, or component(s) thereof. A 3D model of a component of mesh installation rig 100 may comprise 3D geometry data of the component, obtained for example from a computer aided design (CAD) model of the respective physical component.

[0068] A kinematic model of mesh installation rig 100, or component(s) thereof, may comprise a mathematical description of at least a part of mesh installation rig 100. A kinematic model may describe motion of mesh installation rig 100 or component(s) of mesh installation rig 100 without taking into account the forces that cause the motion. The kinematic model may be used for estimating a position of mesh installation rig 100 or component(s) of mesh installation rig 100, for example based on measurement data from one or more sensors associated with mesh installation rig 100 or motion of mesh installation rig 100 caused by given control inputs. The kinematic model of mesh installation rig 100 may comprise at least dimensions of mesh installation rig 100 and/or reach of mesh installation rig 100 such as a movement range of at least one boom 120 of mesh installation rig 100. The kinematic model may comprise information on dimensions of boom(s) 120, or parts thereof, for example gripper 124 or bolter 126, characteristics of joint(s) 122 (e.g. their degrees of freedom), constraints between moving parts of mesh installation rig 100, or the like. The kinematic model may thus enable modelling movement of the component(s) of mesh installation rig 100, for example to determine possible positions for installing mesh 402 from a particular installation position. The kinematic model may for example enable determining a maximum distance reachable by gripper 124 or bolter 126. 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 mesh installation rig 100 and its component(s) or other objects in the environment of mesh installation rig 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.

[0069] Mesh installation rig 100 may be controlled by a remote mesh control device 200, which may be external to mesh installation rig 100, as illustrated in FIG. 2. Remote mesh control device 200 may be for example a server located remote from mesh installation rig 100, for example outside the tunnel. Functionality of mesh controller 114 may be distributed between mesh installation rig 100, for example a local mesh controller of mesh installation rig 100, and remote mesh control device 200. Information may be exchanged between remote mesh control device 200 and mesh installation rig 100 over a communication interface including any suitable wireless or wired connection. Examples of suitable communication interfaces are described with reference to FIG. 8.

[0070] Mesh controller 114 may be configured to determine and/or maintain the digital meshing plan. The 3D and kinematic model(s) of mesh installation rig 100 may be stored at mesh controller 114, for example based on pre-configuration of the models. Alternatively, mesh controller 114 may be configured to receive one or more of the models from mesh installation rig 100 or the data management server. Mesh controller 114 may also be configured to receive, for example from mesh installation rig 100, the scanned sensor data of sensor 112, which mesh controller 114 may be configured to use for detecting mesh(es) installed on rock surface 140 or located near rock surface 140. Example embodiments of the present disclosure may be thus implemented locally at mesh installation rig 100 and/or at remote mesh control device 200.

[0071] FIG. 3 illustrates an example of a flow chart for controlling mesh installation.

[0072] At operation 301, mesh controller 114 may be configured to control scanning of rock surface 140. Mesh controller 114 may be configured to cause scanning of rock surface 140, for example by requesting sensor 112 to initiate scanning. Sensor(s) 112 may be positioned such that their sensor signal(s) are configured to be directed to rock surface 140, when mesh installation rig 100 is operated near rock surface 140. Scanning data may comprise data captured by sensor 112 during scanning of rock surface 140. Mesh controller 114 may be configured to obtain the scanning data of rock surface 140, for example by receiving the scanning data from sensor 112. Mesh controller 114 may be however configured to process, for example select or filter, raw sensor data provided by sensor 112 to obtain the scanning data. It is noted that mesh controller 114 may be configured to cause scanning of rock surface 140 when mesh installation rig 100 is not located at the installation position for installing the next mesh. For example, mesh controller 114 may be configured to cause scanning of rock surface 140 before mesh installation rig 100 arrives at the installation position for installing the next mesh. Mesh controller 114 may be configured to determine the installation position based on the scanning data, which may be obtained for example while mesh installation rig is moving away from a previous installation location.

[0073] At operation 302, mesh controller 114 may be configured to detect a mesh installed on rock surface 140. This mesh may be referred to as a first mesh. More than one first mesh may be detected. Mesh controller 114 may be therefore configured to detect one or a plurality of first meshes already installed on rock surface 140. Detecting the first mesh may comprise detecting distinctive features of the first mesh, such as for example edge(s) and/or corner(s) of the first mesh. Mesh controller 114 may be configured to detect the first mesh, or features thereof, for example based on applying computer vision or pattern recognition algorithms on the scanning data, for example sensor data received from sensor 112.

[0074] At operation 303, mesh controller 114 may be configured to determine a position of the first mesh based on the scanning data. This position may be referred to as a first position. Mesh controller 114 may be configured to indicate the position of the first mesh by position(s) of distinctive feature(s) of the first mesh, for example edge(s) and/or corner(s) of the first mesh. For example, mesh controller 114 may be configured to determine data (e.g., point could data) indicative of a position of an edge, for example an outer edge, or corner(s) of the first mesh. An outer edge may refer to an edge that is not yet located next to other meshes installed on rock surface 140. It may for example comprise an edge towards the forward driving direction (x) of mesh installation rig 100.

[0075] Mesh controller 114 may be configured to initially provide information on the position of the first mesh with respect to the coordinate frame of mesh installation rig 100. Mesh controller 114 may be therefore configured to provide information on the position of the first mesh with respect to the location of mesh installation rig 100 during the scanning by sensor 112. Subsequently, after movement of mesh installation rig 100, the position of the first mesh may be updated at the coordinate frame of mesh installation rig 100 such that its position with respect to rock surface 140 remains stationary (cf. operation 306). It is also possible to perform the scanning at multiple positions. Movement of mesh installation rig 100 during the scanning may be compensated, if necessary. Alternatively, mesh installation rig 110 may be configured to provide the information on the position of the first mesh with respect to a stationary reference coordinate frame, such as for example a coordinate frame stationary with respect to rock surface 140.

[0076] At operation 304 mesh controller 114 may be configured to determine an installation position for mesh installation rig 100, in order to install a next mesh. The next mesh subject to installation may be referred to as a second mesh. Installation position may refer to a position of mesh installation rig 100 and not to position of any mesh. Mesh controller 114 may be configured to determine the installation position at any time between installing the first mesh and stopping mesh installation rig 100 for installation of the second mesh, for example during movement of mesh installation rig.

[0077] Mesh controller 114 may be configured to determine the installation position based on the first position of the first mesh, determined based on the scanning data, and the kinematic model of mesh installation rig 100. Based on the position of the first mesh and the kinematic model, mesh controller 114 may be configured to determine a position from which mesh installation rig 100 is able to reach the edge of the first mesh, for example such that desired overlapping of the first and second meshes may be achieved. When the first and second mesh overlap, they may occupy or cover the same area of rock surface 140. Mesh controller 114 may be for example configured to determine the installation position based on dimension(s) of boom 120-1, and optionally a position for gripping mesh 402 by gripper 124. Mesh controller 114 may be configured to determine the installation position such that mesh installation rig 100 is enabled to place mesh 402 (cf. second mesh) with a desired overlap with already installed mesh(es) (cf. first mesh). Mesh controller 114 may be configured to determine the installation position based on dimension(s) of boom 120-2 (e.g., including bolter 126) such that mounting mesh 402 at the desired position by bolter 126 is enabled.

[0078] At operation 305, mesh controller 114 may be configured to control movement of mesh installation rig 100 to the installation position. Controlling movement of mesh installation rig 100 may comprise controlling driving direction, speed, and/or orientation of mesh installation rig 100. Controlling movement of mesh installation rig may comprise determining a position of mesh installation rig 100. For example, mesh controller 114 may be configured to determine that mesh installation rig 100 has reached the installation position. Mesh controller 114 may be configured to control movement of mesh installation rig 100 autonomously or based on instructions received from a human operator, either locally or remotely.

[0079] At operation 306, mesh controller 114 may be configured to update coordinates for installing the second mesh. Since mesh installation rig 100 may have moved from the position(s) at which the first mesh was detected by scanning, mesh controller 114 may be configured to update the position of the first mesh (first position), in the coordinate system of mesh installation rig 100 based on the movement from the scanning position(s) to the installation position.

[0080] At operation 307, mesh controller 114 may be configured to determine a position for installing the second mesh on rock surface 140. This position may be referred to as a second position and it may refer to a position of the second mesh on rock surface 140. Mesh controller 114 may be configured to determine the second position such that the first mesh and the second mesh overlap, for example at an edge of the first mesh, subsequent to installation of the second mesh on rock surface 140 at the second position. This enables to prevent rocks falling from rock surface 140 and thereby increases safety and reduces the risk of damage to mesh installation rig 100. Mesh controller 114 may be configured to determine the second position based on the first position of the first mesh.

[0081] FIG. 4 illustrates an example of overlapping meshes. Considering an example scenario, where mesh 404 (as the first mesh) has been previously installed on rock surface 140, mesh controller 114 may determine position of mesh 401 (as the second mesh) such that meshes 404 and 401 overlap in direction x after installation of mesh 401. Meshes 404 and 401 may overlap at an edge of mesh 404. Similarly, when mesh 401 (as the first mesh) has been already installed, mesh controller 114 may determine position of mesh 402 (as the second mesh) such that meshes 401 and 402 overlap in direction y after installation of mesh 402. Meshes 401 and 402 may overlap at an edge of mesh 401. In this example, the overlap between the meshes is slightly more than one mesh opening (mesh eye). The amount of overlapping may be however larger, for example more than two (e.g. 2-4) mesh openings. Overlap of 2-4 mesh openings sufficiently prevents rocks from falling from rock surface 140, while not causing excessive extra cost. The amount of overlapping may be defined with respect to a direction perpendicular to the edge of the already installed mesh, for example direction x when installing mesh 401 such that it overlaps with mesh 404 and direction y when installing mesh 402 such that it overlaps with mesh 401.

[0082] FIG. 5 illustrates an example of meshes installed on a tunnel surface based on a digital meshing plan. FIG. 5 illustrates a cross-sectional view of a tunnel along the yz-plane (left) and also an example of a digital meshing plan (right) for the tunnel surface viewed from above roof 140-1 and from outside of right wall 140-3 of the tunnel. In this example, rock surface 140 comprises a tunnel surface, for example roof 140-1 and/or wall(s) 140-2, 140-3 of the tunnel. Mesh controller 114 may be configured to determine positions for the meshes based on the digital meshing plan, which may comprise planned mesh positions. Planned positions for meshes 401 to 406 are illustrated on the right. The digital meshing plan may comprise planned mounting positions 501 represented by the black dots. When determining a position for installing a mesh, mesh controller 114 may be configured to initially use the respective position included in the digital meshing plan. However, due to various imperfections, such as for example bending or inaccurate placement of previous meshes, the planned position might not provide sufficient overlap in practise. It is also possible that mounting the mesh at the planned mounting positions is not possible, for example due to mesh wire(s) being located at the planned mounting positions. Based on scanning of rock surface 140 and detecting the already installed mesh(es), it is possible to provide sufficient overlap and to find suitable mounting position.

[0083] Considering mesh installation at a particular point of axis x, the meshes may be installed starting from the roof, for example from the highest point of roof 140-1, and moving down along the tunnel surface such that meshes located on wall 104-2, for example mesh 403, are installed after meshes located on roof 140-1, for example mesh 401 and mesh 402. This enables to keep rocks falling from roof 140-1 behind the meshes. In general, the first mesh (e.g., mesh 402) may have been installed on roof 140-1 of the tunnel and the second mesh (e.g., mesh 403) may be configured to be installed on a wall 140-3 of the tunnel. A wall 140-2, 140-3 of the tunnel may comprise a portion of the tunnel surface for which the inclination angle α from axis y is below a threshold, for example less than 45°. Roof 140-1 of the tunnel may comprise a portion of the tunnel surface for which the inclination angle α from axis y is above the threshold, for example greater than 45°.

[0084] Referring back to FIG. 3, at operation 308 mesh controller 114 may be configured to control installation of the second mesh to rock surface 140. For example, mesh controller 114 may be configured to control movement of at least one boom, for example booms 120-1, 120-2 and their respective tools, to cause placement of the second mesh at the determined second position and to mount the second mesh at rock surface 140 at this position. An example of a method for controlling installation of the second mesh is provided in FIG. 6.

[0085] Some operations of FIG. 3 may be optional and operations may be also performed in different order. For example, mesh controller 114 may be configured to cause movement of mesh installation rig 100 at a planned installation position before scanning rock surface 140 to detect the first mesh. Mesh controller 114 may be for example configured to control movement of mesh installation rig for example based on the digital mesh plan. In this case, it might not be necessary to update coordinate(s) (cf. operation 306) of the first mesh before determining the position of the second mesh (cf. operation 307), if mesh installation rig 100 does not move between scanning the first mesh and installation of the second mesh. Further, mesh controller 114 may be configured to determine the position for the second mesh (cf. operation 307) before mesh installation rig 100 moves to the installation position. In this case, mesh controller 114 may be configured to update both coordinates of the first mesh and the second mesh based on the movement of mesh installation rig 100 to its installation position.

[0086] FIG. 6 illustrates an example of a flow chart for controlling mesh installation via overlapping openings of first and second meshes. The flow chart of FIG. 6 may be used for implementing operation 308 of FIG. 3. Based on this flow chart it is however possible to implement a stand-alone method for controlling mounting of the second mesh at or near a predetermined location.

[0087] At operation 601, mesh controller 114 may be configured to control positioning of the second mesh for installation at rock surface 140. For example, mesh controller 114 may be configured to control at least one boom, for example boom 120-1 comprising gripper 124, to position the second mesh for being installed on rock surface 140. Mesh controller 114 may be configured to determine the position of the second mesh based on the digital meshing plan and/or scanning of the rock surface, for example as described with reference to FIG. 3.

[0088] At operation 602, mesh controller 114 may be configured to control scanning of rock surface 140, similar to operation 301. However, mesh controller 114 may be configured to cause rock surface 140 to be scanned when the second mesh has been positioned for installation. Mesh controller 114 may therefore configured to obtain scanning data of rock surface 140, in order to detect the first mesh(es) installed on rock surface 140 and the second mesh positioned for being installed on rock surface 140. When combined with operations of FIG. 3, this scanning data may comprise further scanning data in addition to the scanning data obtained at operation 301.

[0089] At operation 603, mesh controller 114 may be configured to determine whether overlapping opening(s) of the first mesh and the second mesh are detected. Mesh controller 114 may be configured to use any suitable method for this, including, but not limited to, machine-vision-based algorithm(s). Mesh controller 114 may be configured to determine whether a predetermined number of overlapping opening(s) exist. The predetermined number may comprise a positive integer, for example one, two, three, five, ten, or any integer within the range of 1 to 10. Mesh controller 114 may be configured to determine, in response to detecting overlapping opening(s), or the predetermined number of openings, one or more overlapping openings for mounting the second mesh to rock surface 140. Mesh controller 114 may be configured to determine the overlapping opening(s) for mounting the second mesh based on selecting particular overlapping openings from the detected overlapping openings, for example based on their distance(s) to the planned mounting positions 501 of the digital meshing plan. Determining the overlapping opening(s) may therefore comprise selecting a subset of the detected openings for mounting the second mesh on rock surface 140. Mesh controller 114 may be for example configured to select, for mounting the second mesh, overlapping opening(s) that are closest to the mounting position(s) of the digital meshing plan. Mesh controller 114 may be configured to determine, based on the scanning data of rock surface 114, position(s) where openings of the first and second meshes overlap. Mesh controller 114 may be configured to determine the position(s) with respect to the coordinate frame of mesh installation rig 100.

[0090] Determining the overlapping openings by mesh controller 114 may be based on searching for the overlapping openings of the first and the second meshes in proximity of gripping position(s) of boom 120-1, which may be configured to position the second mesh for installing the second mesh to rock surface 140. This improves detection of the overlapping openings, because the distance between the first and second meshes along an axis perpendicular to rock surface 140 is generally smaller close the gripping position(s) due to bending of the second mesh. Mesh controller 114 may be for example configured to search for the overlapping openings within a threshold distance from the gripping position(s) or a threshold number of mesh openings. The threshold distance may be dependent on thickness of the mesh wires and size (e.g., width or diameter) of the mesh openings. The threshold number of mesh openings may be dependent on the thickness of the mesh wire. The thickness of the mesh wires may be for example 10 mm. The threshold distance may be for example 50 cm or 1 m. In case of square mesh openings, the width of the mesh opening may be for example 10 cm or 15 cm. The threshold number of mesh openings may be for example 6-10 openings. Mesh controller 114 may be configured to move to execution of operation 604 in response to detecting overlapping openings, or the predetermined number thereof. Mesh controller 114 may be configured to move to execution of operation 605 in response to not detecting overlapping openings, or the predetermined number thereof. Detecting overlapping openings may be subject to detecting overlapping openings at suitable positions, for example with respect to the digital meshing plan or kinematic model of mesh installation rig 100, for example boom 120-2 and/or bolter 126. Detecting overlapping openings may be subject to determining that the openings overlap at least to a predetermined extent, for example such that mounting to rock surface 140 is enabled via the overlapping portions of the openings.

[0091] FIG. 7 illustrates an example of first and second meshes with overlapping openings. In this example, mesh 401 has been installed previously and mesh installation rig 100 has positioned mesh 404 with gripper 124 for mounting on rock surface 140. Four gripping positions of gripper 124 have been illustrated by the black dots. Mesh controller 114 may be configured to determine positions of a plurality of overlapping openings 701, 702, 703, for example by first searching in proximity of the gripping positions, for example within distance d to find position 701 and thereafter extending the search range to find positions 702 and 703. Distance d may be predetermined, for example preconfigured at mesh controller 114, or determined by mesh controller 114 by other means, for example based on properties of the first and/or second mesh (e.g., size of mesh openings). The positions of the overlapping openings may be determined such that they are located close to, e.g., within another threshold distance, the planned mounting positions 501 of the digital meshing plan.

[0092] Referring back to FIG. 6, at operation 604 mesh controller 114 may be configured to control mounting of the second mesh to rock surface 140. Controlling the mounting of the second mesh may comprise causing mesh installation rig 100 to mount the second mesh at rock surface 140. Controlling the mounting of the second mesh may comprise determining an order of mounting positions or a mounting rate (e.g., in bolts/min). Controlling the mounting of the second mesh may comprise causing mesh installation rig 100 to mount the second mesh to rock surface 140 according to the determined order of mounting positions or the mounting rate. Mesh controller 114 may be configured to control mesh installation rig 100 based on the determined positions and detected overlapping openings such that the second mesh is mounted to rock surface 140 at the determined position(s) via the overlapping openings of the first and second meshes. For example, mesh controller 114 may be configured to cause boom 120-2 to mount (e.g., by bolting) the second mesh at rock surface 140. Mounting the second mesh may cause also the first mesh to be mounted at the determined positions, in addition to positions at which the first mesh was mounted earlier.

[0093] Mesh controller 114 may be configured to control mounting of the second mesh to rock surface 140 via the overlapping openings such that the second mesh is mounted to rock surface 140 in an order of increasing distance from the gripping position(s) of boom 120-1. This makes the mounting easier, because the distance between the first and second meshes is generally smaller in proximity of the gripping position(s). For example, mesh controller 114 may be configured to control boom 120-2 to first cause mesh 404 to be mounted at position 701, which is closest to the gripping positions of gripper 124. Mesh controller 114 may be configured to next control boom 120-2 to cause mesh 404 to be mounted at position 702. Mounting the second mesh at position 702 decreases the distance between meshes 401 and 404 at position 703, which makes it easier to subsequently mount mesh 404 at position 703.

[0094] At operation 605, mesh controller 114 may be configured to control adjustment of the position of the second mesh. Mesh controller 114 may perform this in response to determining (cf. operation 603) not to find overlapping openings, for example the predetermined number of them, of first and second meshes. For example, mesh controller 114 may be configured to control boom 120-1 and/or gripper 124 to adjust the position of the second mesh. The adjustment may be preconfigured, for example a preconfigured distance to a preconfigured direction, or determined by mesh controller 114 based on the scanning data. Adjusting the position of the second mesh increases the probability of finding suitable overlapping openings for mounting the second mesh to rock surface 140. In response to the adjustment, mesh controller 114 may be configured to move back to execution of operation 602, where mesh controller 114 may be configured to control re-scanning of rock surface 140 in order to obtain re-scanning data. Based on the re-scanning data, mesh controller 114 may be configured to determine whether there are overlapping openings (operation 603), control mounting of the second mesh (operation 604), and/or control a further adjustment of the position of the second mesh (operation 605). The potentially iterative approach enables to find suitable positions for mounting the second mesh at rock surface 140. This enables to speed up the installation process and to save energy because suitable mounting positions may be determined in advance, without actually trying to mount the second mesh at unsuitable positions, for example with bolter 126.

[0095] FIG. 8 illustrates an example of an apparatus configured to practise one or more example embodiments. Apparatus 800 may be or comprise a mesh control apparatus, such as for example a server, communicatively coupled to mesh installation rig 100, a mesh control apparatus located at mesh installation rig 100, mesh controller 114, mesh installation rig 100 itself, or in general any device or system configured to implement the functionality described herein. Although apparatus 800 is illustrated as a single device, it is appreciated that, wherever applicable, functions of apparatus 800 may be distributed to a plurality of devices.

[0096] 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 microprocessor, 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.

[0097] 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.

[0098] 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.

[0099] 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.

[0100] For example, mesh controller 114 may be at least partially implemented as program code configured to cause apparatus 800 to perform functionality of mesh controller 114. Similarly, transmission or reception of data (e.g. sensor data, kinematic model(s), or the digital meshing plan) over an internal or external communication interface of mesh installation rig 100 may be controlled by software.

[0101] 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-α-chip systems (SOCs), complex programmable logic devices (CPLDs), graphics processing units (GPUs), neural processing unit (NPU), tensor processing unit (TPU), or the like.

[0102] 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 communication interface, such as for example a radio interface between mesh installation rig 100 and remote mesh control device 200. Apparatus 800 may further comprise other components and/or functions such as for example a user interface (not shown) 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. The user interface may enable a human operator to monitor various functions and data, such as for example the digital meshing plan, or the like.

[0103] 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 of 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.

[0104] According to a first aspect, apparatus 800 may be configured for controlling mesh installation. 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 to detect at least one first mesh installed on the rock surface; determine, based on the scanning data, a first position of the at least one first mesh; determine, a second position for installing a second mesh on the rock surface, wherein the at least one first mesh and the second mesh are configured to overlap at an edge of the at least one first mesh, when the second mesh has been installed on the rock surface at the second position; and control installation of the second mesh on the rock surface at the second position.

[0105] 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: control at least one boom to place the second mesh at the second position and to mount the second mesh to the rock surface at the second position.

[0106] 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: control a first boom to place the second mesh at the second position; and control a second boom to mount the second mesh to the rock surface at the second position.

[0107] According to an example embodiment of the first aspect, mounting of the second mesh to the rock surface comprises bolting the second mesh to the rock surface.

[0108] 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 first position of the at least one first mesh and a kinematic model of a mesh installation rig, an installation position for the mesh installation rig for installing the second mesh on the rock surface at the second position; control movement of the mesh installation rig to the installation position; update the first position of the at least one first mesh and the second position of the second mesh in a coordinate system of the mesh installation rig based on the movement to the installation position.

[0109] According to an example embodiment of the first aspect, the apparatus comprises the mesh installation rig.

[0110] According to an example embodiment of the first aspect, the apparatus is configured to obtain the scanning data from at least one of the following: a camera, a radio detection and ranging sensor, or a light detection and ranging sensor laser.

[0111] According to an example embodiment of the first aspect, at least two openings of the at least one first mesh and the second mesh are configured to overlap in a direction perpendicular to the edge of the at least one first mesh, when the second mesh has been installed on the rock surface at the second position.

[0112] According to an example embodiment of the first aspect, the first position comprises a position on a roof of a tunnel and the second position comprises a position on a wall on the tunnel.

[0113] According to a fifth aspect, apparatus 800 may be configured for controlling mesh installation. 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 to detect at least one first mesh installed on the rock surface and a second mesh positioned for being installed on the rock surface; determine, based on the scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap; and control mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

[0114] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: control adjustment of a position of the second mesh, in response to determining not to find a predetermined number of overlapping openings of the at least one first mesh and the second mesh.

[0115] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: obtain re-scanning data of the rock surface to detect the overlapping openings of the at least one first mesh and the second mesh, in response to the adjustment the position of the second mesh.

[0116] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: control at least one boom to position the second mesh for installing the second mesh to the rock surface and to mount the second mesh to the rock surface.

[0117] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: determine the at least one position where the openings of the at least one first mesh and the second mesh overlap based on searching for the overlapping openings of the at least one first mesh and the second mesh in proximity of at least one gripping position of a first boom configured to position the second mesh for installing the second mesh to the rock surface.

[0118] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: determine a plurality of positions where the openings of the at least one first mesh and the second mesh overlap; and control mounting of the second mesh to the rock surface at the plurality of positions via the overlapping openings of the at least one first mesh and the second mesh in an order of increasing distance from the at least one gripping position of the first boom configured to position the second mesh for being installed to the rock surface.

[0119] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: control a second boom to mount the second mesh to the rock surface.

[0120] According to an example embodiment of the fifth aspect, mounting of the second mesh to the rock surface comprises bolting the second mesh to the rock surface.

[0121] According to an example embodiment of the fifth aspect, the apparatus comprises a mesh installation rig.

[0122] According to an example embodiment of the fifth aspect, the computer program code is configured to, with the at least one processor, cause the apparatus to: obtain the scanning data or the re-scanning data from at least one of the following: a camera, a radio detection and ranging sensor, or a light detection and ranging sensor laser.

[0123] According to an example embodiment of the fifth aspect, the first position comprises a position on a roof of a tunnel and the second position comprises a position on a wall on the tunnel.

[0124] FIG. 9 illustrates an example of a method for controlling mesh installation. The method may comprise a computer-implemented method performed by, for example, apparatus 800 such as mesh controller 114.

[0125] At 901, the method may comprise obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock surface.

[0126] At 902, the method may comprise determining, based on the scanning data, a first position of the at least one first mesh.

[0127] At 903, the method may comprise determining, a second position for installing a second mesh on the rock surface, wherein the at least one first mesh and the second mesh are configured to overlap at an edge of the at least one first mesh, when the second mesh has been installed on the rock surface at the second position.

[0128] At 904, the method may comprise controlling installation of the second mesh on the rock surface at the second position

[0129] FIG. 10 illustrates another example of another a method for controlling mesh installation. The method may comprise a computer-implemented method performed by, for example, apparatus 800 such as mesh controller 114.

[0130] At 1001, the method may comprise obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock surface and a second mesh positioned for being installed on the rock surface.

[0131] At 1002, the method may comprise determining, based on the scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap.

[0132] At 1003, the method may comprise controlling mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

[0133] FIG. 11 illustrates yet another example of a method for controlling mesh installation. The method may comprise a computer-implemented method performed by, for example, apparatus 800 such as mesh controller 114.

[0134] At 1101, the method may comprise obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock surface.

[0135] At 1102, the method may comprise determining, based on the scanning data, a first position of the at least one first mesh.

[0136] At 1103, the method may comprise determining, a second position for installing a second mesh on the rock surface, wherein the at least one first mesh and the second mesh are configured to overlap at an edge of the at least one first mesh, when the second mesh has been installed on the tunnel rock surface at the second position.

[0137] At 1104, the method may comprise obtaining further scanning data of the rock surface to detect the at least one first mesh and the second mesh, when the second mesh is positioned for being installed on the rock surface.

[0138] At 1105, the method may comprise determining, based on the further scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap.

[0139] At 1106, the method may comprise controlling mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

[0140] The method(s) may be performed by mesh controller 114, mesh installation rig 100, or remote mesh 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 mesh controller 114, mesh installation rig 100, and/or remote mesh 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.

[0141] 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.

[0142] 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.

[0143] 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.

[0144] 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.

[0145] 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 cover also 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".

[0146] 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.

[0147] 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 mesh installation, 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 to detect at least one first mesh installed on the rock surface and a second mesh positioned for being installed on the rock surface;
      determine, based on the scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap; and
      control mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

2. The apparatus according to claim 1, wherein the computer program code is further configured to, with the at least one processor, cause the apparatus to: control adjustment of a position of the second mesh, in response to determining not to find a predetermined number of overlapping openings of the at least one first mesh and the second mesh.

3. The apparatus according to claim 2, wherein the computer program code is further configured to, with the at least one processor, cause the apparatus to: obtain re-scanning data of the rock surface to detect the overlapping openings of the at least one first mesh and the second mesh, in response to the adjustment the position of the second mesh.

4. The apparatus according to any preceding claim, wherein the computer program code is further configured to, with the at least one processor, cause the apparatus to:
   control at least one boom to position the second mesh for installing the second mesh to the rock surface and to mount the second mesh to the rock surface.

5. The apparatus according to any preceding claim, wherein the computer program code is further configured to, with the at least one processor, cause the apparatus to:
   determine the at least one position where the openings of the at least one first mesh and the second mesh overlap based on searching for the overlapping openings of the at least one first mesh and the second mesh in proximity of at least one gripping position of a first boom configured to position the second mesh for installing the second mesh to the rock surface.

6. The apparatus according to claim 5, wherein the computer program code is further configured to, with the at least one processor, cause the apparatus to:

   determine a plurality of positions where the openings of the at least one first mesh and the second mesh overlap; and
   control mounting of the second mesh to the rock surface at the plurality of positions via the overlapping openings of the at least one first mesh and the second mesh in an order of increasing distance from the at least one gripping position of the first boom configured to position the second mesh for being installed to the rock surface.

7. The apparatus according to claim 5 or 6, wherein the computer program code is further configured to, with the at least one processor, cause the apparatus to: control a second boom to mount the second mesh to the rock surface.

8. The apparatus according to any preceding claim, wherein mounting of the second mesh to the rock surface comprises bolting the second mesh to the rock surface.

9. The apparatus according to any preceding claim, wherein the apparatus comprises a mesh installation rig.

10. The apparatus according to any preceding claim, wherein the apparatus is configured to obtain the scanning data or the re-scanning data from at least one of the following: a camera, a radio detection and ranging sensor, or a light detection and ranging sensor laser.

11. The apparatus according to any preceding claim, wherein the first position comprises a position on a roof of a tunnel and the second position comprises a position on a wall of the tunnel.

12. A method, comprising:

   obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock

surface and a second mesh positioned for being installed on the rock surface;
determining, based on the scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap; and
controlling mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

13. The method according to claim 12, further comprising:
controlling adjustment of a position of the second mesh, in response to determining not to find a predetermined number of overlapping openings of the at least one first mesh and the second mesh.

14. The method according to claim 13, further comprising:
obtaining re-scanning data of the rock surface to detect the overlapping openings of the at least one first mesh and the second mesh, in response to the adjustment the position of the second mesh.

15. A computer program comprising instructions which, when executed by an apparatus, cause the apparatus at least to:

obtain scanning data of a rock surface to detect at least one first mesh installed on the rock surface and a second mesh positioned for being installed on the rock surface;
determine, based on the scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap; and

control mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh.

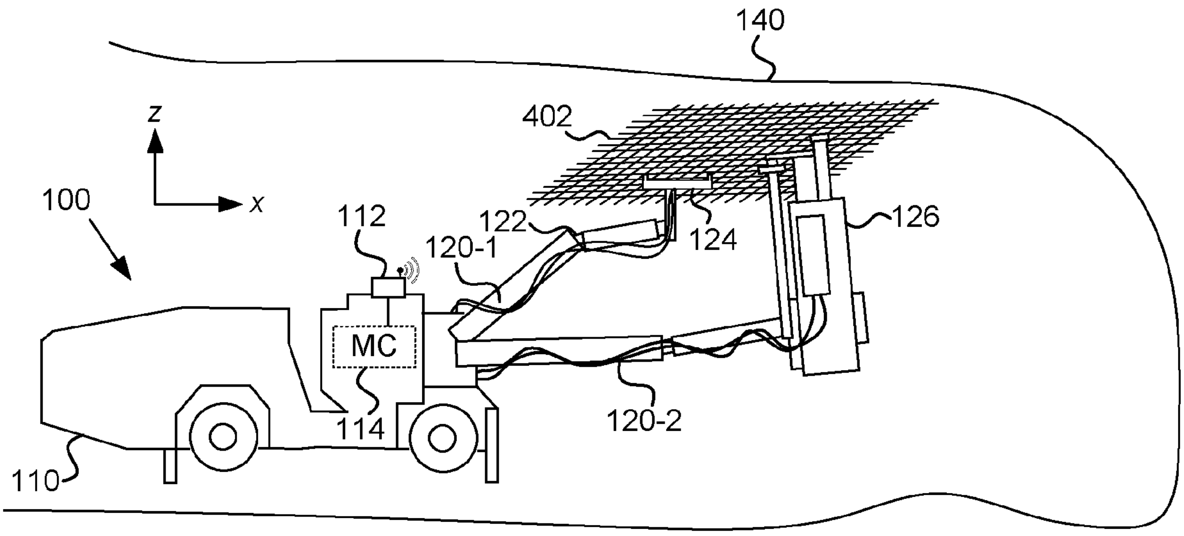

FIG. 1

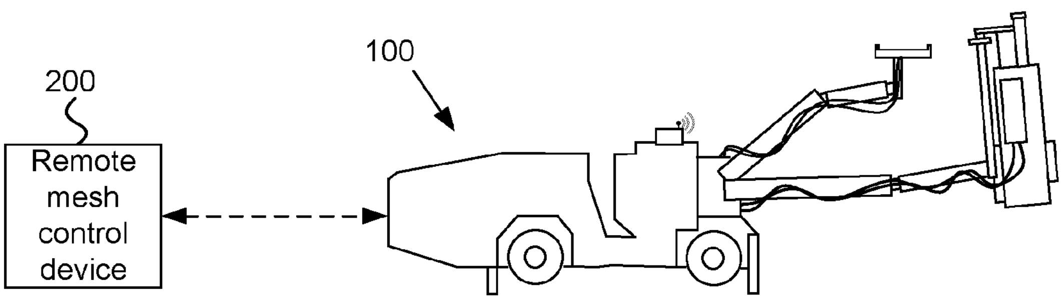

FIG. 2

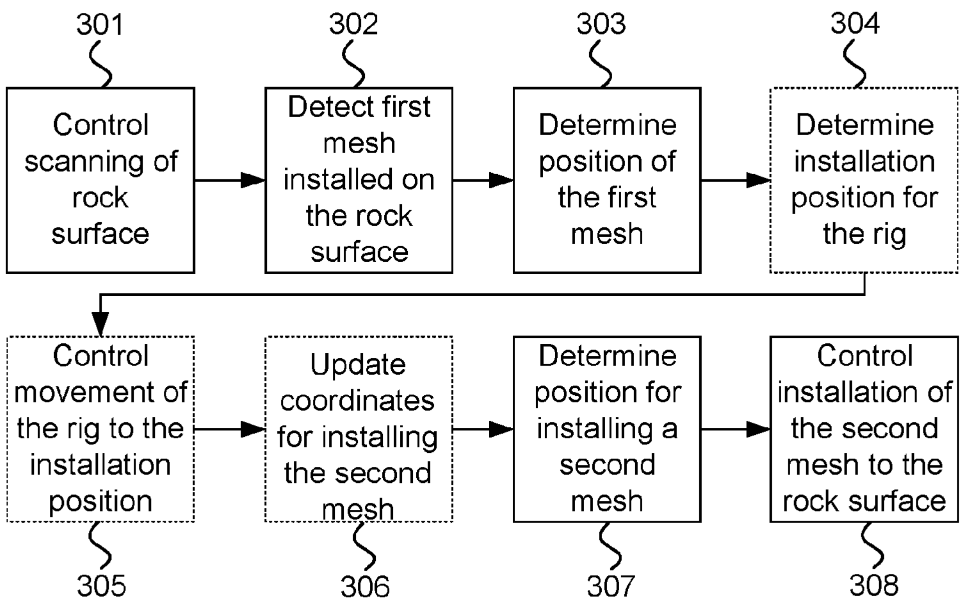

FIG. 3

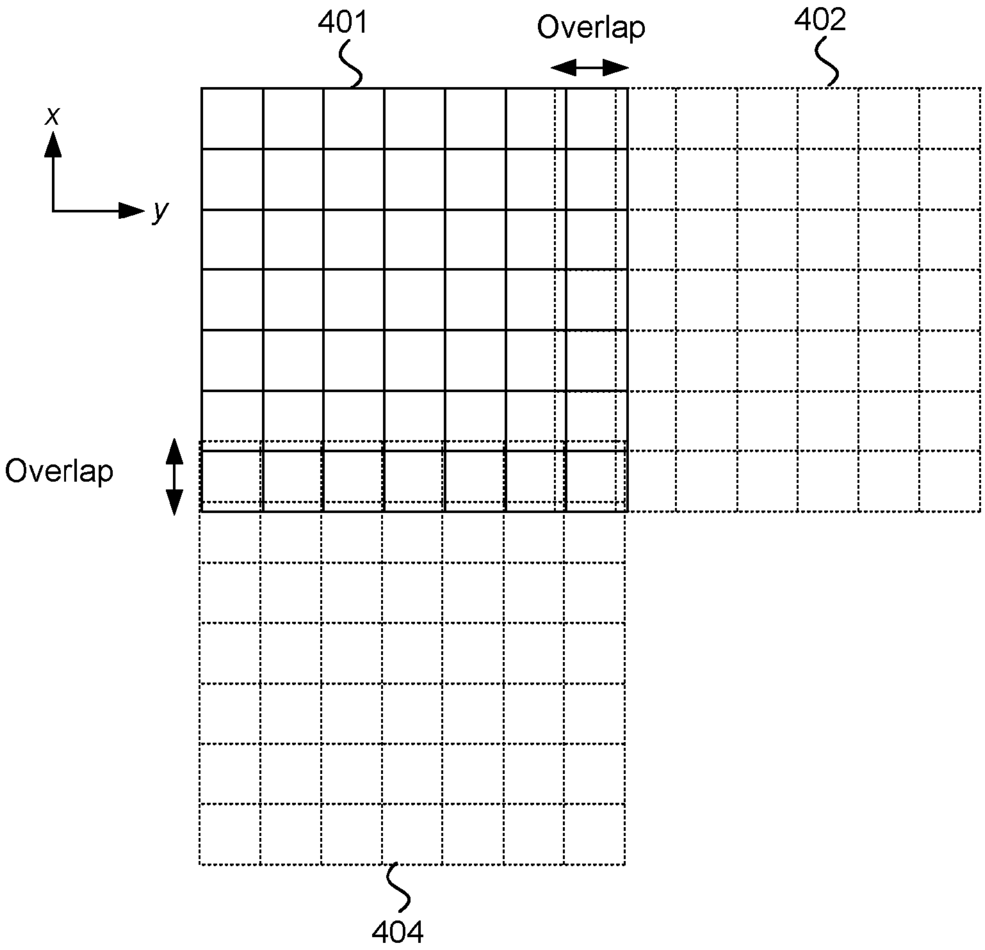
401
Overlap
402
x
y
Overlap
404

FIG. 4

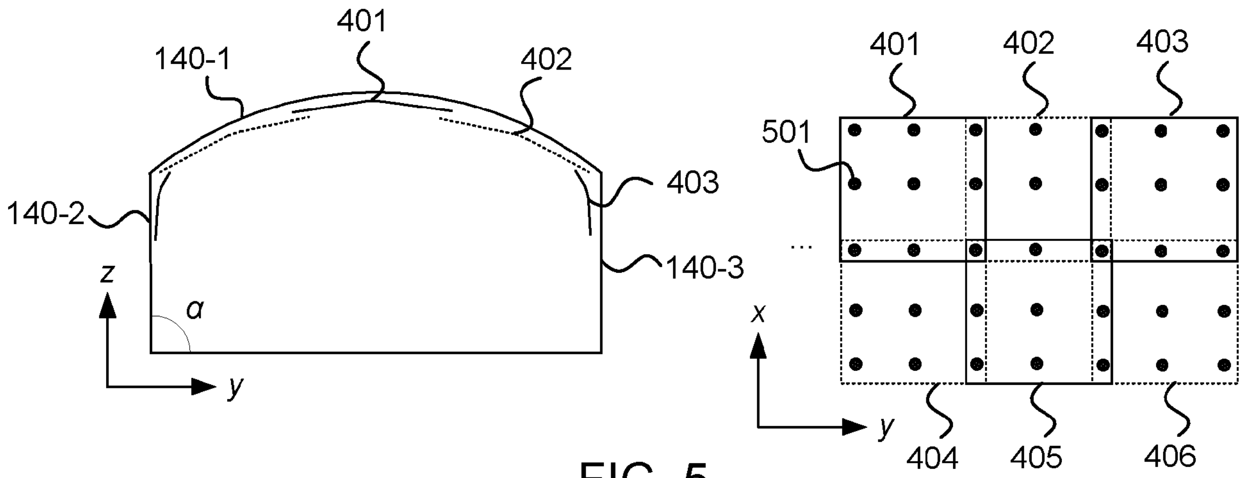
401
140-1
402
140-2
403
140-3
z
α
y
401
402
403
501
...
x
y
404
405
406

FIG. 5

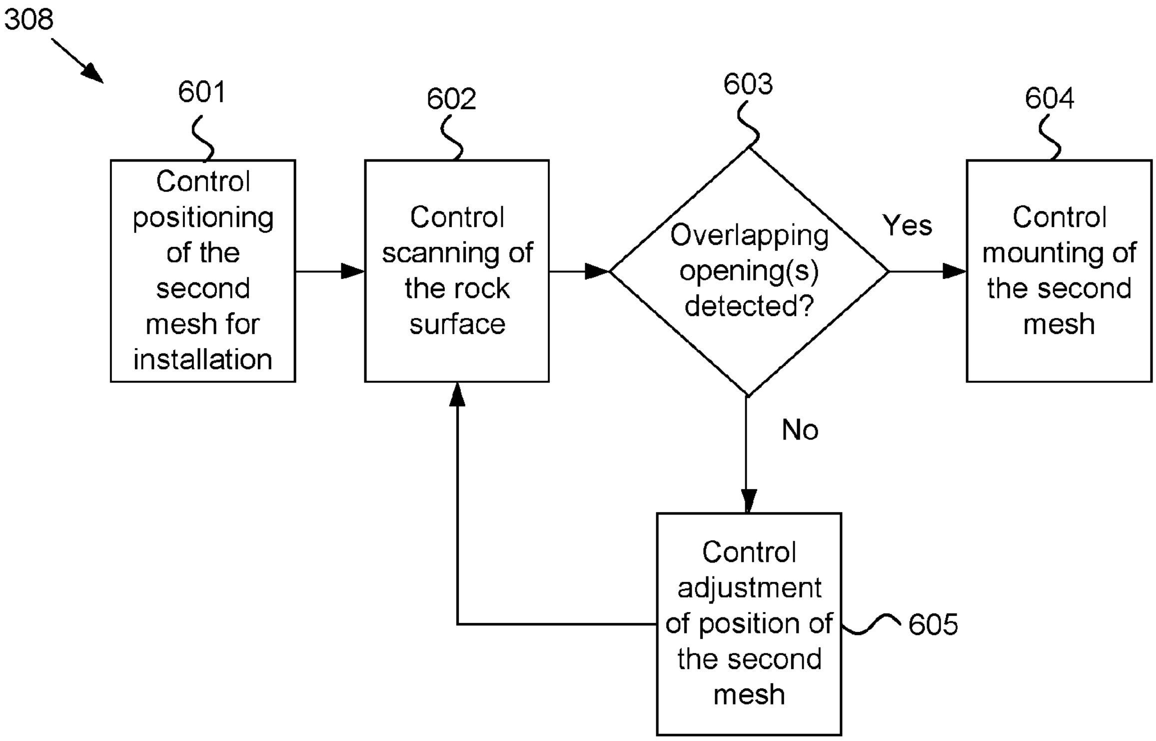
308
601
Control positioning of the second mesh for installation
602
Control scanning of the rock surface
603
Overlapping opening(s) detected?
Yes
No
604
Control mounting of the second mesh
605
Control adjustment of position of the second mesh

FIG. 6

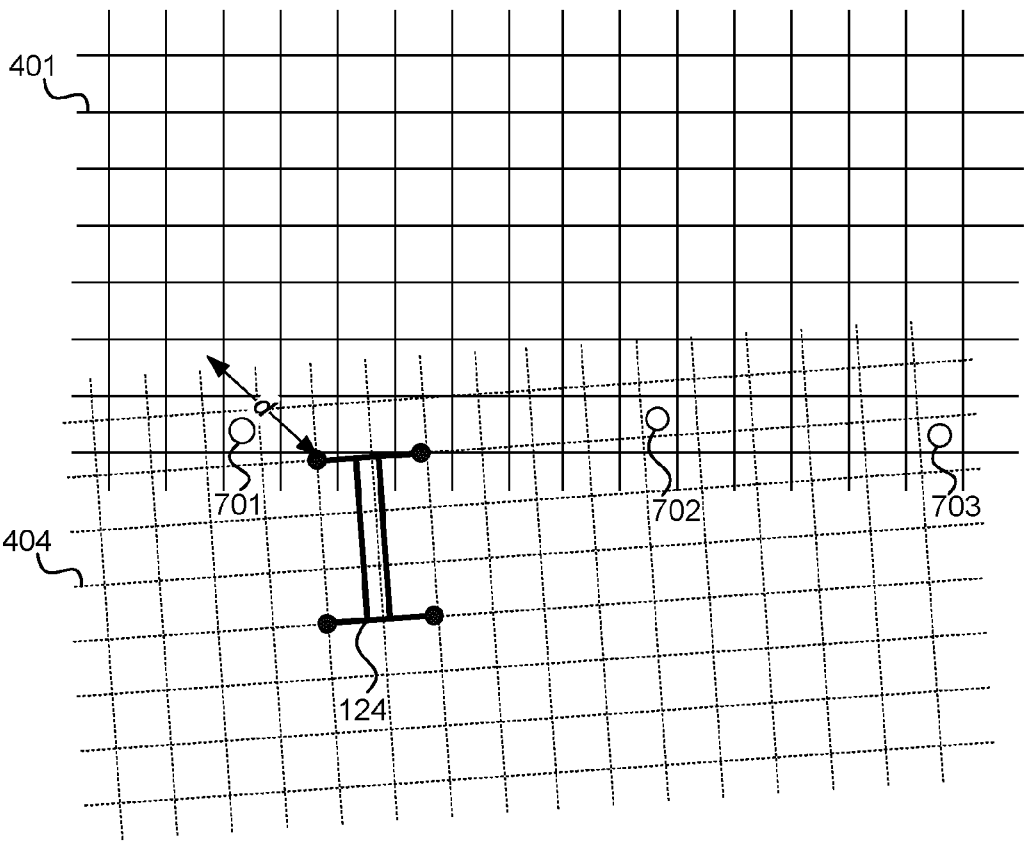
401
404
d
701
702
703
124

FIG. 7

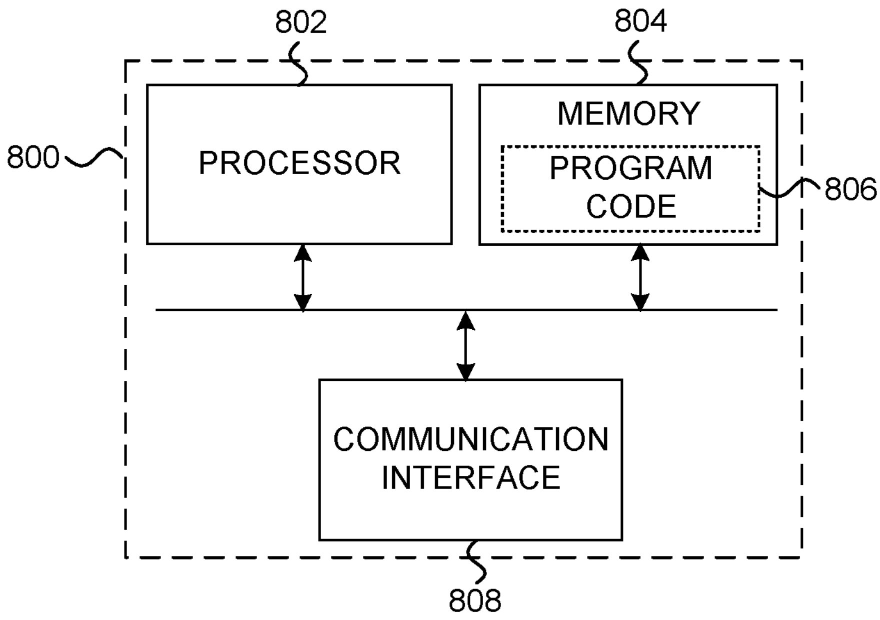
802
804
800
PROCESSOR
MEMORY
PROGRAM
CODE
806
COMMUNICATION
INTERFACE
808

FIG. 8

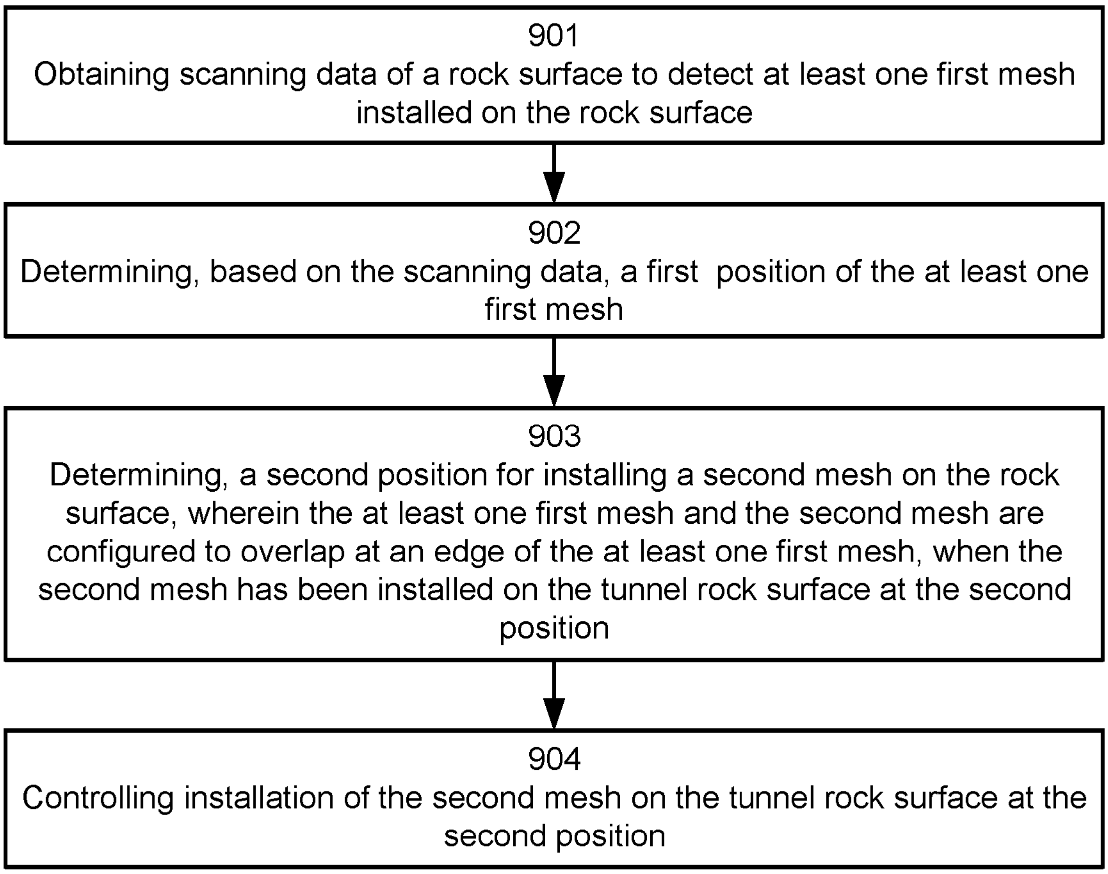
901
Obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock surface
902
Determining, based on the scanning data, a first position of the at least one first mesh
903
Determining, a second position for installing a second mesh on the rock surface, wherein the at least one first mesh and the second mesh are configured to overlap at an edge of the at least one first mesh, when the second mesh has been installed on the tunnel rock surface at the second position
904
Controlling installation of the second mesh on the tunnel rock surface at the second position

FIG. 9

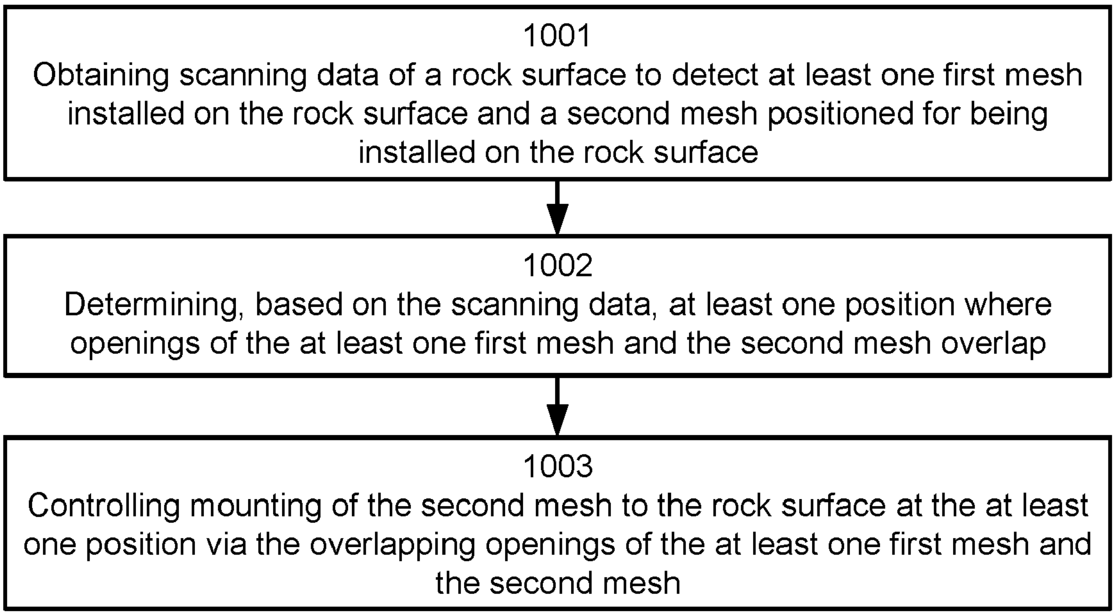
1001
Obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock surface and a second mesh positioned for being installed on the rock surface
1002
Determining, based on the scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap
1003
Controlling mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh

FIG. 10

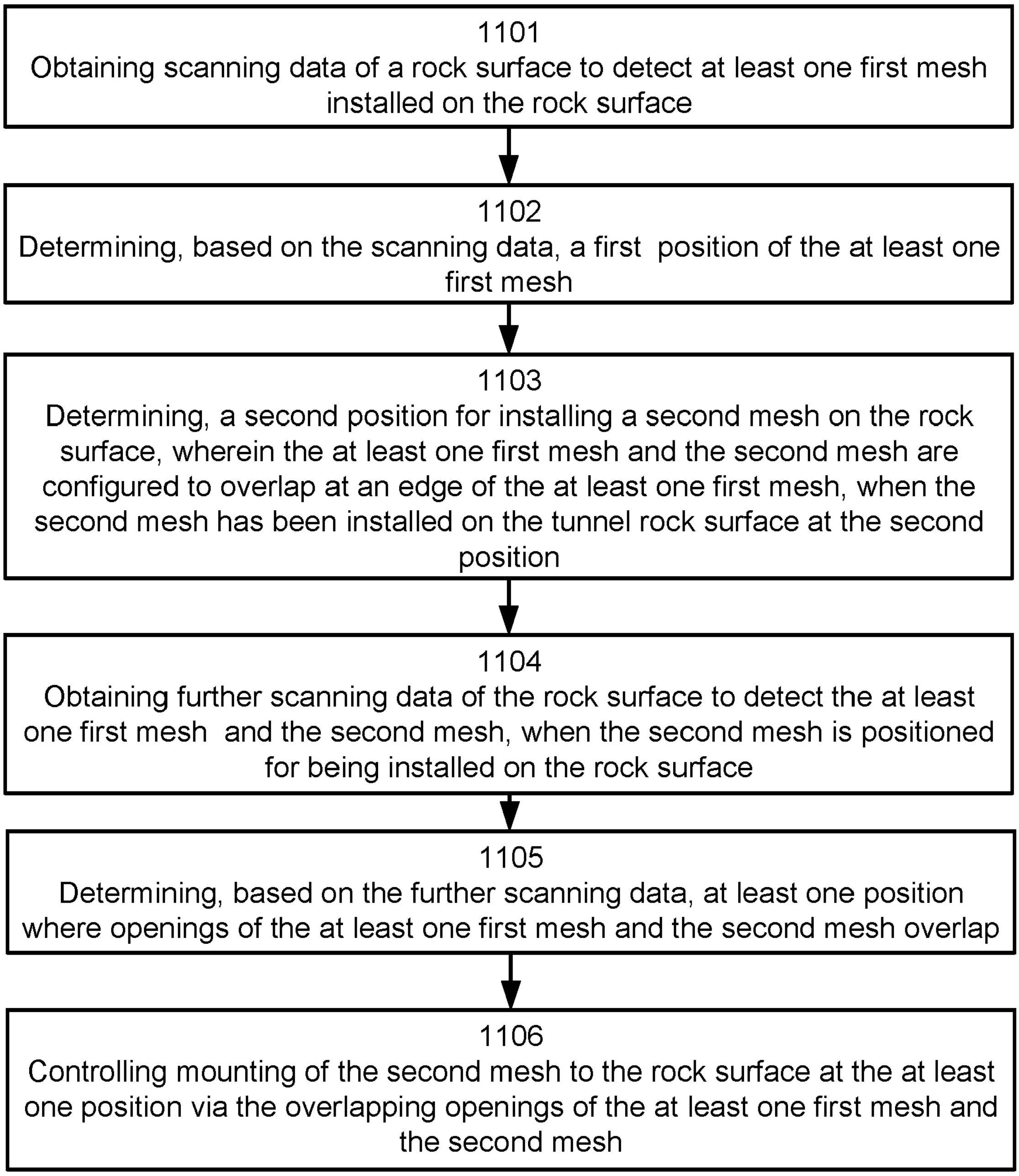
1101
Obtaining scanning data of a rock surface to detect at least one first mesh installed on the rock surface
1102
Determining, based on the scanning data, a first position of the at least one first mesh
1103
Determining, a second position for installing a second mesh on the rock surface, wherein the at least one first mesh and the second mesh are configured to overlap at an edge of the at least one first mesh, when the second mesh has been installed on the tunnel rock surface at the second position
1104
Obtaining further scanning data of the rock surface to detect the at least one first mesh and the second mesh, when the second mesh is positioned for being installed on the rock surface
1105
Determining, based on the further scanning data, at least one position where openings of the at least one first mesh and the second mesh overlap
1106
Controlling mounting of the second mesh to the rock surface at the at least one position via the overlapping openings of the at least one first mesh and the second mesh

FIG. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 23 15 2075

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CN 112 360 525 A (TAIYUAN INST CHINA COAL TECH & ENG GROUP ET AL.) 12 February 2021 (2021-02-12) * paragraph [0077]; claims 1,5 * -----	1-15	INV. E21D11/00 E21D11/15 E21D19/00
A	CN 109 595 014 B (SHOUGANG GROUP CO LTD) 25 May 2021 (2021-05-25) * claim 1; figure 1 * -----	1-3,5,6, 12-15	

TECHNICAL FIELDS SEARCHED (IPC)

E21B
E21D
E21C
E21F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	30 June 2023	Maukonen, Kalle

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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L : document cited for other reasons
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EPO FORM 1503 03.82 (P04C01)

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30-06-2023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 112360525 A	12-02-2021	NONE	
CN 109595014 B	25-05-2021	NONE	

EPO FORM P0459

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