(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 July 2015 (23.07.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/106799 A1

(51) International Patent Classification:
*E21B 7/02* (2006.01) *G01C 21/16* (2006.01)
*G01C 7/06* (2006.01)

(21) International Application Number:
PCT/EP2014/050598

(22) International Filing Date:
14 January 2014 (14.01.2014)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17**:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

**Published**:

— *with international search report (Art. 21(3))*

**(54) Title**: MINE VEHICLE, MINE CONTROL SYSTEM AND MAPPING METHOD

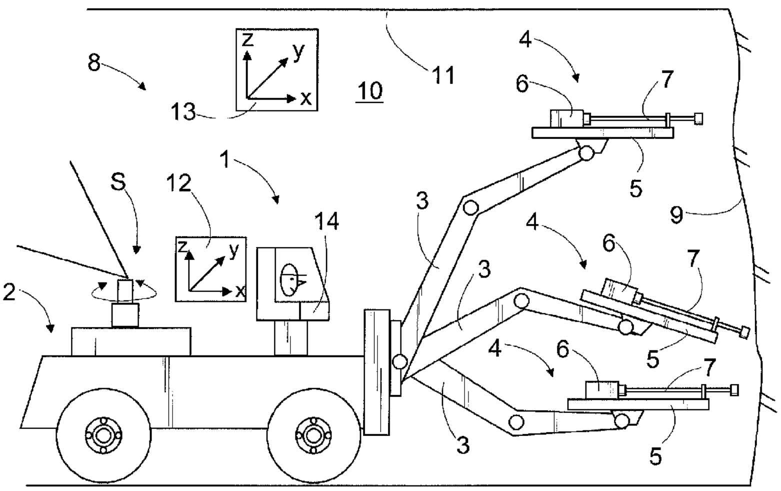


FIG. 1

**(57) Abstract**: The invention relates to a mine vehicle, a mine control system and a mapping method. The mine vehicle comprises at least one scanning device for scanning surroundings of the mine vehicle and producing a second point cloud data. The mine vehicle comprises a control unit which is provided with a reference point cloud data of the mine. The control unit is configured to match the second point cloud data to the reference point cloud data in order to determine position data of the mine vehicle.

WO 2015/106799 A1

# Mine vehicle, mine control system and mapping method

## Background of the invention

The invention relates to a mine vehicle, which is provided with a scanning device for scanning surroundings of the mine vehicle in order to produce data for determining position and orientation of the mine vehicle.

The invention further relates to a mine control system and mapping method.

The field of the invention is defined more specifically in the preambles of the independent claims.

Mine vehicles are used in underground and surface mines, construction sites and at other work sites. Positioning of the mine vehicle may require use of extensive and complicated position systems. The known positioning systems and methods also require skilled operators and are difficult to automate.

## Brief description of the invention

An object of the invention is to provide a novel and improved mine vehicle provided with a positioning system. A further object is to provide a novel and improved mine control system and a mapping method.

The mine vehicle according to the invention is characterized in that the control unit is provided with at least one processor and at least one point cloud matching program allowed to be executed in the processor; an initial first point cloud data is input to the control unit, the first point cloud data comprising stored reference model of the mine in a mine coordinate system; at least one second point cloud data produced by the scanning device of the mine vehicle is input to the control unit, the second point cloud data comprising operational scanning data of the current position of the mining vehicle; the control unit is configured to execute the point cloud matching program in order to match the operational second point cloud data to the reference first point cloud data; and the control unit is configured to determine position and direction of the scanning device in the mine coordinate system on the basis of the determined matching between the operational point cloud data and the reference cloud data.

The mine control system according to the invention is characterized in that the mine vehicle is arranged to scan the mine by means of the scanning device of the mine vehicle; at least one of the control units is arranged to determine the position of the mine vehicle by comparing a reference point cloud data of the mine and a scanned point cloud data by means of a point cloud matching program; and the determined position data of the mine vehicle is recorded in the mine control system for updating the current position data.

The method according to the invention is characterized by inputting the produced at least one second point cloud data of the operational scanning of the surroundings to at least one control unit provided with a point cloud matching program; inputting the point cloud data of the 3D mine model to the control unit and using it as a reference point cloud data of the mine; executing the matching program in a processor of the control unit for searching matching points between the second point cloud data and the reference point cloud data; and utilizing results of the matching process for determining position and orientation of the mine vehicle in the mine coordinate system.

An idea of the disclosed solution is that position and direction of a mining vehicle is determined by means of scanning data and comparison of the produced point cloud data with a reference point cloud data of a 3D mine model. Location of a scanner device in the mine vehicle is determined by means of a point cloud matching. The disclosed solution may implement a point cloud best fit method.

An advantage of the disclosed solution is that the position determination may be carried out without a need for extensive surveying and measuring infrastructure and equipment. An additional advantage is that the procedure does not need skilled workers and can be easily automated. A feasible further advantage is that the disclosed solution may obtain a strong statistical certainty for the produced results because repeating the scanning and analyzing processes is easy and fast.

According to an embodiment, the mine vehicle comprises a machine coordinate system. At least one reference object is determined in the mine vehicle. The operational second point cloud data comprises scanned points of the at least one reference object in addition to the scanned points of the surroundings. Position of the at least one reference object in the machine coordinate system is input to the control unit. The control unit is configured to execute the point cloud matching program to match the operational second point cloud data with the reference first point cloud data, whereby also position and direction of the at least one reference object is determined in the mine coordinate system. The control unit is configured to execute a coordinate transformation process and determine position and direction of the scanning device in the machine coordinate system in response to determined position and direction of the at least one reference object in the mine coordinate system and the input position of the at least one reference object in the machine coordinate system.

According to an embodiment, the mining vehicle comprises at least one supplementary reference object, which is arranged to a basic structure of the mining vehicle. The supplementary reference object does not have any use for the normal operation of the mine vehicle, such as drilling or bolting.

According to an embodiment, the supplementary reference object arranged to the mining vehicle comprises a spherical surface or curved surface. The spherical surface creates a special point pattern in the scanning data and is therefore easy to search and detect. The control unit may comprise a searching algorithm for examining the scanning data and finding predetermined point patterns.

According to an embodiment, the supplementary reference object arranged to the mining vehicle has predetermined two-dimensional configuration. An outer rim of the supplementary reference object may be a square, a circle, or any other form which deviates clearly from shapes of the structural components of the mine vehicle. The shape of the supplementary reference object is input to the control unit and is thereby easy to search and detect in the scanning data. The control unit may comprise a searching algorithm for examining the scanning data and finding predetermined point patterns.

According to an embodiment, the control unit is provided with a design point cloud data, which is converted from a 3D design data of a predetermined structural reference object of a basic structure of the mine vehicle. The structural reference object is inside a reach area of the scanning device and is thereby recorded in the operational second point cloud data. The control unit is configured to execute the point cloud matching program to determine position and direction of the structural reference object. Further, the control unit is configured to fit the design point cloud data to the determined position and direction of the structural reference object.

According to an embodiment, the control unit may determine coordinates of any point of the fitted design point cloud data, including also points, which are non-visible in the scanned second point cloud data. This embodiment allows choosing one or more points inside the observed structural reference object and defining coordinates of the chosen points. This way, any point defining the structural reference object may be chosen as a target to monitoring, and not only points which are located on the visible outer surface.

According to an embodiment, the mine vehicle comprises at least one boom and at least one mine work device at a distal end portion of the boom. At least one part of the mine work device is the observed structural reference object.

According to an embodiment, position and shape of the at least one reference object in the machine coordinate system are input to the control unit. The control unit is configured to examine the operational second point cloud data in order to find a point pattern matching with the input shape of the at least one reference object allowing position and direction of the at least one reference object to be determined.

According to an embodiment, the control unit is serving as a navigation device for determining position and direction of the mine vehicle in the mine coordinate system. The produced position and direction data may be implemented in the operational purposes of the mine vehicle, and also for mine control and fleet managing purposes.

According to an embodiment, the mine vehicle comprises at least one data communication device allowing data communication between the control unit and a mine control system. The data communication may be based on any wireless data transfer technique. The mine may be provided with a wireless network utilizing radio wave signals. The data transmission may be based on a wireless local area network (WLAN), for example.

According to an embodiment, the mine control system may comprise one or more computers or control units external to the mine and mine vehicle. Alternatively, the mine control system may comprise one or more servers allowing access to electrical terminal devices for retrieving the data transmitted from the control unit where the scanning data in analyzed. The mine control unit may also be considered to mean other data communication and distribution means allowing access to the processed data.

According to an embodiment, the control unit provided with at least one processor and the at least one point cloud matching program is located in the mine vehicle. Thus, the mine vehicle is provided with all the needed resources to gather data form the surroundings and to process it on-board. This embodiment is operable also in situations where the data connection to mine system is lost or is not operating properly. Latest version of the reference model of the mine may be downloaded to the on-board control unit at suitable instances and may be stored in an on-board storage media. The downloaded mine model may consist of the original mine model, or it may be filtered to only include descriptive patterns and features.

According to an embodiment, the control unit provided with at least one processor and the at least one point cloud matching program is located external to the mine vehicle. The scanning data may be transmitted to the external control unit via wireless data transmission connection, for example. The control unit may process the received scanning data and may send processed data back to a control unit, which is located in the mine vehicle. The analyzing and processing service may be implemented as a cloud service in an external server, such as a mine server, whereby the control unit of the mine vehicle needs not to be provided with calculation capacity.

According to an embodiment, the control unit is configured to detect in the second scanning data new surrounding point cloud objects around the mine vehicle allowing newly created walls to be detected and recorded. The control unit is configured to incorporate the new point cloud data to the reference point cloud data of the reference model of the mine.

According to an embodiment, the control unit is configured to detect in the second scanning data changed surrounding point cloud objects around the mine vehicle allowing changed walls to be detected and recorded. The control unit is configured to incorporate the new point cloud data to the reference point cloud data of the reference model of the mine.

According to an embodiment, the mine vehicle provided with the scanning device is serving as a mobile surveying device. The mine vehicle may execute the surveying continuously when executing dedicated normal operations of the mine vehicle. If the mine vehicle is a rock drilling rig or a reinforcing rig, it may scan the surroundings when it stops at a work site for executing drilling or feeding reinforcing elements or material. It may also be defined that the scanning is executed at least once each time when the mine vehicle is not moving. Thanks to this procedure, the mine may be surveyed repeatedly and in parallel to the normal operational process without any need for extra resources. The 3D model of the mine may thus be accurate and updated.

According to an embodiment, the mine vehicle provided with the scanning device is serving as a mobile surveying device. The scanning is executed only when the mining vehicle is not moving.

According to an embodiment, the mine vehicle is provided with the scanning device and is serving as a mobile surveying device. At least one scanning may be executed automatically when the mining vehicle is stopped.

According to an embodiment, the surveying scanning is repeated two or more times for a work site or a desired area of the mine. The mining vehicle may be moved between the successive scanning procedures. These measures may improve accuracy of the surveying. The scanning may take such a short time that scanning does not cause problems to the basic operation of the mine vehicle.

According to an embodiment, the mine vehicle is provided with the scanning device and is serving as a mobile surveying device. The control unit is configured to process the second scanning data by extracting point cloud data of the surrounding surfaces and removing point cloud data of all the other objects, whereby a simplified point cloud data of the surrounding surfaces is created. The control unit is configured to incorporate the new simplified point cloud data to the reference point cloud data of the reference model of the mine. Thanks to this embodiment, no irrelevant data is incorporated to the model of the mine.

According to an embodiment, the control unit is provided with at least one incorporating rule defining required matching ratio between the second scanning data and the reference point cloud data. The control unit is configured to incorporate the new point cloud data to the reference point cloud data of the reference model of the mine only when the set incorporating rule is fulfilled.

According to an embodiment, the incorporating rule defines a need for 50 % matching. Thus, at least half of the points of the second scan need to correspond to the points of the reference model. The defined need for matching may be another value, such as 40% or 30 %, for example.

According to an embodiment, the control unit is provided with at least one incorporating rule defining required matching ratio between the second scanning data and the reference point cloud data. The control unit is configured to store the new point cloud data when the set incorporating rule fails. However, the control unit is configured to monitor oncoming future scanning data and is configured to incorporate the new point cloud data to the reference point cloud data when the set incorporating rule is fulfilled. Failing to find required match between the point clouds means that the scanning data and the existing mine model do not have enough overlapping areas and similarity. In such a case, the unfitting scanning data may be stored and utilized later. The control unit may monitor the scanning data that is produced later and may try to match the stored data to the oncoming scanning results. When a suitable overlapping scanning data is received the stored data may be included to the reference model.

According to an embodiment, the control unit is configured to communicate data on the updated reference model of the mine to a mine control system. The mine control system may indicate the updated portions for an operator. The mine control system may comprise a control room provided with one or more display devices. The updated data may be displayed in the display device with special markings or colors. Thus, supervision is facilitated.

According to an embodiment, the mine vehicle is provided with at least one separate reference object, which is settable to the mine external to the mine vehicle at least for the duration of surveying. The separate reference object may be a mobile marker that may be placed on a ground of a mine space. The separate reference object may comprise an appearance, outer surface or shape, which is easily recognizable from the scanning data. The separate reference object may be a ball.

According to an embodiment, the several separate reference objects set in unknown locations in a work site in the mine are detected in the second scanning data by the control unit. Coordinates of the reference objects are not known. The reference objects are stationary for the duration of successive scans. The reference objects may be plastic balls, for example. The reference objects may be thrown from the mine vehicle by the operator or a specific feeding device arranged on a carrier of the mine vehicle.

According to an embodiment, the control unit is provided with a collision prevention feature. The control unit is configured to produce a collision point cloud data by removing a point cloud data of the mine vehicle from the second scanning data, whereby the collision point cloud data only comprises coordinates of physical obstacles surrounding the mine vehicle. At least one control unit is configured to monitor position of at least one object of the mine vehicle in relation to the collision point cloud data. The disclosed collision prevention system may prevent collision to surrounding surfaces such as rock walls. In addition, the collision prevention system may prevent collision to other vehicles, other booms, auxiliary devices, rock blocks, persons or any other physical objects which may be located close to the mining vehicle or are entering to the proximity.

According to an embodiment, the control unit is configured to produce a wall collision point cloud data by removing point cloud data of objects being smaller in size than the mine vehicle. Thus, the wall collision point cloud data may only comprise coordinates of walls surrounding the mine vehicle.

According to an embodiment, the control unit is configured to execute collision prevention measures when the monitored object of the mine vehicle becomes at a distance from the any coordinate of the collision point cloud data shorter than a predetermined range.

According to an embodiment, the control unit is configured to execute collision prevention measures when a movement vector or a forecast of movement path of the monitored object of the mine vehicle becomes at a distance from the any coordinate of the collision point cloud data shorter than a predetermined range.

According to an embodiment, the mine vehicle comprises a boom and the collision monitored object is located in the boom. The control unit is configured to stop movements of the boom when the monitored object of the boom becomes at a distance from any coordinate of the collision point cloud data shorter than a predetermined range.

According to an embodiment, the mine control system is configured to monitor and record at least one of the following features: realized mine, mine portions and surrounding surfaces in 3D; drill holes currently influenced by the mine work device; current positions of selected or all mine vehicles operating in the mine or in a selected observation area; current status of the selected or all mine vehicles operating in the mine or in a selected observation area; estimated remaining duration of the current work task of the mine vehicle or the mine work device.

According to an embodiment, the mine control system is configured to update the reference point cloud data of a reference model of the mine on the basis of the scanned point cloud data.

According to an embodiment, the updating of the positioning data or reference point cloud data is performed in real time or at least in substantially real time.

According to an embodiment, the control system is part of a control room product configured to visualize the at least one monitored feature on at least one display device.

According to an embodiment, the mine control system comprises at least one server allowing monitoring data to be distributed to one or more terminal device via a data connection.

According to an embodiment, the control system is part of a control room product comprising a fleet managing feature monitoring the positions of selected mine vehicles.

According to an embodiment, the control system is part of a control room product comprising a fleet managing feature monitoring the operating status of selected mine vehicles.

According to an embodiment, the control system is part of a control room product comprising a fleet managing feature monitoring the operating condition and maintenance need for selected mine vehicles.

According to an embodiment, the control system is part of a control room product comprising a fleet managing feature monitoring a general status of one or more mine vehicles and one or more mine work devices.

According to an embodiment, the scanning device has a reach area and the scanning device is positioned so that at least one physical object of the mine vehicle is intentionally inside the reach area of the scan.

According to an embodiment, position of the scanning device is not predetermined and input to the control unit. The position of the scanning device may be set without calibration. Thanks to the disclosed point cloud matching systems and methods, no specific place is needed for the scanner device on a carrier.

According to an embodiment, the scanning device may comprise a 2D scanning unit, a rotating frame, a rotating device and a fastening unit. The 2D scanning unit is mounted to the rotating frame, which may be a shaft, a rotating table or any other support structure, which is rotatable and may be rotated by means of the rotating device. Thus, the 2D scanning unit is arranged to be rotated 360° degrees around a rotating axis of the rotating frame. The fastening unit allows fastening of the scanning device to the mine vehicle.

According to an embodiment, the scanning device may comprise a 3D scanning unit capable of producing scanning data 360° degrees around itself. In this embodiment the scanning device may be without any separate rotating means for rotating the scanning unit.

According to an embodiment, the scanning device comprises fastening unit allowing the scanning device to be fastened freely to a desired position on the carrier. The fastening unit may allow the scanning device to be fastened to an unknown position on the carrier or anywhere in else in the mining vehicle. Thus, the mining vehicle may be without any specific scanner mounting position.

According to an embodiment, the scanning unit is a laser scanner.

According to an embodiment, the scanning unit comprises at least one camera. The scanning device may be based on stereo vision system comprising at least two cameras. Alternatively, the scanning may be based on a technology known as a depth from focus –system, wherein one camera is used and the method basically works by taking a focus stack of an object, and then analyzing the luminance of each pixel in relation to its neighbors. The control unit may be provided with image processing system for processing data received from the one or more cameras.

According to an embodiment, the scanning device comprises in addition to the scanning unit at least one camera for recording color information of the scanned obstacles. The recorder color information may be connected to the scanned point cloud data. This way additional information may be gathered.

According to an embodiment, the 3D scanning data is obtained by round trip time of flight of a laser that is swept across measured surface or object. This type of remote sensing technique is also known as LiDAR (Light Detection And Ranging).

According to an embodiment, the 3D scanning data is obtained by round trip time of flight of single (modulated) light source and the return times of reflections from different parts of the measured surface or object. This type of remote sensing technique is also known as ToF (Time of Flight). In this embodiment ToF -cameras may be used.

According to an embodiment, the 3D scanning data is obtained by geometry of a known pattern of light projected to the measured surface or object shown in one or more camera images. This type of 3D scanning is also known as a structured light 3D scanning technique.

According to an embodiment, the 3D scanning data is obtained by analysis of multiple pictures taken of same target from different points of view. In this embodiment a stereo camera system may be exploited. The control unit may be provided with an image processing system for processing image data received from the two or more cameras.

According to an embodiment, the fastening unit of the scanning device comprises fast coupling means whereby the scanning device is readily mountable and dismountable to the mine vehicle. The fast coupling means may comprise at least one magnetic coupling element.

According to an embodiment, the scanning device is arranged movably. Thus, the scanning device has an operable position for executing the scanning and an idle position. The fastening unit of the scanning device may comprise at least one transfer device for moving the scanning device. The transfer device is configured to move the scanning device between the operable position and the idle position.

According to an embodiment, the scanning device comprises a protective housing or shield for covering at least the scanner. The protective housing may protect the scanning device against impurities, moisture, falling material and impacts. The protective housing may provide shield to the scanning device or at least to the scanning unit continuously or, alternatively only when not in use.

According to an embodiment, the scanning device is movable and comprises an operable position and an idle position. The idle position is located inside a protective housing. The protective housing may protect the scanning device against impurities, moisture, falling material and impacts.

According to an embodiment, the mine is an underground mine. The underground mine comprises an underground rock space, such as a tunnel, or a storage hall.

According to an embodiment, the mine is a surface mine comprising obstacles on the surface. The surface mine may be an opencast mine.

The disclosed mine vehicle may be utilized when implementing the disclosed mine control system and mapping method. The detailed embodiments, which are disclosed in connections to the mine vehicle, also relate to the method and the system, and vice versa.

The same equipment comprising the scanning device, point cloud matching program and control unit may be utilized in navigation, position detection of the mine work device and drill holes, mine surveying, collision prevention and also for providing information for the mine control system.

The above-disclosed embodiments can be combined to form suitable solutions provided with necessary features disclosed.

## Brief description of the figures

Some embodiments are described in more detail in the accompanying drawings, in which

Figure 1 is a side view of a rock drilling rig provided with a drilling unit,

Figure 2 shows schematically a principle of scanning surfaces and obstacles surrounding a mining vehicle,

Figure 3 is a schematic side view of a scanning device arranged on a carrier of a mining vehicle and being able to be covered by a cover,

Figure 4 is a schematic view of a basic principle of point cloud matching,

Figure 5 is a schematic and strongly simplified view of a process detecting new or changed surfaces of a mine, and incorporating the detected deviating point cloud data after matching scanned data with a reference data,

Figure 6 is a schematic and strongly simplified view of an updated reference point cloud data, which incorporates detected new scanned points,

Figure 7 is a schematic and strongly simplified view of a situation where the second point cloud data fails to match with the reference point cloud data, and Figure 8 illustrates a situation when the when the second point cloud data matches with the reference point cloud data afterwards when one or more scanning results have been incorporated to the reference point cloud data,

Figure 9 is a schematic and strongly simplified view of an updated reference point cloud data comprising several new point cloud data elements,

Figure 10 is a schematic view of a control block or diagram showing related elements, control means and features of the disclosed solution, and

Figures 11a to 11f show schematically a procedure of scanning new areas and utilizing movable reference points for assisting point cloud matching.

For the sake of clarity, the figures show some embodiments of the disclosed solution in a simplified manner. In the figures, like reference numerals identify like elements.

**Detailed description of some embodiments**

Figure 1 shows a rock drilling rig 1 as an example of a mine vehicle. Also rock bolting rigs, charging rigs, measuring vehicles and transport and loading vehicles are mine vehicles. The disclosed system and solution may be applied in all type mine vehicles. The rock drilling rig 1 comprises a movable carrier 2 and one or more booms 3 connected to the carrier 2. At a distal end portion of the boom 3 may be a drilling unit 4. The drilling unit 4 may comprise a feed beam 5 and a rock drilling machine 6 supported on it. The rock drilling machine 6 comprises a shank at a front end of the rock drilling machine 6 for connecting a tool 7. At least one boom 3 may comprise a mine work device other than the drilling unit. Thus, the mine work device may be a rock bolting unit or a charging unit, for example.

In Figure 1 the rock drilling rig 1 is operating in an underground mine space 8, which may be a tunnel, storage hall or corridor, for example. The mine space 8 may comprise a face surface 9, wall surfaces 10 and a roof surface 11. The rock drilling rig 1 is provided with one or more scanning devices S for measuring surroundings of the rock drilling rig 1. The scanning device S may scan 360° and may thus measure the surrounding surfaces and other obstacles around the rock drilling rig 1 and produce scanning data for the system. The scanning device S may comprise a laser scanner, a camera or any other device capable of producing point cloud data. The scanning device S may be placed on the carrier 2. The position of the scanning device need not be accurately predetermined and calibrated because of the disclosed system utilizing point cloud matching techniques. At least one component or object of the rock drilling rig is detected in the scanning data and produced point cloud data of the detected object is utilized in determination of relative position of the scanning device S on the carrier 2. The rock drilling rig 1 has a machine coordinate system 12 and the mine has a mine coordinate system 13. On-board the rock drilling rig 1 may be one or more control units 14 for receiving scanning data, performing point cloud matching and searching measures, producing position data and executing needed coordinate transformations according to principles disclosed before in this patent application.

Figure 2 shows scanning of surfaces of a mine space 8 surrounding a mining vehicle 1. Thus, point cloud data 15 is produced of wall surfaces 10a, 10b and a roof surface 11. As it is disclosed in the simplified Figure 2 with enlargements, the surfaces of the wall surfaces 10a, 10b and the roof surface 11 have individual shapes since the rock material is detached by blasting. Topography of the surfaces may be considered to be a kind of finger print of the mine. Figure 2 also discloses that by means of the scanning other obstacles 16, such as persons in a work site, may also be detected and a point cloud is then produced. In Figure 2, as well as in other Figures, it is illustrated by black dots 17 points where a ray of a scanning device S meets a physical target and causes detection. The point cloud data 15 comprises several points 17 created by the scanning. The points 17 are shown as black dots. It can be considered that the point cloud data represents information of what the scanning sees.

In Figure 3 a scanning device S is arranged on a carrier 2 of a mining vehicle 1. The scanning device S may comprises a protective housing 18 for protecting the scanning device S against impurities, moisture and impacts. The scanning device S and the protective housing 18 may be moved relative to each other, so that the scanning device has an operable position 19 for executing the scanning and an idle position 20 where it is protected by the protective housing 18. Alternatively, the scanning device S comprises fast coupling means whereby it can be easily mounted to the mine vehicle 1 only when a need for scanning exists.

Figure 4 discloses a basic principle of determining position and orientation of a mine vehicle 1 by means of scanning and point cloud matching. A surrounding of the mine vehicle 1 is scanned and a second point cloud data 21 is produced. An initial first point cloud data 22 may be created beforehand and it may be stored to a control unit 14a on-board the mine vehicle 1 or to an external control unit 14b. The control unit 14a, 14b may be provided with a processor and a point cloud matching program or algorithm for matching the second point cloud data 21 to the first point cloud data 22. Thus, the first point cloud data 22 serves as a reference point cloud data and the second point cloud data 21 serves as an operational point cloud data. In Figure 4 the match 23 is shown in a strongly simplified manner. On the basis of the match 23, the control unit 14a or 14b may determine position and orientation of the mine vehicle 1 in a mine coordinate system 13. Every point 17 of the point cloud data has x-, y-, and z- coordinates. In the simplified example of Figure 4, the second point cloud data 21 fits completely to the reference point cloud data 22.

Figure 5 discloses detecting new or changed surfaces of a mine. A mine vehicle provided with a scanning device may serve as a mobile surveying device. Thus, the mine vehicle may scan the surroundings when it stops at a work site for executing drilling or any other normal mine operation. A control unit is configured to execute point cloud matching analysis and to compare an operational second scanning data 21 to a reference scanning data 22 stored in the control unit or retrieved therein. During pattern matching the system detects if the operational second scanning data 21 comprises one or more new surrounding points 17a, which do not exist in the reference point cloud data 22. These new points 17a are shown in Figure 5 as dots with white filling. The control unit may be provided with one or more incorporating rules defining required matching ratio between the second scanning 21 and the reference point cloud data 22. The incorporating rule may define a need for 50 % matching, for example. If the set incorporating rule is fulfilled, the new points 17a are incorporated to the reference point cloud data 22. Thus, the mine vehicle allows newly created walls or changed surfaces to be detected and recorded. Figure 6 discloses the updated new reference point cloud data 22a, which incorporates detected new scanned points.

Figure 7 differs from Figure 5 in that the point pattern of the operational second point cloud data 21 fails to match with the point pattern of the reference point cloud data 22. Since no sufficient match between the patterns is found, the scanned second point cloud data 21 cannot be used for position and orientation determination. If no required match between the point clouds is found during pattern matching, this simply means that the scanning data and the existing mine model do not have enough overlapping areas and similarity. In such a case, the unfitting scanning data may be stored and utilized later.

Figure 8 illustrates a situation when the when the stored, and previously unfitting second point cloud data 21 now matches with the reference point cloud data 22 since one or more other matching scanning results 24 have been incorporated to the reference point cloud data. Then, the stored point cloud data 21 suddenly fulfills the incorporating rule. Thus, the control unit may monitor the scanning data that is produced later and may try to match the stored data to the oncoming scanning results. When a suitable overlapping scanning data is received the stored data may be included to the reference model. Figure 9 discloses the updated new reference point cloud data 22a, which incorporates detected new scanned points.

Figure 10 is a simplified diagram showing the related elements, control means and features of the disclosed solution. These issues are already presented above.

Figures 11a to 11f disclose a procedure allowing scanning new areas in a mine. The procedure utilizes movable, separate reference points 25 for assisting point cloud matching. The movable reference points 25 may be set to the mine external to the mine vehicle 1 at least for the duration of surveying. The separate mobile marker 25 may be a ball which may be thrown by an operator to unknown positions on a ground of a mine space 8. An appearance, outer surface or shape of the marking object 25 may be designed so that it is easy to recognize the marker 25 from the scanning data. Successive scans are made and the positions of the markers 25 are kept stationary between the scans. In Figure 11a the mine vehicle 1 is driven to a new area 26. Point cloud data 27 of the previous surfaces is already incorporated to a mine model. In Figure 11b mobile markers 25 are arranged on a ground and the scanning device S executes a new scan and explores new surfaces around the mine vehicle 1. A new point cloud data 28 is created, which includes points of the surfaces surrounding the mine vehicle and also points of the mobile markers 25. Then the mine vehicle is driven forward to a second new area 29 and mobile markers 25a arranged on the ground, as it is shown in Figure 11c. Thereafter a new scan is made. A second new point cloud data 30 comprises points of wall surfaces and also includes data on mobile markers 25 and 25a. The point clouds 28 and 30 may be bind together by means or recognized points of mobile markers 25. In Figure 11e the mine vehicle 1 is driven to a face area 31 and a final scan is made. A new third point cloud data 32 comprises points of surrounding surfaces and also points of mobile markers 25a. Figure 11f shows an updated reference point cloud data 22a, incorporating several point cloud elements 27, 28, 30 and 32, which may be accurately stitched together by means of identified mobile markers and disclosed pattern matching procedures and programs.

In order to improve understanding of the solution disclosed in this patent application below is presented additional material and disclosure of the solution and some embodiments. The disclosed solution provides a navigation procedure or position and orientation detection system, which may have the following advantages:

- Does not require any special skills for the operators.
- Can be completely automated.
- Does not need any infrastructure to support position measurement.
- No need for prisms or check-up points in the mine, no separate surveying tools, no special surveying crews.
- No need to place the scanning device on a specific place on a specific machine.
- The system is based on a point cloud best fit method.
- Provides statistical certainty since the outcome may be based on thousands of measurements. One or even hundred failed measurements do not have a major effect on the accuracy.
- Measuring is fast and may take only a minute or less time.
- Gives all six degrees of freedom for the position of the mine vehicle or part of a mine vehicle in the mine. In a rock drilling rig the degrees of freedom may be: X, Y and Z coordinates, tilt, roll and jaw angles.
- May provide a 3D scan of the entire surroundings of the mine vehicle.
- May provide visualization of the entire mine in a control room.
- May be connected to fleet management systems for indicating position and status of mine vehicles in the mine.
- The system may allow removal of all sensors in a boom of a rock drilling rig and may still give accurate position and angle information for drilled holes or installed bolts. The system may also avoid a need for any compensation model needed for deflection etc.
- The system may be applied in mine vehicles designed for underground and surface mines.
- Investment costs may be low since. The mine vehicle may be equipped with a scanning device and a calculation PC.
- With the real scanned model of the mine, the fleet management system may show the mine as it is – including the locations of the machines.

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Initial scanning of the mine

Production drills, bolters and secondary breaking machines work in already created tunnels in a mine or a construction site. Development drill rigs work in an existing tunnel and create more tunnels. Because all these mine vehicles work in an already made space inside rock and the rock space is never the same, the shapes and curves of the rock surfaces around the mine vehicle may be used to locate the mine vehicle. Every wall and curve is like a fingerprint for the location. Exactly the same surfaces cannot be found in different mines.

The disclosed system can be taken into use in any existing mine, work site or construction area. A technician with a 3D scanner may enter to the work site and perform a 3D scan of the work site or the entire mine. This stage may be done with an accuracy of 2 mm with a grid size as small as 1 mm. Commercial products for scanning are available. Scans are done from multiple locations and the scanning results may be automatically stitched together so that the common parts of the scans have the best fit. Thus, several separate scans form one scan of the entire mine.

This stage provides a 3D model of the entire mine. The model can be used as visualization in fleet management and mine management systems to show the realized mine in 3D instead of a simplified drawing. When locations of mine vehicles are determined, they may be shown in a real model of the mine.

This initial scanning of the mine provides a point cloud of the entire mine in a mine coordinate system coordinates to be used as reference in the navigation, for example.

Determining position and orientation of the scanning device in the mine

On-board a mine vehicle is placed one or more scanning devices which may scan 360 degrees around themselves. The made scan may cover multiple square meters of tunnel walls, roof and possibly also a view longer into the tunnel to show some macro level of the mine in addition to small surface fluctuations next to the mine vehicle. The scanning device needs not to be placed in any special accurate position on the mine vehicle. Installation tolerances have no importance. What matters is, that the scanning device sees around and sees one or more parts or components of the mine vehicle as well.

In order to determe position of the scanning device in the mine the following process steps may be executed:

a. The scanning device makes a full scan of the surroundings.
b. Two point clouds exist: one from the initial scan and one provided by the scanning device.
c. An algorithm or pattern matching software program may be utilized to find out the best fit between the mine model and the scan made from a random mine vehicle location in the mine. The matching algorithm provides a best fit coordinate transformation between the scanning device (new scan) and the mine coordinate system (the mine scan).

Determining position and orientation of the scanning device in relation to the mine vehicle

In addition to the mine model, a control unit may also be provided with a point cloud of a key part of the mine vehicle. Mechanical engineering may transform for example a 3D model of a boom support of the mine vehicle to a surface point cloud data and determine coordinates of every point in the 3D model in relation to a machine coordinate system.

1. Once the scanning device made the scan of the surroundings it also made scanning of parts of the mine vehicle. The desired part, for example the boom support, is thus in the field of view of the scanning data.
2. A pattern matching algorithm is used to compare the scan to the point cloud of the desired part of the mine vehicle.

The algorithm provides the best fit between the compared point clouds. The result is the position and orientation of the scanning device in relation to the machine coordinate system.

Machine position in the mine

Machine position in the mine is the product of these two coordinate transformations. The transformation produces the position of the mine vehicle in the mine and the direction that the mine vehicle is in 3D.

The mine vehicle is provided with a boom position measurement system, whereby positions of all drilled production drill holes and installed rock reinforcing bolts may be determined and recorded in relation to the mine – not only in relation to the carrier. This information may be offered to fleet management systems and mine management systems and may also be used for example in blast pattern verification for production drilling purposes.

Expanding the mine model beyond the initial scan

Development drill rigs create new tunnels. When the rock drill rigs perform their normal operation, they work in existing tunnels and the new tunnel part is created by a blast. Once the development drill rig has navigated itself with the old part of the tunnel, it can incorporate the new part of the scan that it sees into the mine model and send it to a mine system. This gives immediate information of under- or over-break in the tunnel to the system and expands a mine network as the development excavation progresses.

Boom position measurement

A boom position measurement embodiment allows determination of drill hole and reinforcing bolt positions. The same procedure as was used to find out what is the relation between the scanner device and the carrier; a 3D design model of a feed beam or even the entire drilling module may be utilized to find out a relation between a drilling center and the scanner device. When the relation between the scanner device, the mine and the carrier is already determined by the disclosed system, coordinates of the drilled hole in relation to the mine vehicle or in relation to the mine may also be determined.

This embodiment may have the following advantages:

- No need for sensors in booms.
- More robust structure, no electronics in critical areas of the boom.
- Joints of the boom may be designed to be more robust since no space for sensors needs to be designed in.
- No need for calibration of joints of the boom in production or after sensor maintenance.
- Joint clearances have no effect on measurement accuracy.
- Boom deflection has no effect on accuracy.
- No need for complicated compensation models for un-ideal booms.
- More accurate boom position measurements; may be +/- 1mm when scanning is utilized.

- The scanning technique may be used together with the conventional joint measurement techniques, whereby some of the joint sensor may be removed.

Mine surveying

Mine surveying is an integral task in any mine development. It is also a task that currently requires special expertise and services for conducting the actual measurements. It is also a task that is divided into performing actual measurements and analysing and reporting the measurements into results.

According to the disclosed solution a 3D scanning device is arranged on-board a mobile mine vehicle for performing the needed mine measurements. The scanning device may interact with the mobile machines operation. Alternatively, the scanning device is a dedicated solution for surveying. The solution does not require that the mine vehicle has any kind of automated control system. Thus, the solution may also be applied to existing fully manual mine vehicles.

All mapping and surveying tasks may be outsourced to be done by the mine vehicle as a continuous parallel process to normal operations of the mine vehicle.

Every time the drill rig stops it may scan a 3D model of its surroundings and may then try to match the scanned data to the latest model of the mine. Algorithms have been developed to automatically extract mine rock surfaces from the scan and remove all objects such as people, mobile machines, cars etc. This way no irrelevant data ends up in the mine model or disturbs the following work flow.

If for example 50% of the area the drilling rig sees in its environment scan, is common to the existing mine model (or overlapping areas exists in the mine model), the new data can be fitted to the same coordinate frame as the mine model. If no match is found, it may mean that no overlapping area exists in the mine model. The unfitting scan can be stored so that it can be incorporated to the model when suitable overlapping data is received from a later scan.

After a match has been found, it can be checked if all points or surfaces in the new environment scan already existed in the mine model. If the surfaces have changed or new areas found, the changed areas may be updated to the mine model and sent forward to the mine central system where the main survey model may be stored.

An example is disclosed in the following:

A mine vehicle comprises an on-board scanning device, a calculation PC and a WLAN link.

The calculation PC, or a control unit, is provided with a current model of the mine. Latest version of the mine model can be downloaded via a WLAN link. Bandwidth and disk space are required. As an option for the fully on-board system is that the entire service may also be implemented as a cloud service in the mine server with no calculation on-board.

The mine vehicle is driven into a tunnel and is stopped.

The scanning device scans the area around the mine vehicle. A best fit algorithm determines where a new scan fits to an old scan.

Areas that are not in the original model, or areas that have changed, are updated into the survey model. The detected changes may be sent to a mine control room or central system. Data transfer may be limited by only sending changed or new areas.

After this, the mine vehicle may be moved and the measurement may then be repeated as many times as needed.

Entire new areas may also be surveyed without additional work phases or surveyors. Up to date mine model may be used for whatever purposes.

An accuracy improvement for the mine surveying:

Accuracy of fitting multiple scans may be improved by placing markers to the environment. Markers may be objects which have an easily recognizable shape such as round ball shaped objects. Coordinates of the objects need not to be known. All that is needed is that the markers stay in the same place between two consecutive scans. The added accuracy scenario does not require any special skills for the operators and can be easily automated.

An example of the accuracy improvement case is presented in the following:

1. When an operator wishes to scan or survey a new area of a mine, he drives the mine vehicle to a start point of the area to be surveyed. Preferably to an area that is already in the mine survey model.
2. The operator has 6 plastic balls or corresponding mobile markers on board the mine vehicle. The operator throws 3 pieces of the plastic balls to the ground near the sides of the tunnel and near the machine - in random places.
3. First scan is initiated and locations of the balls are identified.
4. The mine vehicle is driven forward.
5. The other 3 balls are thrown to the ground.
6. A second scan is initiated from a new location.
7. First two scans are tied accurately together by recognizing the first 3 balls that stayed in same place.
8. The mine vehicle is moved forward.
9. The first 3 markers are picked up and moved closer to the mine vehicle. The second 3 markers stay in place.
10. Third scan is initiated from a new location.
11. Scans 2 and 3 are tied accurately together by recognizing the 3 balls that stayed in same place.
12. The procedure is repeated as many times as needed. For the operator this embodiment involves only driving and placing six balls on the ground.

The above disclosed embodiment is disclosed in Figures 11a to 11f, which show schematically a procedure of scanning new areas and utilizing movable reference points for assisting point cloud matching.

The disclosed surveying procedure may have the following advantages:

- Survey crew underground time is minimized.
- Amount of information about mines status is expanded.
- Surveyor or mine planning has access to all surface coordinates instead of scattered measurements here and there.
- Fully automatic functionality and data flow are possible.
- The mine may update itself.
- Fully automatic system is possible.

- No special skills are required.
- Data for mapping purposes is created.
- Data for mine/fleet management purposes is created.
- Provides data for mine control room products.

Collision prevention

Currently even automatic machines have to have an operator on-board. One of the reasons for this is that the operator is needed there to watch that the automatic movement sequences designed in the office don't cause collisions to walls or other booms. No proper products exist for avoiding boom collisions to rock or objects in tunnel.

The same on-board scanner installation disclosed above is capable of retrieving a 3D scanned representation of the surroundings of the mine vehicle, while the mine vehicle is in the drilling position.

Algorithms, which are created to automatically separate the detected objects and the tunnel walls, may be utilized. Since rock walls don't move and the machine itself does not move during drilling operation, the scan needs to be done only once and may be used until the machine moves again.

The mine vehicle may be automatically removed from the scan, whereby all that remains in the model are coordinates for things that the machine should not collide with. Extraction process may separate all the objects from the walls. All the objects may also appear as separate elements from each other. The walls, the mine vehicle, people, small obstructions and inanimate objects on the ground may all be shown as separate elements from each other. If desired, only the mine vehicle is removed and all the smaller objects are left in the collision model. The mine vehicle may be recognized by object size when removing undesired elements. The booms may be prevented from colliding with anything at all, not only with the walls. In a simpler embodiment only collisions to the walls is monitored.

By using the navigation algorithm presented in this patent application, the position of the mine vehicle inside the scan may be determined automatically. Thus, all coordinates of the rock surface may be determined in relation to the mine vehicle. In order to improving computational speed, the surfaces may also be reduced to surface models with limited amount of points.

In mine vehicles provided with boom sensors, the position of the boom and all its parts may be calculated in relation to the mine vehicle. Any possible collision of the drilling module to the rock surface may be detected beforehand by monitoring the shortest distance from a determined point of the feed beam or boom to any point in the rock surface model.

The collision calculation needs not to be exact and include every detail of the mine vehicle. Instead, the distance calculation of perhaps 2 to 10 identified collision-prone points of the boom to the rock surface model should be enough. A forwards kinematics calculation may also be done easily for any point of the boom structure. If the distance between any point of the rock model and any one of the monitoring points becomes less than a set threshold, the boom may be stopped and warning signal may be produced. On the other hand, since the control system of the mine vehicle is aware of the position of the rock surface and other objects in the mine, collisions may be automatically avoided.

The drawings and the related description are only intended to illustrate the idea of the invention. In its details, the invention may vary within the scope of the claims.

## Claims

1. A mine vehicle comprising:

a movable carrier;

at least one scanning device for scanning surroundings of the mine vehicle and producing 3D scanning data of the surroundings; and

the mine vehicle being in operational communication with at least one control unit configured to receive and process the scanning data;

c h a r a c t e r i z e d in that

the control unit is provided with at least one processor and at least one point cloud matching program allowed to be executed in the processor;

an initial first point cloud data is input to the control unit, the first point cloud data comprising stored reference model of the mine in a mine coordinate system;

at least one second point cloud data produced by the scanning device of the mine vehicle is input to the control unit, the second point cloud data comprising operational scanning data of the current position of the mining vehicle;

the control unit is configured to execute the point cloud matching program in order to match the operational second point cloud data to the reference first point cloud data; and

the control unit is configured to determine position and direction of the scanning device in the mine coordinate system on the basis of the determined matching between the operational point cloud data and the reference cloud data.

2. The mine vehicle as claimed in claim 1, c h a r a c t e r i z e d in that

the mine vehicle comprises a machine coordinate system;

the mine vehicle comprises at least one reference object;

the operational second point cloud data comprises scanned points of the at least one reference object in addition to the scanned points of the surroundings;

position of the at least one reference object in the machine coordinate system is input to the control unit;

the control unit is configured to execute the point cloud matching program to match the operational second point cloud data with the reference first point cloud data, whereby also position and direction of the at least one reference object is determined in the mine coordinate system; and

the control unit is configured to execute a coordinate transformation process and determine position and direction of the scanning device in the machine coordinate system in response to determined position and direction of the at least one reference object in the mine coordinate system and the input position of the at least one reference object in the machine coordinate system.

3. The mine vehicle as claimed in claim 2, characterized in that

the mining vehicle comprises at least one supplementary reference object, which is arranged to a basic structure of the mining vehicle.

4. The mine vehicle as claimed in claim 2, characterized in that

the control unit is provided with a design point cloud data;

the design point cloud data is converted from a 3D design data of a predetermined structural reference object of a basic structure of the mine vehicle;

the structural reference object is inside a reach area of the scanning device and is thereby recorded_in the operational second point cloud data;

the control unit is configured to execute the point cloud matching program to determine position and direction of the structural reference object; and

the control unit is configured to fit the design point cloud data to the determined position and direction of the structural reference object.

5. The mine vehicle as claimed in claim 4, characterized in that

the control unit being able to determine coordinates of any point of the fitted design point cloud data, including also points, which are non-visible in the scanned second point cloud data.

6. The mine vehicle as claimed in claim 4 or 5, c h a r a c t e r i z e d in that

the mine vehicle comprises at least one boom and at least one mine work device at a distal end portion of the boom; and

at least one part of the mine work device is the observed structural reference object.

7. The mine vehicle as claimed in claim 2, c h a r a c t e r i z e d in that

position and shape of the at least one reference object in the machine coordinate system are input to the control unit;

the control unit is configured to examine the operational second point cloud data in order to find a point pattern matching with the input shape of the at least one reference object allowing position and/or orientation of the at least one reference object to be determined.

8. The mine vehicle as claimed in any one of the preceding claims 4 to 6, c h a r a c t e r i z e d in that

the mine work device comprises a feed beam and a rock drilling machine supported on feed beam; and

the control unit is configured to determine position and direction of the feed beam, and is configured to record the determined data as drill hole position and direction data when the feed beam is positioned at the drill hole.

9. The mine vehicle as claimed in any one of the preceding claims 4 to 6, c h a r a c t e r i z e d in that

the scanning device and the control unit are serving as a boom position measuring arrangement for detecting position and orientation of the mine work device.

10. The mine vehicle as claimed in claim 9, c h a r a c t e r i z e d in that

the boom is without any physical boom or joint position sensor.

11. The mine vehicle as claimed in any one of the preceding claims 1 to 10, c h a r a c t e r i z e d in that

the control unit is serving as a navigation device for determining position and direction of the mine vehicle in the mine coordinate system.

12. The mine vehicle as claimed in any one of the preceding claims 1 to 11, characterized in that

the mine vehicle comprises at least one data communication device allowing a data communication between the control unit and a mine control system.

13. The mine vehicle as claimed in claims 11 and 12, characterized in that

the control unit is configured to transmit position data of the mine vehicle to the mine control system via the data communication device.

14. The mine vehicle as claimed in any one of the preceding claims 1 to 13, characterized in that

the mine vehicle comprises at least one boom and at least one mine work device at a distal end portion of the boom; and

the mine vehicle is provided with a boom position measuring arrangement for detecting position and direction of the mine work device in a machine coordinate system.

15. The mine vehicle as claimed in claim 14, characterized in that

the mine vehicle is a rock drilling rig comprising at least one drilling boom and a drilling unit at a distal end of the drilling boom; and

the drilling unit comprises a feed beam and a rock drilling machine supported to the feed beam allowing drill holes to be drilled at a work site of the mine vehicle.

16. The mine vehicle as claimed in claim 14, characterized in that

the mine vehicle is a rock reinforcing rig comprising at least one boom and a reinforcing unit at a distal end of the boom for influencing drill holes at a work site of the mine vehicle.

17. The mine vehicle as claimed in any one of the preceding claims 1 to 16, c h a r a c t e r i z e d in that

the control unit is configured to determine and record the position of the mine vehicle at the work site; and

the control unit is configured to determine and record positions and directions of the drill holes influenced by the mine work device of the mine vehicle in the mine coordinate system.

18. The mine vehicle as claimed in claim 17, c h a r a c t e r i z e d in that

the mine vehicle comprises at least one data communication device allowing data communication between the control unit and a mine control system; and

the control unit is configured to transmit position and direction data of the influenced drill holes to the mine control system via the data communication device.

19. The mine vehicle as claimed in claim 17 or 18, c h a r a c t e r i z e d in that

the control unit is configured to store position and direction data of the influenced drill holes.

20. The mine vehicle as claimed in any one of the preceding claims 1 to 19, c h a r a c t e r i z e d in that

the control unit provided with the point cloud matching feature is on board the mining vehicle.

21. The mine vehicle as claimed in any one of the preceding claims 1 to 19, c h a r a c t e r i z e d in that

the control unit provided with the point cloud matching feature is external to the mining vehicle.

22. The mine vehicle as claimed in any one of the preceding claims 11 to 21, c h a r a c t e r i z e d in that

the control unit is configured to detect in the second scanning data new or changed surrounding point cloud objects around the mine vehicle allowing newly created or changed walls to be detected and recorded; and

the control unit is configured to incorporate the new point cloud data to the reference point cloud data of the reference model of the mine.

23. The mine vehicle as claimed in claim 22, characterized in that

the mine vehicle provided with the scanning device is serving as a mobile surveying device;

the control unit is configured to process the second scanning data by extracting point cloud data of the surrounding surfaces and removing point cloud data of all the other objects, whereby a simplified point cloud data of the surrounding surfaces is being created; and

the control unit is configured to incorporate the new simplified point cloud data to the reference point cloud data of the reference model of the mine.

24. The mine vehicle as claimed in claim 22 or 23, characterized in that

the control unit is provided with at least one incorporating rule defining required matching ratio between the second scanning data and the reference point cloud data; and

the control unit is configured to incorporate the new point cloud data to the reference point cloud data of the reference model of the mine only when the set incorporating rule is fulfilled.

25. The mine vehicle as claimed in any one of the preceding claims 22 to 24, characterized in that

the control unit is provided with at least one incorporating rule defining required matching ratio between the second scanning data and the reference point cloud data;

the control unit is configured to store the new point cloud data when the set incorporating rule fails; and the control unit is configured to monitor future scanning data and is configured to incorporate the new point cloud data to the reference point cloud data when the set incorporating rule is fulfilled.

26. The mine vehicle as claimed in any one of the preceding claims 22 to 25, c h a r a c t e r i z e d in that

the control unit is configured to communicate data on the updated reference model of the mine to a mine control system.

27. The mine vehicle as claimed in any one of the preceding claims 22 to 26, c h a r a c t e r i z e d in that

the mine vehicle is provided with at least one separate reference object, which may be set to the mine external to the mine vehicle at least for the duration of the surveying.

28. The mine vehicle as claimed in claim 27, c h a r a c t e r i z e d in that

several separate reference objects set in unknown places in a work site in the mine are detected in the second scanning data by the control unit.

29. The mine vehicle as claimed in claim 27 or 28, c h a r a c t e r i z e d in that

the reference objects are balls.

30. The mine vehicle as claimed in any one of the claims 1 to 29, c h a r a c t e r i z e d in that

the control unit is provided with a collision prevention feature;

the control unit is configured to produce a collision point cloud data by removing a point cloud data of the mine vehicle from the second scanning data, whereby the collision point cloud data only comprises coordinates of physical obstacles surrounding the mine vehicle; and

the control unit is configured to monitor position of at least one object_of the mine vehicle in relation to the collision point cloud data.

31. The mine vehicle as claimed in claim 30, c h a r a c t e r i z e d in that

the control unit is configured to produce a wall collision point cloud data by removing point cloud data of all objects being smaller in size than the mine vehicle, whereby the wall collision point cloud data only comprises coordinates of walls surrounding the mine vehicle.

32. The mine vehicle as claimed in claim 30 or 31, characterized in that

the control unit is configured to execute collision prevention measures when the monitored object of the mine vehicle becomes at a distance from the any coordinate of the collision point cloud data shorter than a predetermined range.

33. The mine vehicle as claimed in claim 32, characterized in that

the mine vehicle comprises a boom;

the monitored object is located in the boom; and

the control unit is configured to stop movements of the boom when the monitored object of the boom becomes at a distance from any coordinate of the collision point cloud data shorter than a predetermined range.

34. A mine control system comprising:

a mine vehicle provided with at least one scanning device and at least one on-board control unit

at least one control unit external to the mine vehicle; and

at least one data communication connection between the on-board control unit and the external control unit;

characterized in that

the mine vehicle is arranged to scan the mine by means of the scanning device of the mine vehicle;

at least one of the control units is arranged to determine the position of the mine vehicle by comparing a reference point cloud data of the mine and a scanned point cloud data by means of a point cloud matching program; and

the determined position data of the mine vehicle is recorded in the mine control system for updating the current position data.

35. The mine control system as claimed in claim 34, c h a r a c t e r i z e d in that

the mine control system is configured to update the reference point cloud data of a reference model of the mine on the basis of the scanned point cloud data.

36. The mine control system as claimed in claim 34 or 35, c h a r a c t e r i z e d in that

the updating is performed in substantially real time.

37. The mine control system as claimed in any one of the claims 34 to 36, c h a r a c t e r i z e d in that

the mine control system is configured to monitor and record at least one of the following features: realized mine, mine portions and surrounding surfaces in 3D; drill holes currently influenced by the mine work device; current positions of selected or all mine vehicles operating in the mine or in a selected observation area; current status of the selected or all mine vehicles operating in the mine of in a selected observation area; estimated remaining duration of the current work task of the mine vehicle or the mine work device.

38. The mine control system as claimed in claim 37, c h a r a c t e r i z e d in that

the mine control system is configured to visualize the at least one monitored feature on at least one display device.

39. The mine control system as claimed in any one of the claims 34 to 38, c h a r a c t e r i z e d in that

the mine control system comprises at least one server allowing monitoring data to be distributed to one or more terminal device via a data connection.

40. A mapping method, comprising:

creating an initial first point cloud data of a mine by means of at least one scanning device;

storing coordinates of the first point cloud data in a mine coordinate system as a 3D mine model;

driving a mine vehicle to the mine;

executing at least one operational scanning of the surroundings of the mine vehicle by means of at least one on-board scanning device of the mine vehicle;

c h a r a c t e r i z e d by

inputting produced at least one second point cloud data of the operational scanning of the surroundings to at least one control unit provided with a point cloud matching program;

inputting the point cloud data of the 3D mine model to the control unit and using it as a reference point cloud data of the mine;

executing the matching program in a processor of the control unit for searching matching points between the second point cloud data and the reference point cloud data; and

utilizing results of the matching process for determining position and orientation of the mine vehicle in the mine coordinate system.

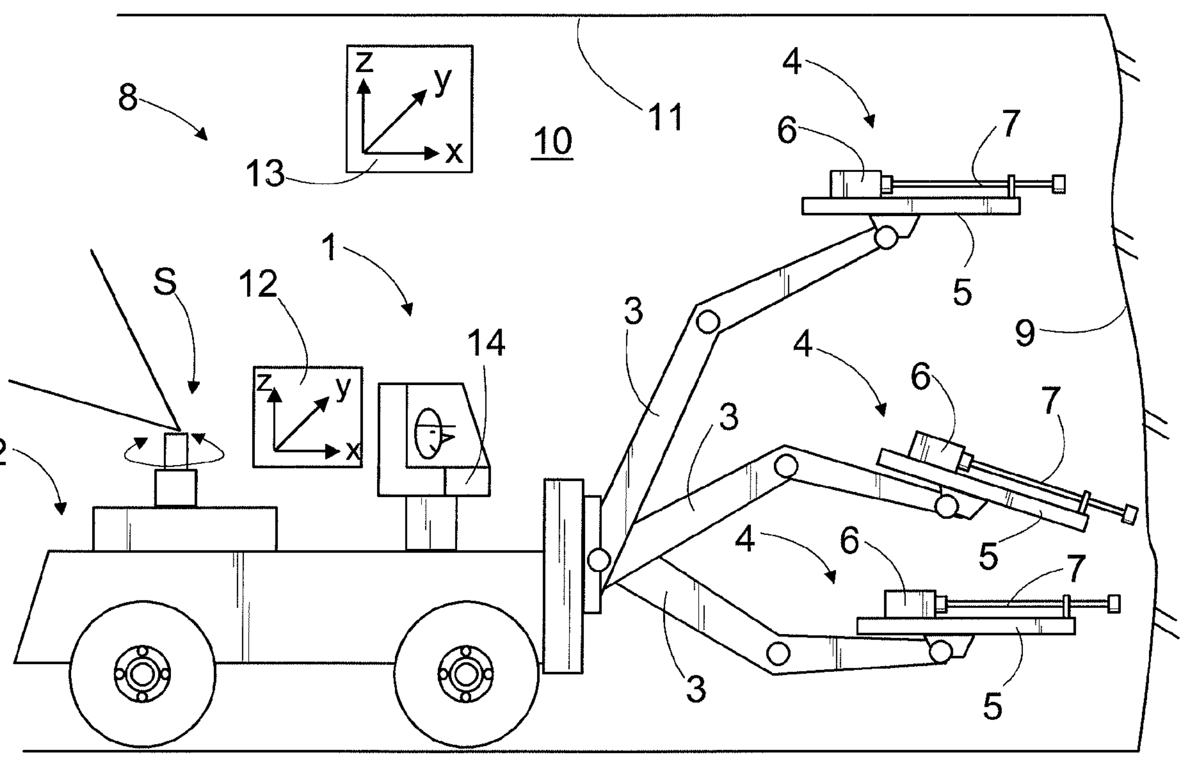


FIG. 1

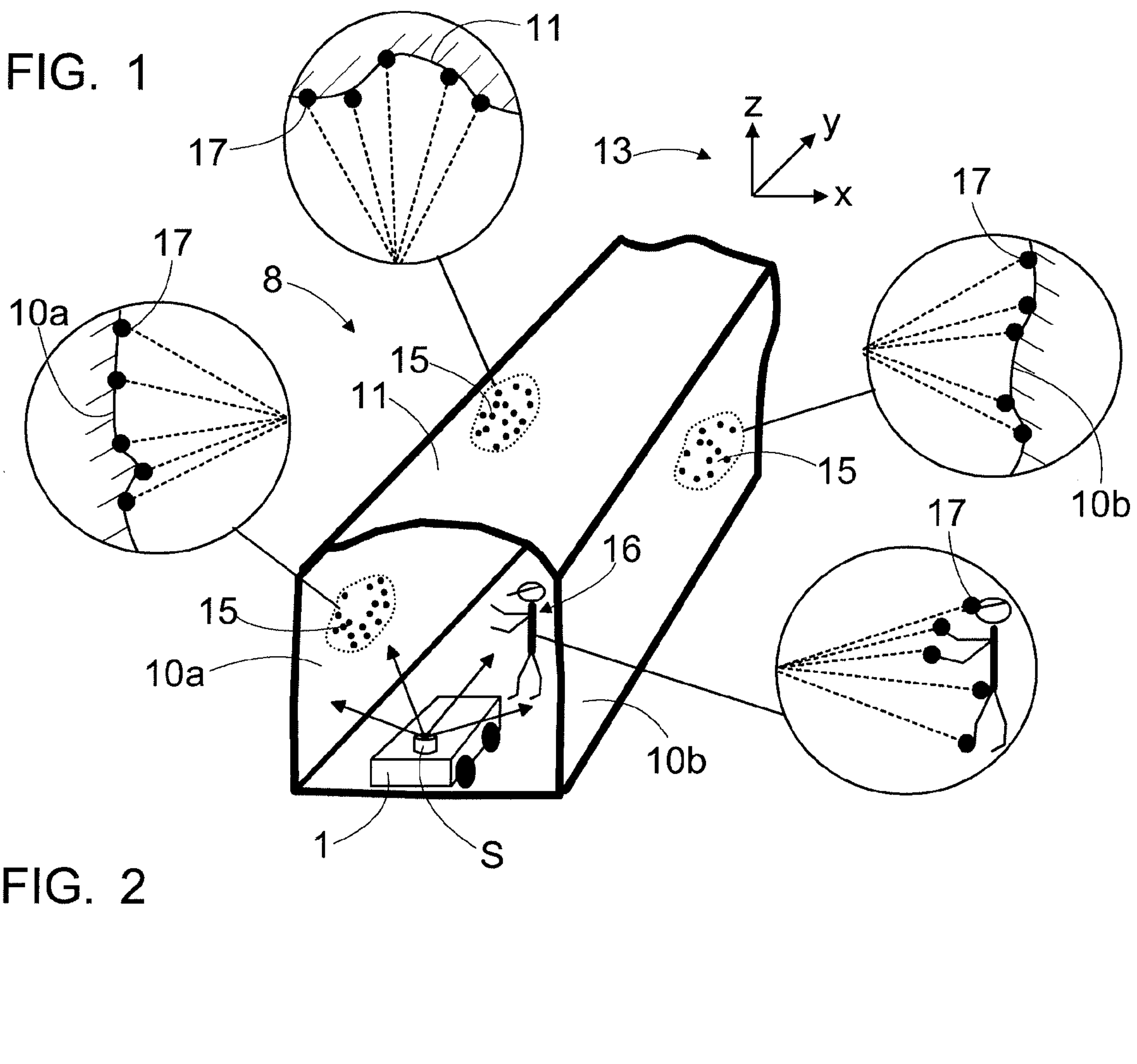


FIG. 2

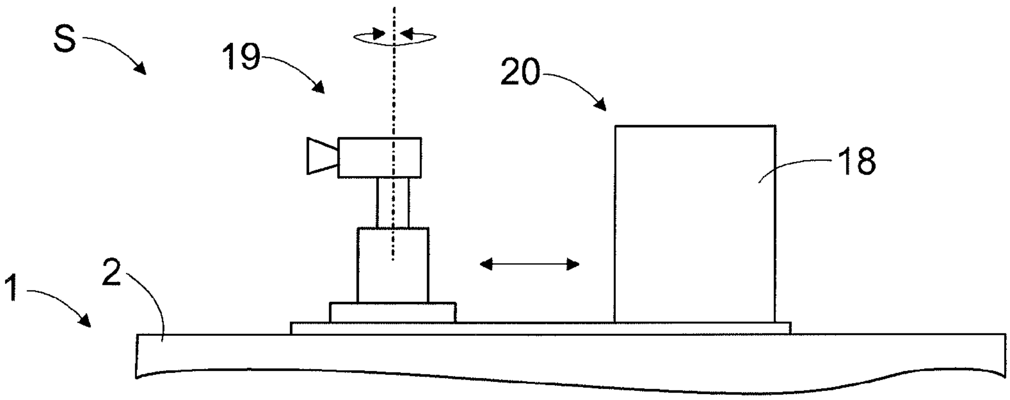
S
19
20
18
1
2

FIG. 3

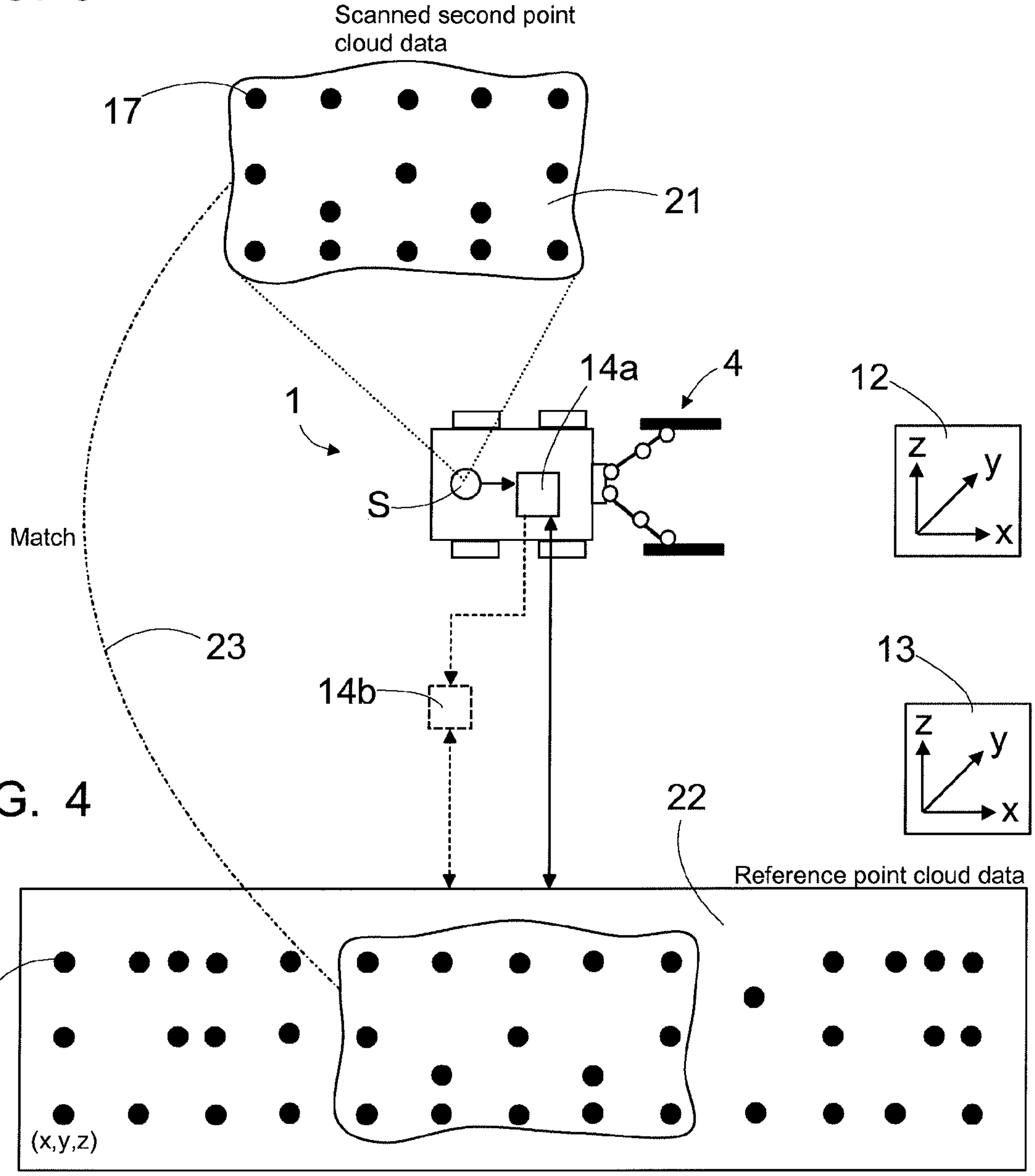
Scanned second point cloud data
17
21
14a
4
12
z
y
x
1
S
Match
23
14b
13
z
y
x
22
Reference point cloud data
17
(x,y,z)

FIG. 4

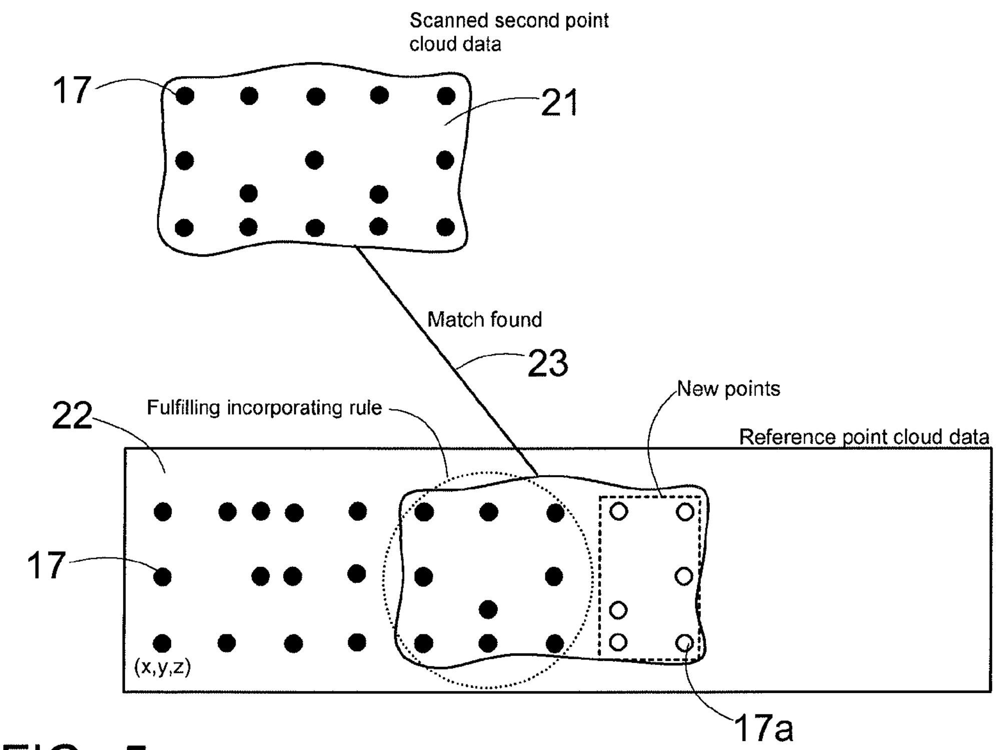
Scanned second point cloud data
17
21
Match found
23
New points
22
Fulfilling incorporating rule
Reference point cloud data
17
(x,y,z)
17a

FIG. 5

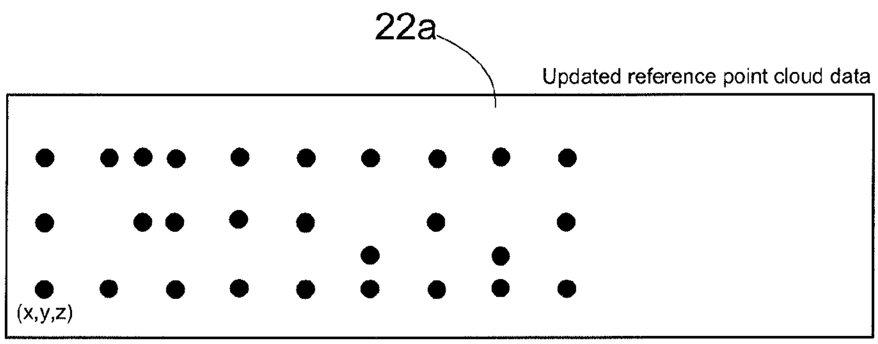
22a
Updated reference point cloud data
(x,y,z)

FIG. 6

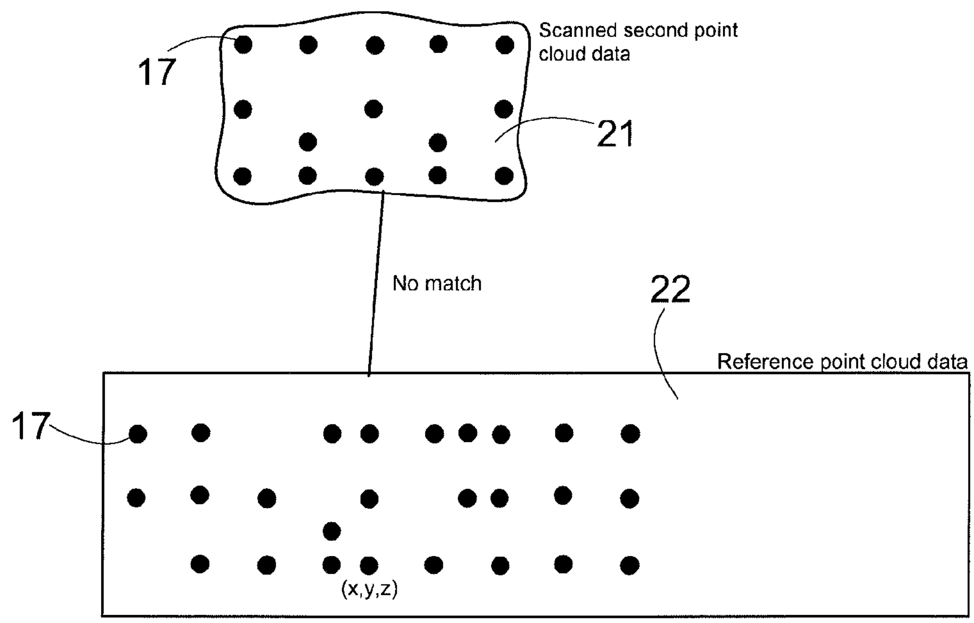


FIG. 7

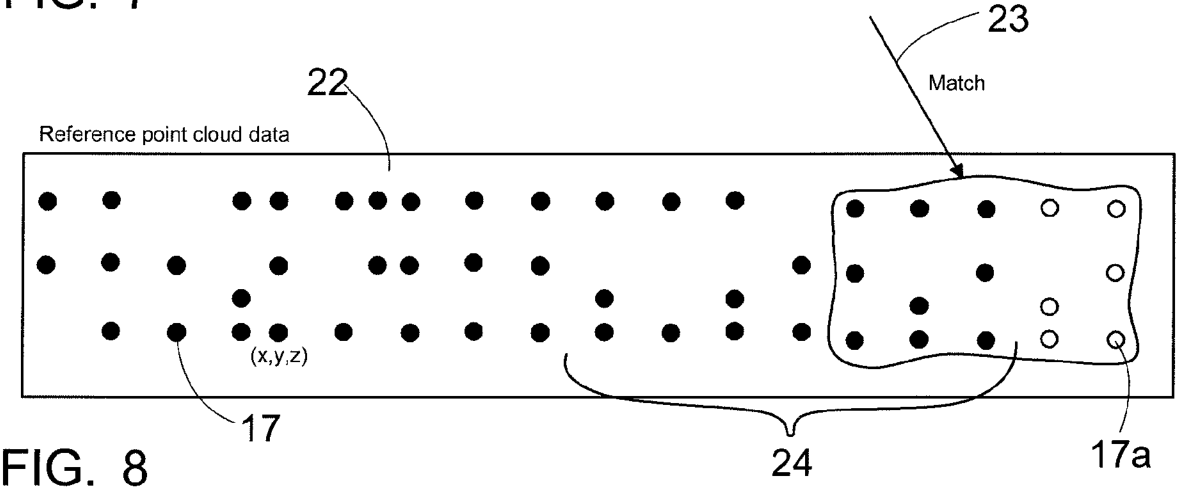


FIG. 8

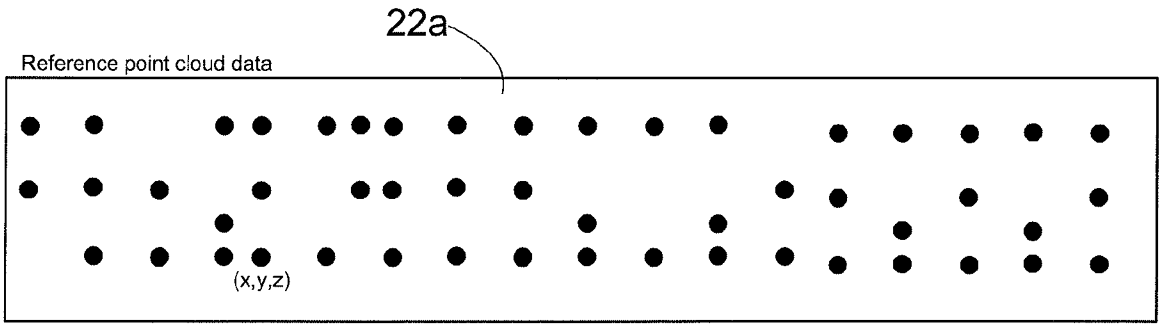


FIG. 9

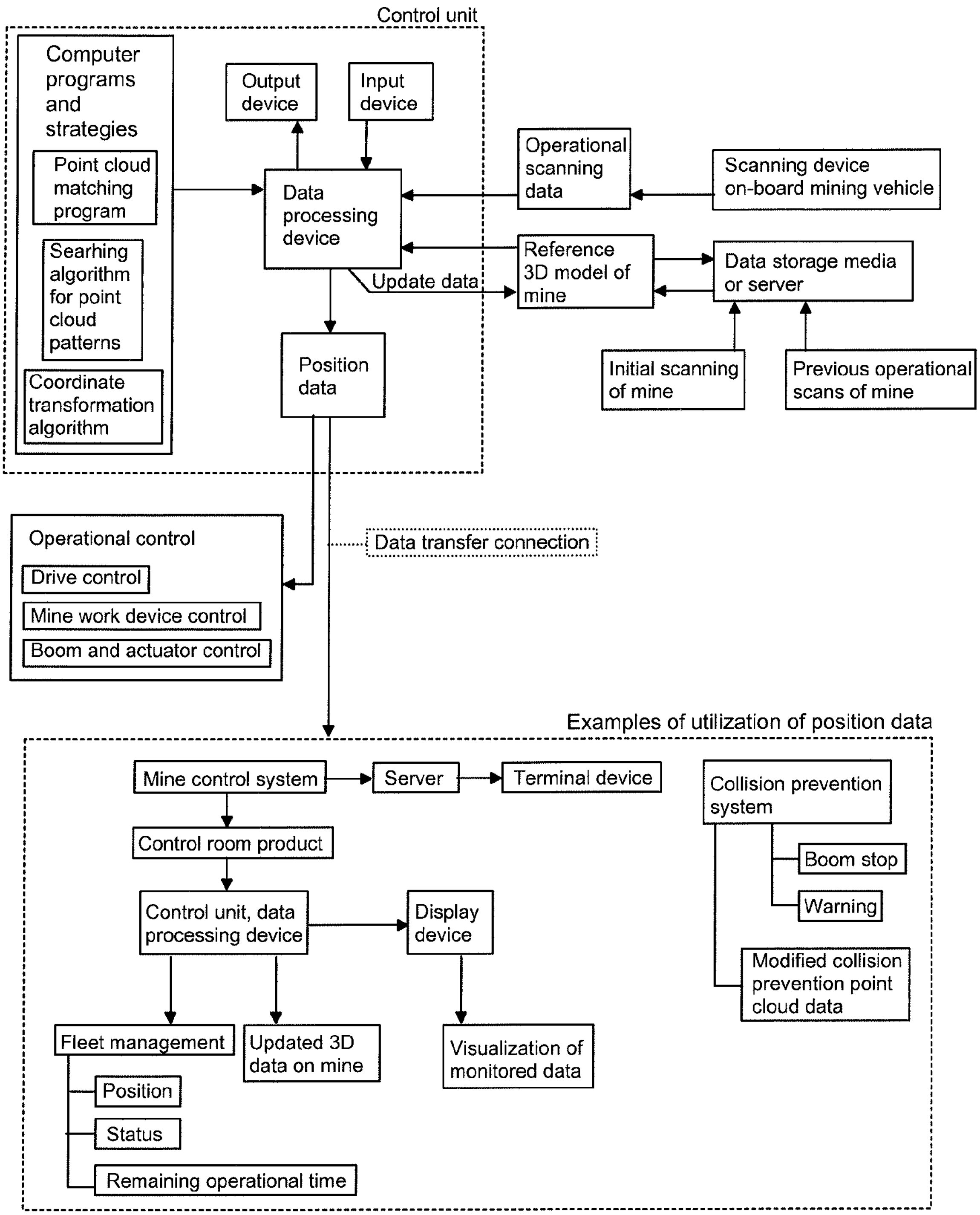
Control unit
Computer programs and strategies
Point cloud matching program
Searhing algorithm for point cloud patterns
Coordinate transformation algorithm
Output device
Input device
Data processing device
Update data
Position data
Operational scanning data
Scanning device on-board mining vehicle
Reference 3D model of mine
Data storage media or server
Initial scanning of mine
Previous operational scans of mine
Operational control
Drive control
Mine work device control
Boom and actuator control
Data transfer connection
Examples of utilization of position data
Mine control system
Server
Terminal device
Control room product
Control unit, data processing device
Display device
Fleet management
Position
Status
Remaining operational time
Updated 3D data on mine
Visualization of monitored data
Collision prevention system
Boom stop
Warning
Modified collision prevention point cloud data

FIG. 10

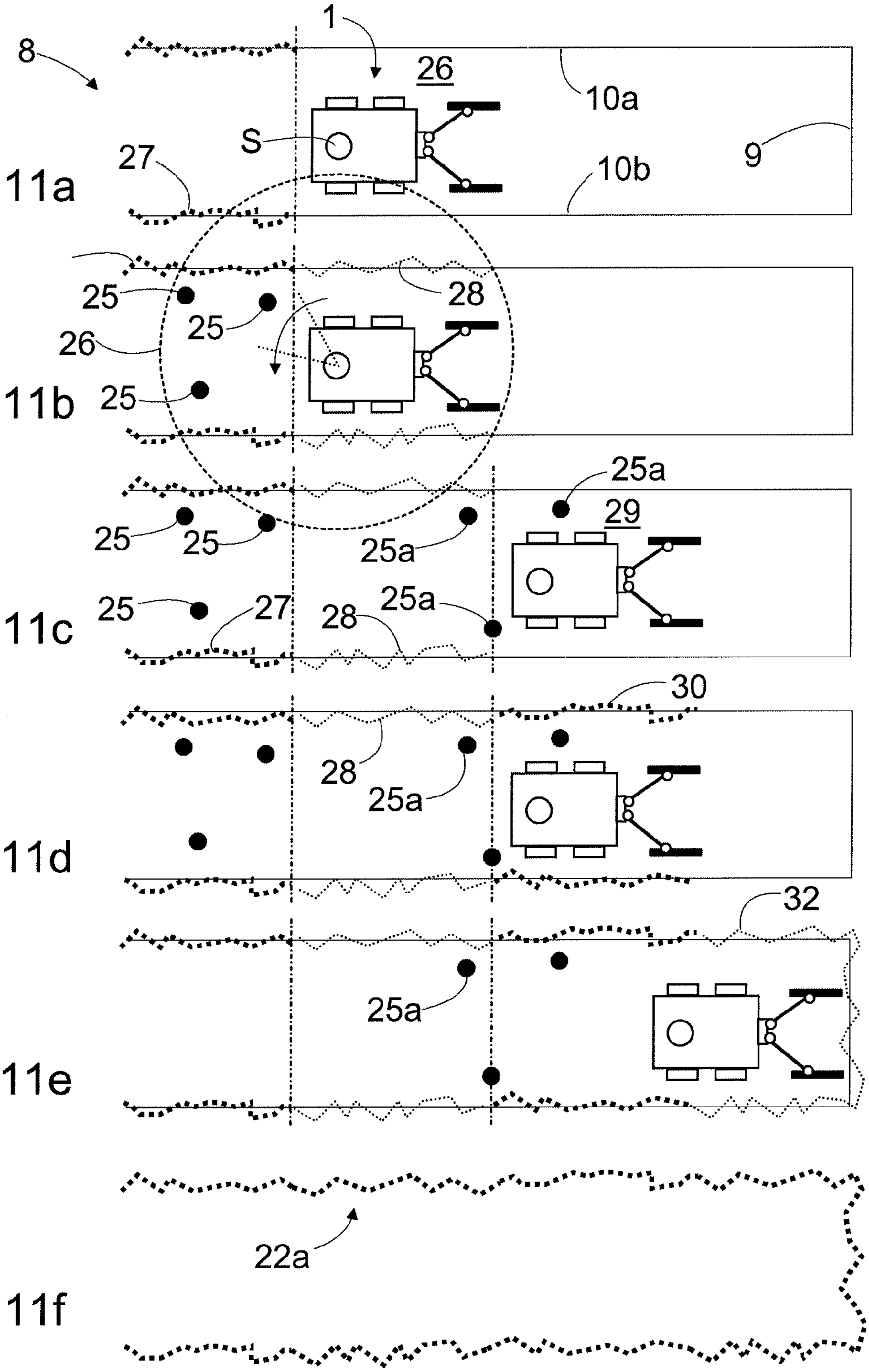


FIG. 11a

FIG. 11b

FIG. 11c

FIG. 11d

FIG. 11e

FIG. 11f

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2014/050598

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

"see additional sheet(s)"

**Remark on Protest**

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/050598

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. E21B7/02 G01C7/06 G01C21/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
E21B G01C G06T G05D G01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 1 176 393 A2 (INCO LTD [CA] CVRD INCO LTD [CA]) 30 January 2002 (2002-01-30)<br>paragraphs [0011], [0012], [0013], [0014], [0021], [0022], [0026], [0027], [0028], [0029], [0031], [0032], [0033], [0039], [0041]; figures 1-4<br>----- | 1,11-15, 20-22, 24,26, 34-40 |
| X | WO 2010/149856 A2 (SANDVIK MINING & CONSTR OY [FI]; RUOKOJAERVI JARKKO [FI]; MAEKELAE HAN) 29 December 2010 (2010-12-29)<br>paragraphs [0013], [0014]; figures 1-3<br>-----<br>-/-- | 1,34 |

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 19 August 2014 | 12/11/2014 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Georgescu, Mihnea |

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | JP 2010 086031 A (KAJIMA CORP; NAT INST OF ADVANCED IND SCIEN) 15 April 2010 (2010-04-15) paragraphs [0005], [0006], [0013], [0017]; figures 1, 2 | 1,34 |
| X | US 2005/283294 A1 (LEHMAN ALLEN A JR [US] ET AL) 22 December 2005 (2005-12-22) paragraphs [0012], [0021], [0023], [0026], [0034]; claim 1; figures 1-4 | 1,34 |
| A | WO 2011/141629 A1 (SANDVIK MINING & CONSTR OY [FI]; MAEKELAE HANNU [FI]; SIEVILAE JOUNI [) 17 November 2011 (2011-11-17) figures 1-6 | 1-15, 20-22, 24,26, 34-40 |

1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2014/050598

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|
| EP 1176393 | A2 | 30-01-2002 | AU | 760824 | B2 | 22-05-2003 |
| | | | AU | 5428801 | A | 24-01-2002 |
| | | | CA | 2347569 | A1 | 17-01-2002 |
| | | | EP | 1176393 | A2 | 30-01-2002 |
| | | | US | 6608913 | B1 | 19-08-2003 |
| WO 2010149856 | A2 | 29-12-2010 | AU | 2010101483 | A4 | 09-02-2012 |
| | | | CN | 102459811 | A | 16-05-2012 |
| | | | DE | 212010000094 | U1 | 30-03-2012 |
| | | | FI | 20095715 | A | 25-12-2010 |
| | | | WO | 2010149856 | A2 | 29-12-2010 |
| JP 2010086031 | A | 15-04-2010 | NONE | | | |
| US 2005283294 | A1 | 22-12-2005 | NONE | | | |
| WO 2011141629 | A1 | 17-11-2011 | AU | 2011251868 | A1 | 06-12-2012 |
| | | | CA | 2796986 | A1 | 17-11-2011 |
| | | | CN | 102893176 | A | 23-01-2013 |
| | | | EP | 2569652 | A1 | 20-03-2013 |
| | | | US | 2013060458 | A1 | 07-03-2013 |
| | | | WO | 2011141629 | A1 | 17-11-2011 |

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-15, 20-22, 24, 26, 34-40

   Vehicle of claim 1, wherein (potential special technical feature of claim 2) the mine vehicle comprises a machine coordinate system; the mine vehicle comprises at least one reference object; the operational second point cloud data comprises scanned points of the at least one reference object in addition to the scanned points of the surroundings; position of the at least one reference object in the machine coordinate system is input to the control unit; the control unit is configured to execute the point cloud matching program to match the operational second point cloud data with the reference first point cloud data, whereby also position and direction of the at least one reference object is determined in the mine coordinate system; and the control unit is configured to execute a coordinate transformation process and determine position and direction of the scanning device in the machine coordinate system in response to determined position and direction of the at least one reference object in the mine coordinate system and the input position of the at least one reference object in the machine coordinate system.
   Technical problem: how to improve the initial determination of the location and direction of the mine vehicle.

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2. claims: 16-19, 27-29

   The vehicle of claims 1 and 14, wherein (potential special technical feature of claim 16) the mine vehicle is a rock reinforcing rig comprising at least one boom and a reinforcing unit at a distal end of the boom for influencing drill holes at a work site of the mine vehicle.
   Technical problem: how to interact with holes present in the rock.

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3. claims: 23, 25

   The vehicle of claims 1 and 22, wherein (potential special technical feature of claims 23 respectively 25) the mine vehicle provided with the scanning device is serving as a mobile surveying device; the control unit is configured to process the second scanning data by extracting point cloud data of the surrounding surfaces and removing point cloud data of all the other objects, whereby a simplified point cloud data of the surrounding surfaces is being created; and the control unit is configured to incorporate the new simplified point cloud data to the reference point cloud data of the reference model of the mine respectively the control unit is provided with at least one incorporating rule defining required matching ratio between the second

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

scanning data and the reference point cloud data; the control unit is configured to store the new point cloud data when the set incorporating rule fails; and the control unit is configured to monitor future scanning data and is configured to incorporate the new point cloud data to the reference point cloud data when the set incorporating rule is fulfilled.
Technical problem: how to keep the reference point cloud data up to date.

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4. claims: 30-33

The vehicle of claim 1, wherein (potential special technical feature of claim 30) the control unit is provided with a collision prevention feature; the control unit is configured to produce a collision point cloud data by removing a point cloud data of the mine vehicle from the second scanning data, whereby the collision point cloud data only comprises coordinates of physical obstacles surrounding the mine vehicle; and the control unit is configured to monitor position of at least one object of the mine vehicle in relation to the collision point cloud data.
Technical problem: how to prevent damages of the vehicle.

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