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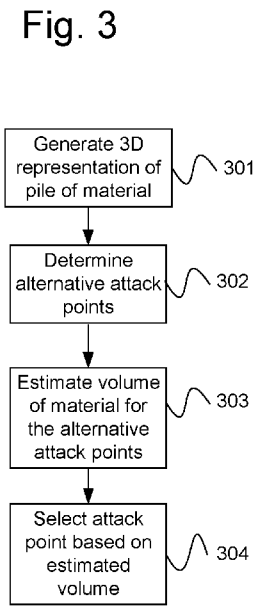
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(54) Title: METHOD AND SYSTEM FOR USE WHEN COLLECTING MATERIAL FROM A PILE OF MATERIAL USING A MINING AND/OR CONSTRUCTION MACHINE

(57) Abstract: The present disclosure relates to a computer-implemented method for selecting an attack point for loading material using a mining and/or construction machine having a bucket, where the attack point represents a bucket point of impact with a pile of material. The method comprises, prior to the mining and/or construction machine reaching the pile of material: generating a 3D representation of the pile of material; determining, using the generated 3D representation of the pile of material, a plurality of alternative attack points representing alternative positions of the pile of material for bucket impact with the pile of material; estimating, using the 3D representation of the pile of material and for each of the plurality of alternative attack points, a volume of material in relation to the respective attack point, wherein each volume of material corresponds to a respective portion of the pile of material; and selecting, based on the estimated volumes of material, an attack point of the plurality of alternative attack points for impact by the mining and/or construction machine.

Fig. 3



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METHOD AND SYSTEM FOR USE WHEN COLLECTING MATERIAL FROM A PILE OF MATERIAL USING A MINING AND/OR CONSTRUCTION MACHINE

Technical Field

The present disclosure relates in particular to mining and tunnelling, and more specifically to a method and system for use when collecting material from a pile of material such as an ore pile using a mining and/or construction machine. The disclosure also relates to a mining and/or construction machine, as well as a control arrangement that implements the method according to the disclosure.

Background

With regard to mining and tunnelling, for example, there is a constant ongoing process of improving, e.g., efficiency, productivity and safety. Examples of changes/improvements that are carried out to an increasing extent is the automation of, fully or partly, and/or remote control of, various processes occurring in mining.

It is, for example, often desirable that at least part of the machines that are used in mining/tunnelling can be operated in an autonomous mode, i.e., without an operator being required to influence the manoeuvring of the machine.

Autonomous operation may be utilised, e.g., to autonomously manoeuvre a machine from one location to another. This may be achieved based on a principle where the machine is first driven along a route in a path recording step, i.e., along the tunnels and/or drifts, along which the vehicle will later be driven autonomously. The machine is manually driven in the first step, e.g., by an operator present in an operator cabin of the vehicle or by remote-control from a remote-control station, from a position at which autonomous driving is to commence to a target position, while at the same time signals from various transmitters arranged on the vehicle are recorded. The recorded path may then be played back and autonomously followed by the machine by simultaneously determining its position in a map that is also generated while recording the path. This provides for an automation of a task that is repeated in precisely the same manner over and over again.

There also exist work tasks that would be desirable to automate, but where the conditions change each time the task is carried out. Such work tasks may include autonomous loading of material from a pile of material, such as an ore pile and/or a pile of rock, where the pile of material must first be identified prior to the machine being able to charge into the pile for excavation of material in the pile.

Summary

It is an object of the disclosure to provide a method for selecting an attack point for loading material from a pile of material using a mining and/or construction machine that may ensure that a sufficient amount of material is present at the location of a selected attack point to fill the bucket of a machine to a desired extent. A further object is to select an attack point that is accessible to the machine without colliding with surrounding obstacles.

According to an aspect of the disclosure, it is provided a computer-implemented method for selecting an attack point for loading material using a mining and/or construction machine, the mining and/or construction machine comprising a bucket, and the attack point representing a bucket point of impact with a pile of material. The method comprises, prior to the mining and/or construction machine reaching the pile of material:

generating a 3D representation of the pile of material;

determining, using the generated 3D representation of the pile of material, a plurality of alternative attack points;

estimating, using the 3D representation of the pile of material and for each of the plurality of alternative attack points representing alternative positions of the pile of material for bucket impact with the pile of material a volume of material in relation to the respective attack point, wherein each volume of material corresponds to a respective portion of the pile of material; and

selecting, based on the estimated volumes of material, an attack point of the plurality of alternative attack points for impact by the mining and/or construction machine.

As was mentioned above, there exists various situations in which it may be desirable to obtain an autonomous operation of a mining and/or construction machine. The present disclosure relates to situations when a machine is used to load and transport away material from a pile of material, such as, e.g., an ore pile. The pile of material may result, e.g., from blasting or be a pile where blasting remnants or other material have been collected in a pile. The pile of material may also be the result of other types of excavation.

The machines that are used for this purpose in general comprises a bucket that is loaded with material from the pile by charging into the pile in order to fill the bucket. In case the machine is manually operated, the operator determines a suitable attack point, i.e., a position of the pile at which the bucket is to impact the pile. The machine is then manoeuvred to the selected attack point. In case the machine is operated autonomously an attack point must also be selected, but the selection of attack point may be poor in that the selected attack point may be located at a portion of the pile that is unsuitable for adequate filling of the bucket. That is, the material being present in the pile at the selected attack point may not be sufficient to allow filling of the bucket to a desired degree. It may also be the case that an attack point is selected, but where, following selection, the machine may not be able to autonomously reach the attack point, e.g., due to obstacles in the surroundings preventing the machine from reaching the selected attack point without collision.

According to the present disclosure, it is provided a method for selecting an attack point for loading material that may increase the possibilities of accomplishing a filling of the bucket to a desired extent. The method is carried out prior to the mining and/or construction machine reaches the pile of material, such as, e.g., when coming within a predetermined distance of the pile, and/or when the pile is identified, so that the machine may be manoeuvred towards the selected attack point once selected. As was mentioned, an attack point is defined herein as a point of the pile of material at which the bucket is to impact the pile of material. The method may also be carried a plurality of times as the machine moves towards the pile, and the selected attack point may be reselected as the machine gets closer to the pile and thereby may establish a better knowledge of the shape of the pile.

During operation, the mining and/or construction machine will generally return multiple times to the same pile, excavating a portion of material from the pile each time. Each time the machine returns to the pile, the shape of the pile will have changed as a result of the previous excavation of material. Subsequently, a new attack point may need to be selected. An advantage of the provided method is that it can be applied every time the machine returns to the pile for successive excavation.

According to the method, a 3D representation of the pile of material is generated, where this 3D representation may be carried out in different ways as will be explained below. The generated 3D representation of the pile of material is then utilised to determine a plurality of, i.e., at least two, alternative attack points. That is, a plurality of alternative points for impacting the pile of material with the bucket are determined.

The 3D representation of the pile of material is then used to estimate, for each of the plurality of alternative attack points, a volume of material in relation to the respective attack point, where these attack points hence represent alternative positions of the pile of material where the bucket may impact with the pile when collecting material. The attack points represent different positions of the pile of material, thereby each estimated volume of material corresponds to a respective portion of the pile of material that is determined based on the position of the attack point. The estimated volumes of material are then used to select an attack point, among the plurality of alternative attack points, that is to be used for impact by the mining and/or construction machine when loading the bucket.

In this way, a plurality of alternative attack points can be evaluated based on the presence of material for portions of the pile that are defined in relation to the positions of the attack points, where, in particular, an attack point to be used can be selected based on the volume of material that is present for a portion of the pile being located at a particular attack point. This may facilitate the filling of the bucket, so that the bucket may be filled to a desirably high degree. The selection of attack point may also be used to ensure that the selected attack point is actually accessible by the machine without colliding with surrounding obstacles.

According to aspects of the disclosure, the selecting comprises to order the determined plurality of alternative attack points in an order of preference based on the estimated volumes of material for the attack points, and to select a highest ordered attack point. Consequently, an attack point may be selected that with a high degree of probability will be located at a portion of the pile comprising the most or at least a large amount of material.

According to aspects of the disclosure, the selecting further comprises to determine the existence of a drivable path from a current machine location to at least one attack point of the plurality of alternative attack points, the drivable path taking into account obstacles in the surroundings of the machine. The highest ordered attack point of the plurality of alternative attack points for which a drivable path from the current machine location to the attack point is determined to exist can be selected. In this way an attack point can be selected that is both reachable by the machine, and that may simultaneously direct the machine to a portion of the pile that comprises a comparatively large amount of material to be excavated.

According to aspects of the disclosure, the method further comprises to repeatedly determine presence of a drivable path for increasingly lower ordered attack points until a drivable path for an attack point is found, or until no ordered attack points remain. In this way, it can be determined whether it is possible to find a drivable path to the highest ordered attack point, and when this is the case this attack point can also be selected. However, if this is not the case, the search for a drivable path can continue to the second highest ordered attack point. If a drivable path is then found, this attack point can be selected for impact. If not, a yet lower ordered attack point can be evaluated for the existence for a drivable path, and this may be repeated until an attack point for which a drivable path exists is found, or until all alternative attack points have been evaluated.

According to aspects of the disclosure, the method further comprises to generate the 3D representation of the pile of material by generating a point cloud representation of the pile of material, and order the attack points at least partly based on a number of points of the point cloud belonging to the respective portions of the pile of material

that belong to the attack points. This provides a solution where, e.g., sensors that are commonly used in underground navigation, such as laser scanners, may be utilised to measure and register distances, including directions, to various positions on a pile of material, to thereby generate a representation of the pile being defined by the various measurements. The number of points being located within a portion of the pile being associated with a particular attack point may then be used to represent a degree of presence of an amount of material, and thereby be used to classify the attack points in relation to each other.

According to aspects of the disclosure, the points of the point cloud representation may represent heights of the pile of material for the position of the points, respectively, wherein the estimating of a volume of material may comprise to take the representations of the height of the pile of material into account. As was mentioned, sensors such as laser scanners may be utilised to determine distance and angle to various positions on the pile of material, and thereby also the elevation of the point and hence pile in relation to, e.g., the surface upon which the machine is resting, and/or the surface upon which the pile is resting, which may also be determined, e.g., using the measurements, where this data may be used to estimate the volume of material of the pile for the portion of the pile being associated with a particular attack point.

According to aspects of the disclosure, the method further comprises to determine the portion of the pile of material as a part of the overall area of the pile of material. Each attack point may thereby be associated with different portions of the pile, and hence volumes of material being present in the pile at the particular location of the attack point.

According to aspects of the disclosure, an attack point is discarded as an alternative attack point when the estimated volume of material is below a predetermined volume of material. In this way it can be ensured that only attack points representing portions of the pile that contain sufficient material to be likely to provide for a satisfactory degree of filling of the bucket are selected.

According to aspects of the disclosure, the estimation of the volume of material may comprise, for each alternative attack point, to divide the portion of the pile of material of the attack point into a plurality of subareas, and for each of the plurality of subareas calculate a mean value of the height of points of the point cloud being present in the subarea. The mean value may then be used to estimate a volume of the subarea, and the volume of the area of the attack point may be determined as a sum of the volumes of the sub areas. In this way, an accurate measure of a volume of material of the portion of the pile corresponding to the attack point may be obtained and utilised to order the alternative attack points in an order of preference based on this method of estimating the volume of material.

According to aspects of the disclosure, it is determined, for each subarea of an attack point, a population of point cloud points being present in the subarea. The subarea may be determined as unpopulated when the number of point cloud points is below a predetermined number of point cloud points. An attack point may be discarded as an alternative attack point if a predetermined number of subareas of the area of the attack point are determined to be unpopulated, since this may indicate that there are not enough point cloud points in the area of the attack point to accurately be able to estimate the volume of material relating to the attack point.

According to aspects of the disclosure, the method further comprises to determine the alternative attack points as points being at a predetermined distance from each other along an edge of the point cloud representation of the pile of material towards the machine. For example, a first attack point may be defined as a point of the point cloud representing the pile that is closest to the machine. A second attack point may be selected as the second closest point of the point cloud. However, since points of the point cloud may be closely located, an additional requirement may be that the points are also located at a predetermined distance from each other, and hence be selected as the closest points fulfilling also the distance requirement. This may provide for a number of alternative attack points that are spread out along the edge of the pile of the material, and/or at different distances from the machine, to thereby increase the probability that alternative attack points are provided where at least one

is both drivable and located at a portion of the pile providing sufficient material for a desired degree of loading.

According to aspects of the disclosure, presence of a pile of material in front of the machine is identified using point cloud data, and/or image processing of one or more camera images, and/or by receiving an indication of presence of a pile of material in front of the mining and/or construction machine. The 3D representation of the pile of material may then be generated in response to the received indication of presence of a pile of material. Hence, according to aspects of the disclosure, the presence of a pile of material in front of the machine can be identified, e.g., through analysing data received by the one or more sensors of the machine. According to aspects of the disclosure, e.g., an operator may signal to the machine that it is approaching a pile of material, and that generation of the 3D representation of the pile therefore is to be commenced.

According to aspects of the disclosure, one or more distances to respective objects in in a plurality of different directions are determined in relation to a longitudinal axis of the machine through obtained sensor data, and the 3D representation of the pile of material is determined using the determined one or more distances. In this way measurement data that is oftentimes any way generated when manoeuvring the machine may be utilised to generate the 3D representation of the pile of material.

According to aspects of the disclosure, sensor means are configured to scan an area in front of the machine in a plurality of angles in relation to a horizontal plane as well as a vertical plane intersecting a longitudinal axis of the of the machine. This provides for measurements that may, inter alia, provide information regarding the width and height of the pile.

As was mentioned, the sensors being utilised to identify, and generate the 3D representation of, the pile of material may comprise scanning laser sensors, such as LIDAR sensors. However, various other alternatives exist, such as radar sensors, one or more cameras providing images for image processing. Steering angle sensors and odometer sensors may also be used in the generation of the 3D representation, where travelled distance and/or steering angle may be taken into account when

determining the location of measurements in relation to previous measurements as the measurements are carried out while the machine is travelling towards the pile.

According to aspects of the disclosure, the method comprises, in addition to selecting an attack point, autonomously manoeuvring the mining and/or construction machine to the selected attack point.

According to aspects of the disclosure the attack points are defined, in addition, with an intended direction of motion of the machine when impacting the pile of material at the particular attack point, where different attack points of the alternative attack points may be defined with different directions of impact. For example, the intended direction of motion when impacting the attack point may be defined by the direction towards the attack point from the current position of the machine.

There may also be attack points having different directions starting at similar locations to thereby account for different portions of the pile, and also different possibilities of accessing the pile from the current machine location.

According to further aspects of the disclosure, it is provided a computer program and/or a computer-readable medium, comprising instructions which, when executed by a computer, cause the computer to carry out the steps of the method aspects of the disclosure. It will be appreciated that all embodiments and advantages discussed above will also be applicable to computer program aspects of the disclosure and to computer-readable medium aspects of the disclosure.

According to a further aspect of the disclosure, it is provided a control arrangement for selecting an attack point for loading material using a mining and/or construction machine comprising a bucket, where the control arrangement comprises processing circuitry configured to carry out the steps of the method aspects of the disclosure.

It will be appreciated that all the embodiments described for the method aspects of the disclosure are applicable also to control arrangement aspects of the disclosure. Thus, all the aspects described for methods according to the disclosure may be performed by the control arrangement, which may also be a control device, i.e., a device. The control arrangement and its embodiments have advantages

corresponding to the advantages discussed above with regard to the various aspects of methods according to the disclosure.

This also applies to the mining and/or construction machine aspect of the disclosure, since the mining and/or construction machine comprises a control arrangement according to the disclosure. The machine may also comprise a control system for manoeuvring the machine to a selected attack point, and for controlling the bucket to impact the pile of material at the selected attack point, where this may be configured to be carried out autonomously.

Further characteristics of aspects of the disclosure and advantages thereof are indicated in the detailed description of exemplary embodiments set out below and the attached drawings.

Brief description of the drawings

Figs. 1A-B illustrates an exemplary machine which may be configured to operate according to embodiments of the disclosure;

Fig. 2 illustrates an exemplary portion of an environment in which the machine of Figs. 1A-B may be operating, wherein a pile of material is present;

Fig. 3 illustrates an exemplary method according to the disclosure;

Fig. 4 illustrates an exemplary 3D point cloud representation of a pile of material and alternative attack points according to aspects of the disclosure;

Fig. 5 illustrates the point cloud representation of fig. 4 from above;

Fig. 6 illustrates a 2D representation of point cloud population of an area of the rock pile of fig. 4 being determined in relation to an attack point;

Fig. 7 illustrates a 3D representation of the subareas of Fig. 6.

Detailed description of aspects of the disclosure

Aspects of the present disclosure will be exemplified in the following in view of a particular kind of mining and/or construction machine. The disclosure is, however, applicable for all kinds of mining and/or construction machines that may be used to load material from a pile of material, such as to load ore from an ore pile.

Figs. 1A and 1B illustrates a side view and elevated view, respectively, of an exemplary machine 100, which may comprise a control system causing the machine to operate according to aspects of the disclosure. According to the present example, the machine 100 is a load-haul-dump (LHD) machine and is used to load and transport away materials such as excavated rock through the use of a bucket 101. The machine 100 comprises, apart from the bucket 101, wheels 102-105 for allowing the machine to be set in motion, and a control system comprising at least one control unit 106. The control unit 106 is configured to control various of the functions of the machine 100. Machines of the disclosed kind may comprise more than one control unit, e.g., a plurality of control units, where each control unit, respectively, may be arranged to be responsible for monitoring and carrying out different functions of the machine 100. For reasons of simplicity, however, it will be assumed in the following that the functions according to the disclosure are controlled by the control unit 106. The control unit 106 may, for example, be configured to control manoeuvring of the machine, e.g., in terms of setting the machine in motion, stopping the machine, and controlling and manoeuvring equipment forming part of or being attached to the machine, such as the bucket 101 e.g. when loading or unloading rock. Requests for setting the machine in motion may be initiated by a part of the control system controlling autonomous driving of the machine. The control unit 106 may further be configured to generate a 3D representation of a pile of material according to the disclosure.

The machine 100 further constitutes an articulated machine, where a front portion 100a is connected to a rear portion 100b by means of a hinge 107, and the machine is steered by means of articulated steering to facilitate manoeuvring of the machine. Machines of the disclosed kind are often driven in surroundings where the distance to surrounding rock walls may be small, and articulated machines may provide manoeuvrability advantages over non-articulated machines in such environments. As

is appreciated by a person skilled in the art, the illustrated machine merely forms an example of usability of the disclosure, and, in principle, the disclosure is applicable for essentially any kind of movable machine being utilized in mining and/or construction.

Motion of the machine 100 and/or equipment thereof, may be generated by setting one or more actuators in motion. Such actuators may comprise cylinders/motors/pumps etc. For example, the machine 100 may comprise actuators in the form of, e.g., hydraulic motors for propelling the machine 100. According to the disclosed example there may also be an actuator in the form of one or more hydraulic cylinders for controlling articulation of the joint 107.

The machine 100 may also comprise actuators, e.g., in the form of hydraulic cylinders for controlling raising/lowering the bucket 101, where further actuators may be present in this regard, e.g., to control tilting of the bucket 101. Machines of the disclosed kind may, e.g., be configured to be controlled by an operator being present in the machine, or configured to be remote-controlled, and/or be autonomously controlled, as may be the case according to the present example.

The machine may also comprise various further features. For example, the machine may be provided with range detectors such as laser scanners 111, 112 to determine distances e.g., to surrounding rock and/or obstacles in the travel path of the machine. The machine may also comprise, e.g., front and/or rear video cameras, which may connected to the control unit 106 and which may be utilized to transfer image and/or video signals to the control unit 106 for further transmission, e.g., to a remote-control operator in a control room in case the machine needs to be remote-controlled, and the cameras may also be used for monitoring and surveillance of an autonomously operating machine, and possibly also be utilized by an operator manually operating the machine. According to aspects of the disclosure, cameras such as stereo cameras may be used as an alternative to scanners for providing signals being used in the generating of a 3D representation of a pile of material.

As was mentioned above, machines of the kind disclosed in Figs. 1A-B may be of very large dimensions and exhibit substantial mass, and even more so when carrying

load, where machines of the disclosed kind may be designed to carry e.g., 10-30 tonnes of broken rock. It is highly desirable that machines of this kind can be driven autonomously as much as possible. According to the present disclosure, it is provided means for increasing the number of situations in which autonomous navigation can be utilised, by facilitating loading of material from a pile of material.

Fig. 2 illustrates a part of an exemplary underground environment 200 where the present disclosure may be utilised. According to the illustrated example, the machine 100 uses the bucket 101 (shown in figs. 1A-B) to load material such as broken rock and/or ore from a pile of material 201 at a location 202, to then, e.g., haul the load for dumping at some other location. The pile 201 may have a length, width and height. The machine 100 is, according to the present example, configured to navigate autonomously to the pile of material 201. Furthermore, according to the present example, the machine 100 is configured to autonomously charge into the pile of material. However, piles of material, such as the pile 201 may vary considerably in terms of physical appearance. That is, the shape of the pile may differ substantially from one pile to another, and the height of the pile may also vary considerably for different locations within a particular pile. It is in general a desire that amount of material being present at the portion of the pile around the attack point, i.e., around the position of the pile at which the bucket charges into the pile to load material, is sufficient to load the bucket to a desired extent.

In case the volume of material is low at the portion of the pile where the machine charges into the pile the resulting degree of filling of the bucket may be undesirably low. Still, when autonomously charging into a pile of material the resulting degree of filling may become whatever it becomes, if aspects such as the shape of the pile of material is not taken into account when autonomously charging into the pile of material.

According to aspects of the disclosure, it is provided a method for increasing the probability that the bucket is filled to a desired extent when charging, e.g. autonomously, into a pile of material. An exemplary method 300 for selecting an attack point for charging into a pile of material is schematically illustrated in Fig. 3. The method is computer-implemented, and may be carried out in the machine 100 by

the control system of the machine, such as by the control unit 106, or at least partly at a location remote from the machine, in which case sensor data may be transmitted from the machine 100 to the remote location. The method may also be implemented as a computer program and/or as instructions comprised in a computer-readable medium. The computer program and/or instructions can for example be executed by the control unit 106, or alternatively at a remote location to which data may be transmitted from the control unit 106 and back.

The method starts in step 301 where, according to the present example, a 3D representation of the pile of material is generated. According to the present example, a 3D representation in the form of a point cloud representation is generated, but according to aspects of the disclosure, other methods for generating the 3D representation may be utilized. For example, a stereo camera solution, or any other suitable solution may be utilized to generate the 3D representation, which may be a representation of the shape of the pile.

Fig. 4 illustrates an exemplary resulting 3D representation of the pile of material 201 of Fig. 2. According to the present example, the point cloud representation of the pile of material 201 is generated utilizing laser scanner 111 that determines distances to surrounding obstacles in various different directions, where measurements may be taken in various different directions in relation to, e.g., a longitudinal axis of the machine, both in relation to a horizontal plane of the machine as well as in relation to a vertical plane of the machine 100. Such measurements may, according to aspects of the disclosure, be used also when autonomously navigating the machine by determining, e.g., distances to surrounding rock walls etc. This is schematically illustrated by measurements indicated by dotted lines 203 in Fig. 2.

However, when travelling towards the pile of material, and in particular when the pile of material comes within reach of the laser scanners, or other sensor means of the machine, measurements representing points on the pile of material will be received by the machine 100. Since the laser scanner may scan in various different directions, a large number of measurements representing different points, i.e. positions, on the pile may be received by the machine, and be used to generate the 3D representation

of the pile of material. This is exemplified in Fig. 4, where a large number of points 401 are illustrated, and where the points, as can be seen in the figure schematically forms the shape of the pile 201. Fig. 4 also illustrates a number of alternative attack point and corresponding areas for the alternative attack points, as will be explained further below.

It is to be understood that when the machine 100 travels towards the pile of material, the part of the pile that is closest to the machine will also first come within range of the one or more laser scanners of the machine. Hence, the 3D representation may first comprise only very few points, but as the machine travels towards the pile of material the number of points forming the point cloud will successively increase until, e.g., a result of the kind disclosed in Fig. 4, is obtained. It is still to be understood that a result, such as the result of Fig. 4 may be obtained when the machine still is at a distance from the pile of material, such as, for example, 10 to 20 m or even further away from the pile. The solution according to the disclosure, which will be described below, may therefore be used as the machine is approaching the pile of material where an attack point is determined during the approach so that the machine during the final approach may steer towards the attack point that has been selected according to the disclosure. The method may also be repeated as the machine continues the travelling towards the pile, and more measurements have been received, until it is determined that a sufficient representation have been obtained, which, e.g., may be considered to be the case when the machine is within a certain distance from the pile.

Following the generation of the point cloud representation of the pile of material, the method continues to step 302 where a plurality of alternative attack points are determined. The alternative attack points may be determined in various different ways. In some embodiments, points of the point cloud that are closest to the machine may be used when determining alternative attack points.

This is schematically illustrated in Fig. 5, which shows the point cloud 201 from above. A movement direction for the machine is indicated in Fig. 5 by an arrow. In the present example, a first alternative attack point 501 is defined as the point of the

point cloud being closest to the machine. With regard to the second alternative attack point 502, this can for example be defined as the closest point of the point cloud that is located at least a predetermined distance from the firstly selected alternative attack point. This means that, as can also be seen from the figure, that there may exist points of the point cloud that are in fact closer than the point being selected as the second attack point, but where these points are considered to be too close to an already selected attack point. If the attack points are too closely located they may exhibit only very small differences in terms of, e.g. volume of material and also be equally easy/difficult to reach with the machine.

In the present example, three different alternative attack points 501-503 are determined in accordance with the illustration in Fig. 5, for example through the described methodology. However, any suitable, higher or lower, number of alternative attack points may alternatively be determined. The alternative attack points are also schematically visible in Fig. 4. Following the determination of alternative attack points in step 302 the method continues to step 303, where a volume of material is estimated for each of the attack points. According to the illustrated example, this is carried out by defining areas 501A-503A corresponding to alternative attack points 501-503 respectively. In the present example, the areas 501A-503A each have a square shape. Each area may more generally be of rectangular shape, defined by a length and width. Each area forms part of the overall area of the pile of material. As can be seen from Fig. 5 the determined attack points 501-503 may, in addition to being defined as a point of impact by the bucket of the machine, also comprise an intended direction of driving when impacting the pile of material. These directions may be determined, e.g., by the direction to a particular attack point from the current machine location (schematically indicated in Fig. 5 by dashed lines towards the (non-visible) machine).

The size of the areas being associated with each attack point, respectively, may be defined as any suitable area, and, for example be defined by a width corresponding to the width of the bucket and a depth corresponding to, e.g., a normal depth of penetration of the pile by the bucket for a machine of the particular kind for which the attack points are determined. The estimation of a volume of material for a particular

attack point is then carried out, according to the present example, by dividing the area of this attack point to a number of sub areas. This is schematically indicated in Fig. 6, where area 501A of attack point 501 of Fig. 5 is illustrated more in detail. The movement direction of the machine is again indicated by an arrow. As can be seen from the figure, the area of the attack point is divided, according to the example, into twenty-five sub areas 1-25. The number of sub areas could however be any suitable number. In the present example, the sub areas are squares, but they may more generally be of rectangular shape. The sub areas do not have to be of the same shape as the area of the attack point. Fig. 6 represents a closer view from above of the area of the attack point in relation to the view of Fig. 5. According to aspects of the disclosure, a number of points of the point cloud that each of the sub areas 1 to 25 are populated with are counted. According to the example, sub areas 1, 6 and 9 are considered to be unpopulated, since no points of the point cloud are fully within these subareas. This is illustrated in the Fig 6. by the sub areas 1, 6 and 9 being crossed out. According to aspects of the disclosure, an attack point may be considered to be unsuitable for use as an attack point in case the number of unpopulated sub areas exceed a predetermined number of sub areas. This is because it may be considered difficult to obtain a desired accuracy when estimating a volume of material for the particular attack point, since having a number of unpopulated sub areas can be an indication of the point cloud containing too little data relating to the particular attack point. As an alternative to using completely unpopulated subareas as a criterion for being unpopulated, the subareas may be considered to be unpopulated if the population of points of the subareas instead is below some predetermined number of points. The limit for determining whether a subarea is to be considered unpopulated may depend on, for example, the overall number of points making up the point cloud, where this may depend on the sensors, for example. According to the present example, area 503A in Fig. 5 has been deemed unsuitable due to having too many unpopulated sub areas. The areas 501A and 502A in Fig. 5 have on the other hand been deemed to have enough populated subareas, which in Fig. 5 has been indicated by a diagonal line pattern in these areas, showing that they could still be suitable as attack points.

The population criterion may hence be used as a first test of the suitability of a particular attack point for actual use as an attack point. If an alternative attack point is deemed unsuitable on this basis, it may for example be discarded as an alternative attack point, or at least be deprioritized, i.e., be less preferred than other alternative attack points in any subsequent selection. Furthermore, when it comes to the estimation of a volume of material of a particular attack point this may be carried out using the heights of the points of the point cloud. This is schematically indicated in Fig. 7 for attack point 501, i.e., the attack point illustrated in Fig. 6. Fig. 7 illustrates an X-axis, a Y-axis as well as a Z-axis, the Z-axis illustrating the heights of the points, e.g., in relation to the current level of the surface upon which the machine, and/or the pile of material, is resting.

As is realized, the heights of the points of the point cloud represents a height of the pile of material at the location of the particular point of the point cloud. These heights may then be used to estimate a volume of material present for a particular sub area, and thereby also for the area of the particular attack point, by adding together the volumes of the various subareas. Furthermore, when estimating the volume of material for a particular subarea comprising more than one point of the point cloud, an average height of the points of the point cloud for the particular sub area may be used when estimating the volume of material for that particular sub area. In this example, the average height of each of the unpopulated sub areas 1, 6 and 9 has been set to zero.

The illustrated example hence provides a straightforward method for estimating a volume of material being present at a particular attack point. Following the estimation of volume of material for the alternative attack points 501-503 the method continues to step 304, where an attack point for impact with a bucket of the machine is selected based on the estimated volumes for the alternative attack points 501-503.

According to embodiments of the disclosure, the alternative attack points may be ordered in an order of preference based on the estimated volumes of material. In some embodiments, the alternative attack points are ordered directly from highest volume to lowest volume. In some embodiments the alternative attack points may

also be ordered partly based also on some other criteria. In particular, in some embodiments, the alternative attack points may be distributed into classes based on their corresponding estimated volume, then ordered within the classes based on some other criteria. For example, the alternative attack points may be distributed into an unpopulated point class, a low volume class, and a high volume class. The unpopulated point class could comprise those alternative attack points for which too many subareas have been deemed unpopulated as mentioned previously. The remaining alternative attack points could then be distributed into the low volume class or high volume class depending on their corresponding estimated volume. The alternative attack points in the high volume class could then be ordered higher than the alternative attack points in the low volume class, which in turn could be ordered higher than the alternative attack points in the unpopulated point class. Two alternative attack points within the same class, for example within the high volume class, could then be ordered based on some other criteria, such as the distance from the machine to the respective attack points. An advantage of ordering the alternative attack points at least partly based on their distance to the machine, is to prevent the machine from during successive excavations only excavating from a part of the pile with the highest volume, e.g., from the left part of the pile, and instead excavate evenly distributed between different parts of the pile, e.g., evenly distributed between the left and right part of the pile, for preserving the general contour of the pile.

Given an ordering of the alternative attack points, the highest ordered alternative attack point may then be provided, e.g., to a path planner of the machine 100, where the path planner then determines whether it is possible to manoeuvre the machine to the attack point in question without, e.g., colliding with surrounding obstacles. It may be the case, for example, that an attack point cannot be reached from the current machine location without colliding, e.g. with a rock wall or other obstacle being present in the surroundings of the machine. Such a path planner may be comprised in the control unit 106 of the machine 100.

If it is determined that the attack point that has been provided to the path planner is not suitable for selection for reasons such as this, the path planner may instead be provided with the second highest ordered attack point, whereupon the path planner

determines whether a drivable path exists for this attack point instead. If this is the case, the particular attack point is selected as the attack point to be used. The machine may then manoeuvre, e.g., autonomously, towards this attack point for charging into the pile and loading the bucket. However, for as long as no drivable path is deemed to exist the path planner may be provided with consecutively lower ordered attack points until an attack point with a drivable path is determined to exist, or no further alternative attack points remain in the order of preference.

In case it is determined that no drivable attack point exists an operator, e.g., being located in a remote-control centre may be alerted so that the operator may manually take over the loading of the bucket. Alternatively, the method may be repeated, and a new set of alternative attack points be determined and evaluated where these additional alternative attack points may be selected with the above-mentioned distance requirements in relation to the attack points that already have been evaluated.

According to the disclosure it is hence provided a method that may increase the probability of a successful autonomous loading of material from a pile of material by determining a plurality of alternative attack points to increase the probability that drivable attack point exist and also that the pile of material is attacked at a position that to the highest extent possible comprises sufficient material to allow filling of, e.g., the bucket of the machine to a desired extent.

Furthermore, a particular method utilising a point cloud for determining alternative attack points and their suitability has been illustrated above. It is to be noted that various other technologies may alternatively be utilised to determine the alternative attack points, and their suitability for use. For example, a stereo camera solution may be utilised, where image processing may be utilised to determine a 3D representation of the pile of material, where attack points may be selected in a similar manner, e.g. through closest distances to the machine as described above, and where volumes may also be estimated through calculations being performed on the 3D representation of the pile of material.

So far, aspects of the disclosure have been described largely with reference to an LHD machine. The disclosure may be utilized in any kind of movable mining and/or construction machine being utilised to collect material from a pile of material. The disclosure is also applicable for underground machines as well machines operating above ground.

Claims

1. A computer-implemented method for selecting an attack point for loading material using a mining and/or construction machine (100), the mining and/or construction machine (100) comprising a bucket (101), and the attack point representing a bucket point of impact with a pile of material (201), the method comprising, prior to the mining and/or construction machine (100) reaching the pile of material (201):

   generating (301) a 3D representation of the pile of material (201);

   determining (302), using the generated 3D representation of the pile of material (201), a plurality of alternative attack points (501-503) representing alternative positions of the pile of material (201) for bucket impact with the pile of material (201);

   estimating (303), using the 3D representation of the pile of material (201) and for each of the plurality of alternative attack points (501-503), a volume of material in relation to the respective attack point (501-503), wherein each volume of material corresponds to a respective portion of the pile of material (201); and

   selecting (304), based on the estimated volumes of material, an attack point of the plurality of alternative attack points (501-503) for impact by the mining and/or construction machine (100).

2. A method according to claim 1, wherein the selecting (304) comprises:

   ordering the determined plurality of alternative attack points (501-503) in an order of preference based on the estimated volumes of material for the attack points (501-503), and

   selecting a highest ordered attack point.

3. A method according to claim 2, wherein the selecting (304) further comprises:

   determining existence of a drivable path from a current machine location to at least one attack point of the plurality of alternative attack points (501-503), the drivable path taking into account obstacles in the surroundings of the machine (100), and

selecting the highest ordered attack point of the plurality of alternative attack points (501-503) for which a drivable path from the current machine location to the attack point is determined to exist.

4. A method according to claim 3, further comprising:

repeatedly determining presence of a drivable path for increasingly lower ordered attack points until a drivable path for an attack point is found, or until no ordered attack points remain.

5. A method according to one of the claims 1-4, further comprising:

generating (301) the 3D representation of the pile of material (201) by generating a point cloud representation of the pile of material (201); and

ordering the attack points (501-503) at least partly based on a number of points of the point cloud belonging to the respective portions of the pile of material (201).

6. A method according to claim 5, wherein the points of the point cloud representation represents heights of the pile of material (201) for the position of the points, respectively, wherein the estimating of a volume of material comprises:

taking the representations of the height of the pile of material (201) into account.

7. A method according to any one of the claims 1-6, further comprising:

determining the portion of the pile of material (201) as a part of the overall area of the pile of material (201).

8. A method according to any one of the claims 1-7, further comprising:

discarding an attack point (501-503) as an alternative attack point when the estimated volume of material is below a predetermined volume of material.

9. A method according to any one of the claims 1-8, further comprising:

identifying presence of a pile of material (201) in front of the machine (100) using point cloud data, and/or image processing of one or more camera images, and/or receiving an indication of presence of a pile of material (201) in

front of the mining and/or construction machine (100), and

generating (301) the 3D representation of the pile of material (201) in response to the received indication of presence of a pile of material (201).

10. A method according to any one of the claims 1-9, further comprising:

determining one or more distances to respective objects in in a plurality of different directions in relation to a longitudinal axis of the machine (100) through obtained sensor data, and

generating (301) the 3D representation of the pile of material (201) using the determined one or more distances.

11. A method according to any one of the claims 1-10, further comprising:

autonomously manoeuvring the mining and/or construction machine (100) to the selected attack point.

12. Computer program comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method according to any one of the claims 1-10.

13. Computer-readable medium comprising instructions which, when executed by a computer, cause the computer to carry out the method according to any one of the claims 1-10.

14. A control arrangement for selecting an attack point for loading material using a mining and/or construction machine (100) comprising a bucket (101), wherein the attack point represents a bucket point of impact with a pile of material (201), the control arrangement comprising processing circuitry configured to, prior to the mining and/or construction machine (100) reaching the pile of material (201):

generate (301) a 3D representation of the pile of material (201);

determine (302), using the generated 3D representation of the pile of material (201), a plurality of alternative attack points (501-503) representing alternative positions of the pile of material (201) for bucket impact with the pile of material (201);

estimate (303), using the 3D representation of the pile of material (201) and for each of the plurality of alternative attack points (501-503), a volume of material in relation to the respective attack point (501-503), wherein each volume of material corresponds to a respective portion of the pile of material (201);

select (304), based on the estimated volumes of material, an attack point of the plurality of alternative attack points (501-503) for impact by the mining and/or construction machine (100).

15. A mining and/or construction machine (100) comprising:

a bucket (101) for impacting with a pile of material (201);

means for receiving sensor signals for generating the 3D representation of the pile of material (201); and

a control arrangement according to claim 14.

16. A mining and/or construction machine (100) according to claim 15, wherein the sensor signals are transmitted by sensor means comprising one or more from: scanning laser sensors, radar sensors, LIDAR sensors, one or more cameras, steering angle sensors, odometer sensors.

17. A mining and/or construction machine (100) according to claim 15 or 16, further comprising:

a control system for manoeuvring the machine (100) to a selected attack point and for controlling the bucket (101) to impact the pile of material (201) at the selected attack point.

Fig. 1A

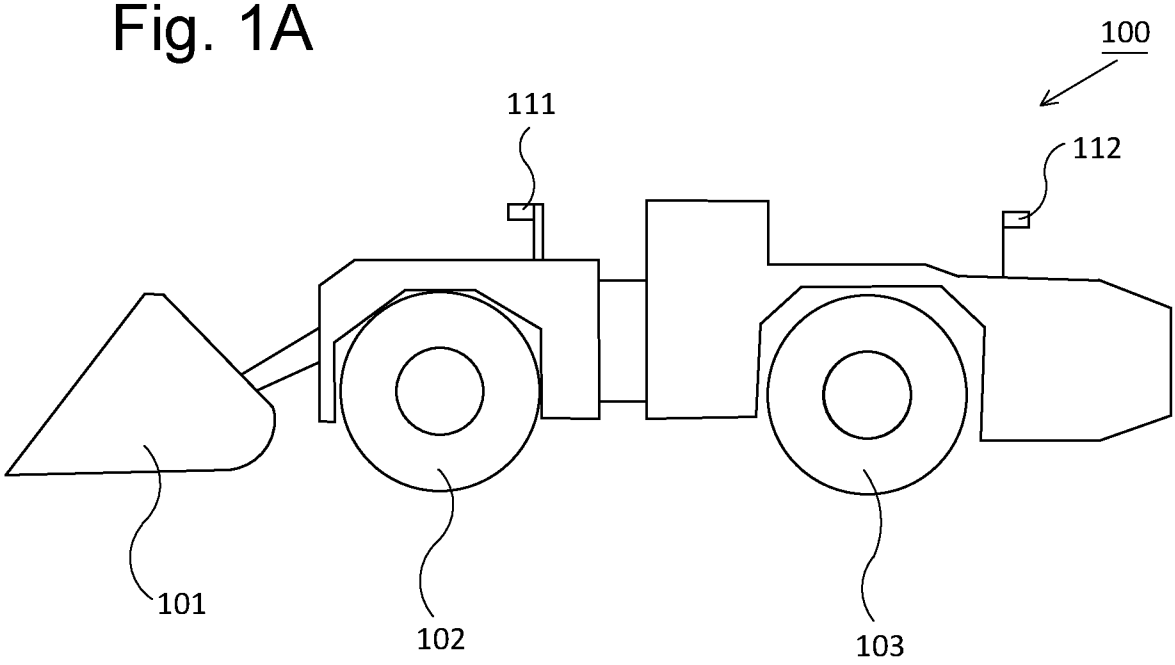
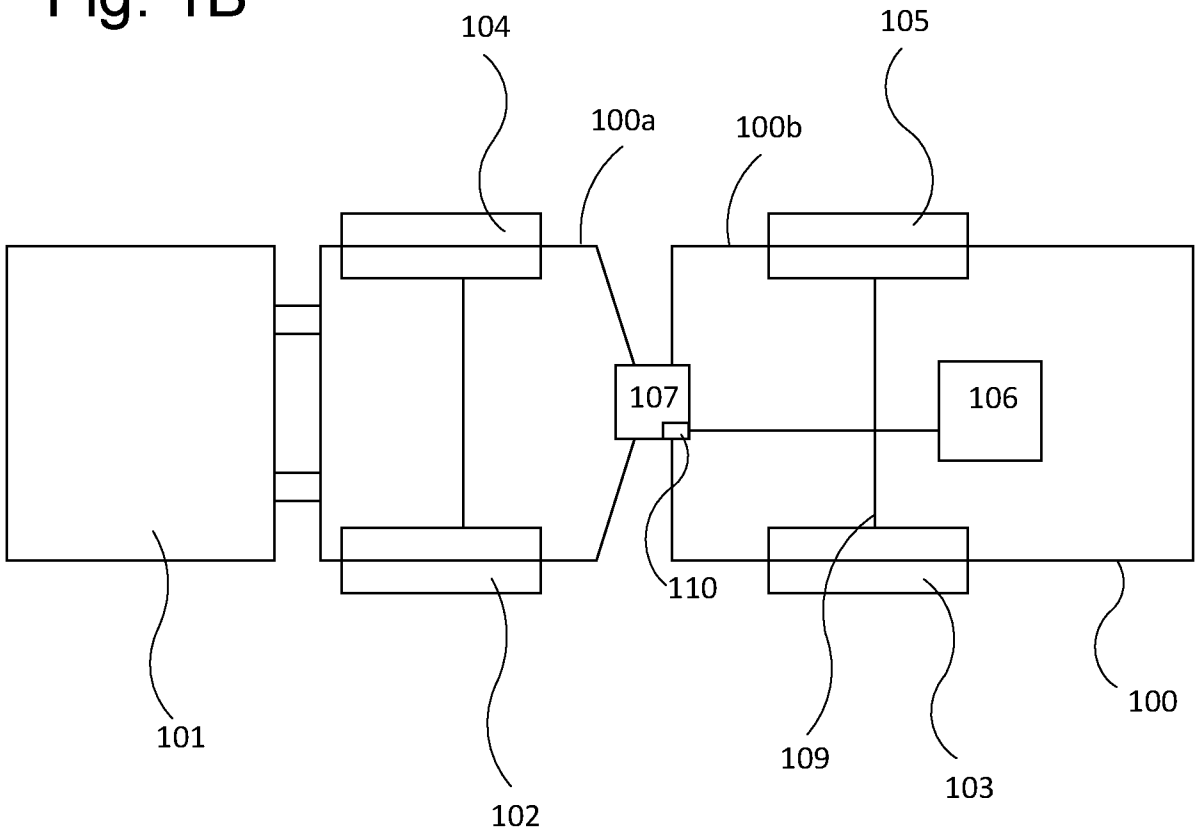

100
111
112
101
102
103

Fig. 1B


104
105
100a
100b
107
106
110
101
102
109
103
100

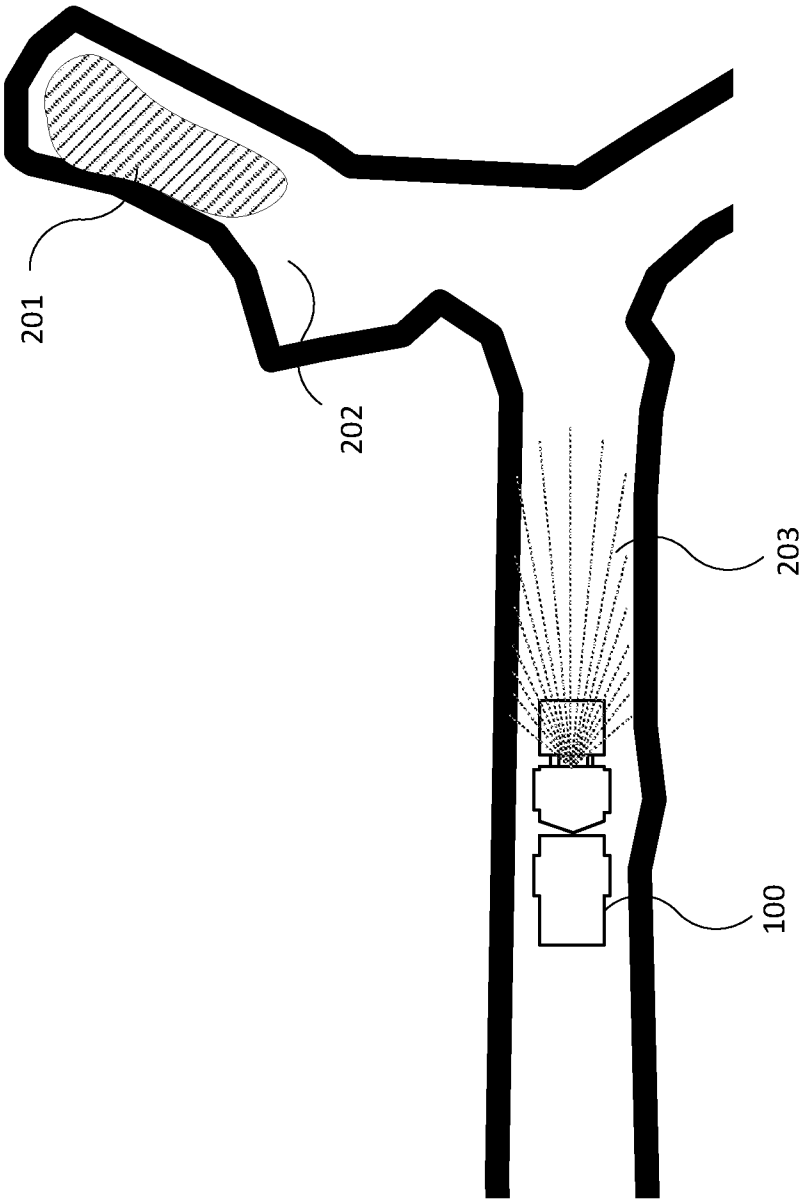
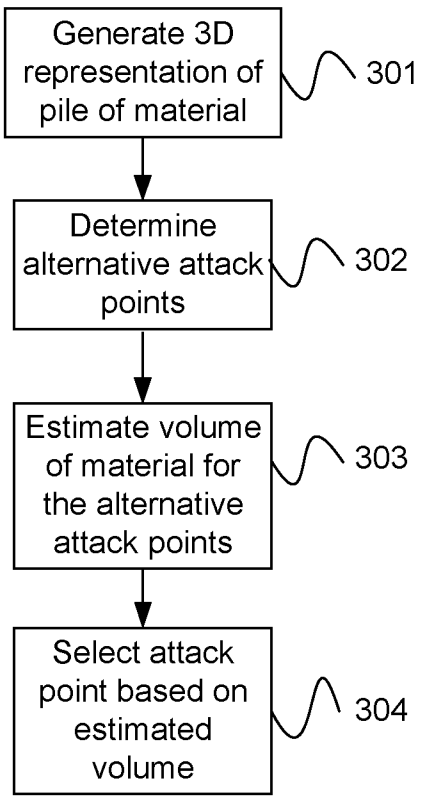


Fig. 2

Fig. 3


300
Generate 3D representation of pile of material
301
Determine alternative attack points
302
Estimate volume of material for the alternative attack points
303
Select attack point based on estimated volume
304

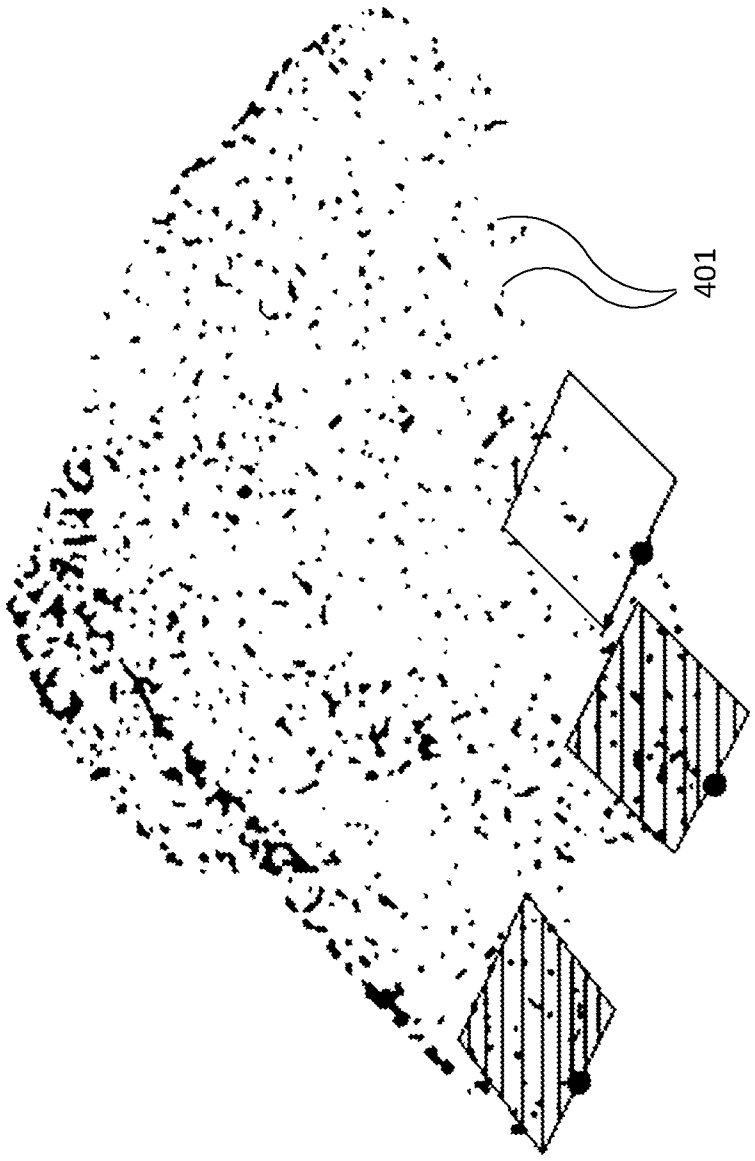
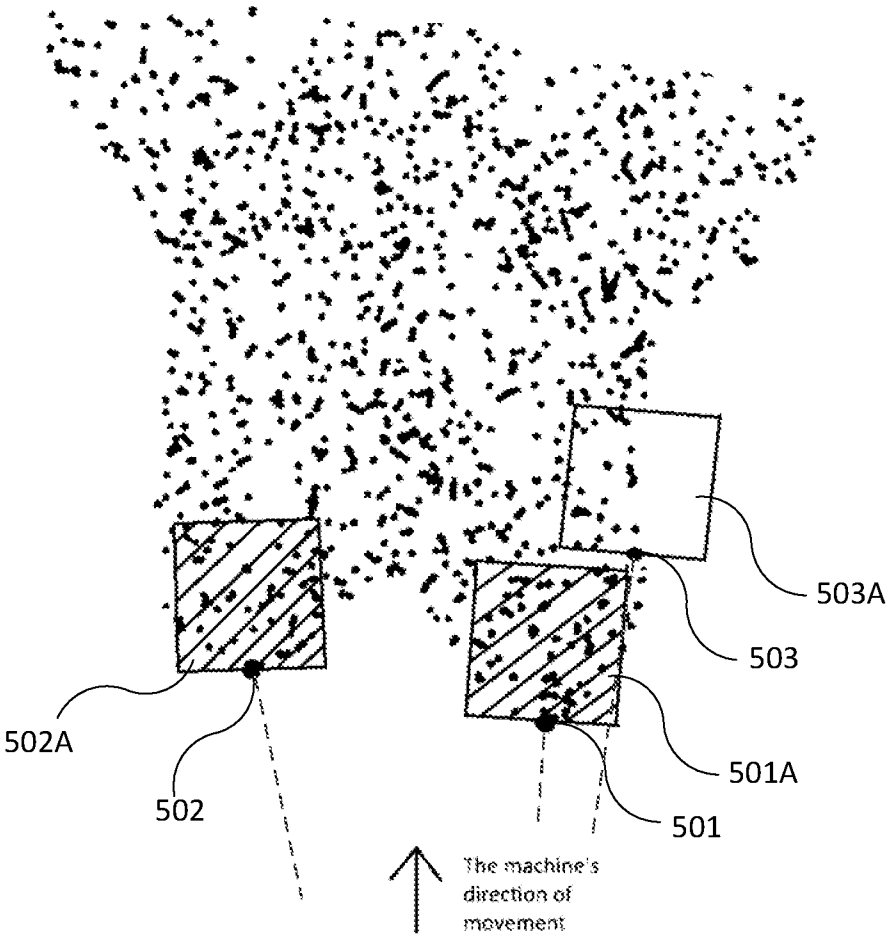


Fig. 4

Fig. 5


503A
503
502A
501A
502
501
The machine's direction of movement

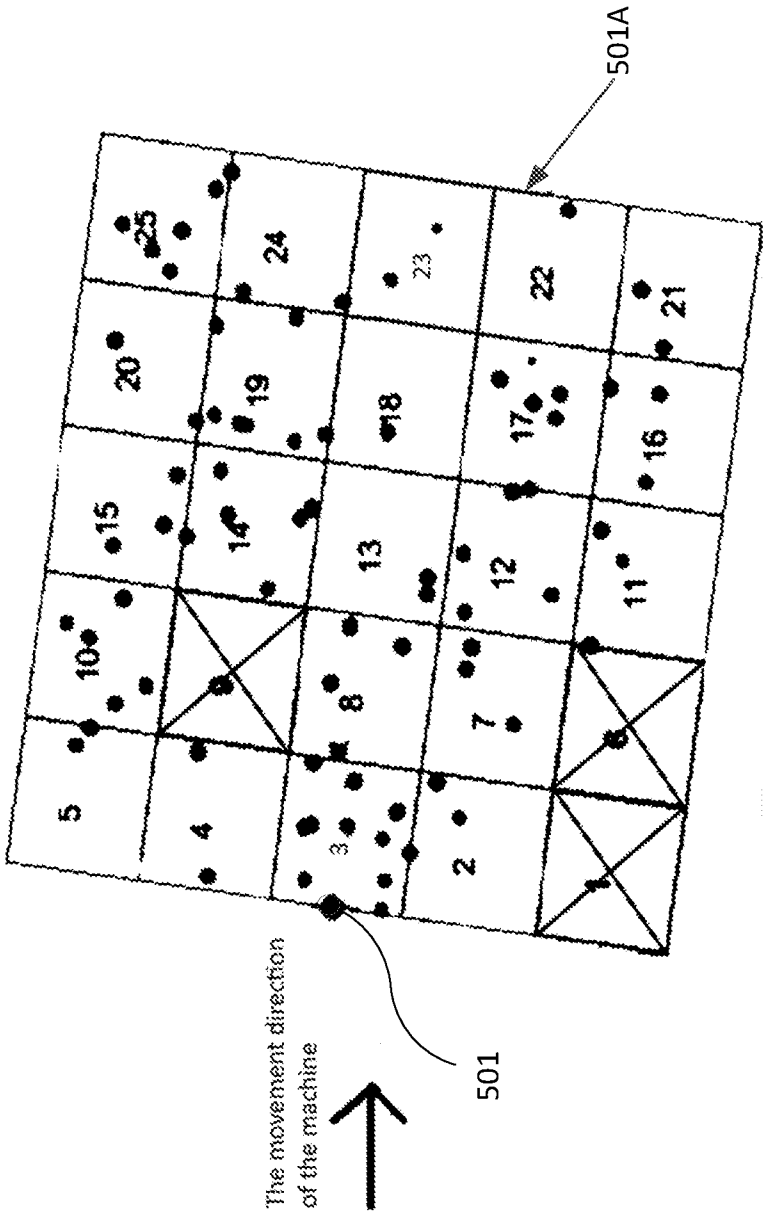

501A
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
8
7
5
4
3
2
501
The movement direction of the machine

Fig. 6

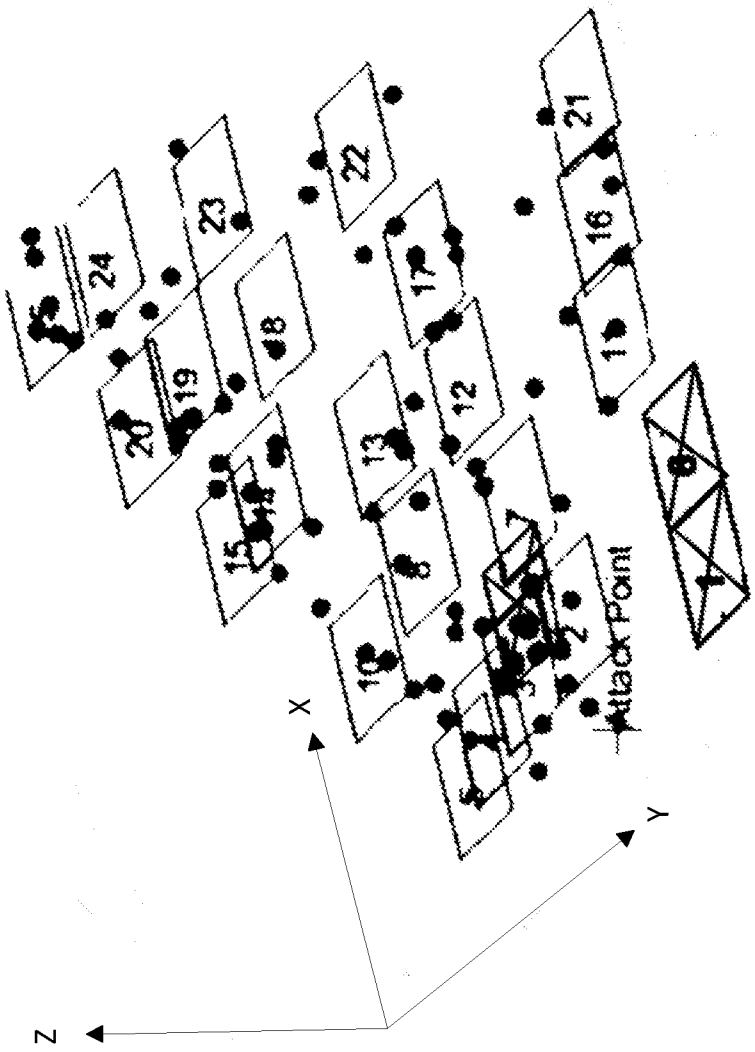


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2023/051304

A. CLASSIFICATION OF SUBJECT MATTER
INV. E02F9/20 E02F9/26
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)
E02F

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 11 668 076 B2 (BEIJING BAIDU NETCOM SCI & TECH CO LTD [CN]) 6 June 2023 (2023-06-06) column 5, line 3 - column 10, line 63; figures	1-17
A	US 6 247 538 B1 (TAKEDA SHU [JP] ET AL) 19 June 2001 (2001-06-19) column 2, lines 17-41 column 6, lines 25-40 column 7, lines 4-36 column 8, lines 1-9; claims; figures	1-17
A	US 11 126 188 B2 (CATERPILLAR INC [US]) 21 September 2021 (2021-09-21) column 12, line 6 - column 13, line 3; figure 2	1-17

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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

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"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
2 July 2024	10/07/2024

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SE2023/051304

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