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(54) Title: SYSTEM AND METHOD FOR THE MEASUREMENT OF THE MINERAL AND/OR ELEMENTAL CONTENT OF ORE

(57) Abstract: A method for the measurement of one or more ore characteristics. The method including positioning a vehicle carrying ore in a measurement zone; moving, based on the position of the vehicle and/or the ore, one or more measurement sensors relative to the vehicle such that the one or more measurement sensors are positioned to generate an effective field of measurement of the ore; and taking one or more measurements of the one or more ore characteristics using the one or more measurement sensors.

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SYSTEM AND METHOD FOR THE MEASUREMENT OF THE MINERAL AND/OR ELEMENTAL CONTENT OF ORE

[0001] This document claims priority from AU2023900442 filed on February 21, 2023 and entitled: System and Method for the Measurement of the Mineral and/or Elemental Content of Or, the contents of which are hereby incorporated by reference in their entirety

TECHNICAL FIELD

[0002] The present disclosure relates to a system and method for the measurement of the mineral and/or elemental content of ore. In particular, although not exclusively, the present disclosure relates to a system and method for measuring the average mineral and/or elemental content of a load of ore carried by a vehicle.

BACKGROUND

[0003] The mined ore grade of many base and precious metal ores has been gradually declining over time around the world. High grade deposits or high-grade components of larger deposits were sufficient to meet metal demand in the early part of the 20th century, but over time the steady increase in metal demand, together with depletion of high-grade reserves and the advent of large scale bulk mining technologies that exploit economies of scale, has led to the lowering of the grades of unmined deposits.

[0004] Because of a decreasing number of high-grade deposits and consequently increasing environmental and economic strain of mining lower grade deposits, it has become beneficial to sort ore before it is processed in order to improve productivity during processing.

[0005] Ore is broadly delineated and assigned based on geological modelling and statistical grade estimates such that low grade ore and ore with a high grade of a deleterious mineral may be diverted to waste or long-term stockpiles, while medium and high-grade ore may be diverted to a processing facility.

[0006] Transportation of ore to processing facilities is usually performed by haul vehicles. Many modern haul vehicles have a payload greater than 350 tonnes and include ultra-class trucks.

[0007] The destination for ore is generally often established prior to loading the haul vehicles using geological model estimations to approximate ore grade. Geological model estimations partition a mine site into regions based on, typically, geostatistical methodologies such as kriging or inverse distance weighting calculations for samples taken from drill cuttings or core. Composite samples are taken along the drill column, analysed, and used to establish an average ore grade of a region.

[0008] When a region is mined, it is assumed that all haul vehicles with loads originating from that region will have the same ore grade and consequently can be sorted and processed in the same manner.

[0009] However, geological modelling estimations struggle to account for discontinuities at the region or movement during blasting. The presence of in-situ grade variability in the form of intrusions, stratigraphic units, bedding, veins, and stockwork mineralisation result in significant deviation from the mean ore grade of a region.

[0010] A further problem associated with geological modelling is that it places an additional burden on miners to mine within the confines of the defined regions which have been disturbed by blasting. In practice, miners mine in the most efficient and safe method and this often results in mischaracterisation of haul vehicle load grade.

[0011] Systems for characterising the grade of ore when it is being carried by a vehicle exist. Such systems use magnetic resonance sensors to discern mineral resonance at a particular radio frequency.

[0012] However, magnetic resonance sensor systems require controlled presentation of the ore load to minimise noise from the local environment and provide an optimal sensing orientation and position.

[0013] Furthermore, magnetic resonance sensor systems do not account for different haul vehicles and different payloads. Variations between haul vehicles and payloads can influence the environment and presentation of ore.

[0014] Incorrectly presented loads can result in unnecessarily long measurement integration times or the inability to produce a response from the ore load.

[0015] Thus, there would be an advantage if it were possible to provide an apparatus and system for bulk ore sorting that allowed for accurate and rapid measurement and sorting of ore, such that the apparatus and system could be used in high throughput applications while ore is being carried by vehicles.

SUMMARY OF DISCLOSURE

[0016] The present disclosure relates to a system and method for the measurement of the mineral and/or elemental content of ore, which may at least partially overcome at least one of the abovementioned disadvantages or provide the consumer with a useful or commercial choice.

[0017] With the foregoing in view, the present disclosure according to an embodiment, resides broadly in a method for the measurement of one or more ore characteristics, the method comprising the steps of:

Positioning a vehicle carrying ore in a measurement zone;

Moving, based on the position of the vehicle and/or the ore, one or more measurement sensors relative to the vehicle such that the one or more measurement sensors are positioned to generate an effective field of measurement of the ore; and

Taking one or more measurements of the one or more ore characteristics using the one or more measurement sensors.

[0018] In another embodiment, the disclosure resides broadly in a system for the measurement of one or more ore characteristics, the system comprising:

One or more measurement sensors configured to take one or more measurements of the one or more ore characteristics;

A movement assembly associated with the one or more measurement sensors, the movement assembly being configured to move the one or more measurement sensors relative to the vehicle in response the position of the vehicle to position the one or more measurement sensors relative to the vehicle and/or the ore such that the one or more measurement sensors generate an effective field of measurement of the ore.

[0019] Advantageously, this method and system disclosed herein improve the accuracy and speed of the classification and/or characterisation of ore prior to processing (such as by a comminution process). This improvement is achieved by moving a magnetic resonance sensor to a position relative to the vehicle and/or the ore wherein the magnetic resonance sensor is capable of generating an effective field of measurement of the ore. In this way, the one or more measurements taken by the magnetic resonance sensor provide a more accurate indication of the one or more ore characteristics, thereby improving bulk ore sorting efficiencies and recovery of the valuable mineral component of the ore.

[0020] The ore may be any suitable form. For example, the ore may be a metalliferous ore. For example, the ore includes both metallic minerals and non-metallic substances. The ore may be an oxide ore, carbonate ore, sulphide or sulphate ore, halide ore, silicate ore, or any suitable combination thereof.

[0021] It is envisaged that the ore carried by the vehicle may be in the form of run-of-mine or crushed ore. Thus, it is envisaged that the ore may be in the form of fragmented material. The fragmented material may comprise ore that has been broken, blasted or otherwise reduced in size to form the fragmented material.

[0022] Specifically, it is envisaged that the fragmented material may be provided as dry or wet solids. The solids may contain no moisture, or may contain relatively small quantities of moisture, such as from precipitation, ground water, washing, dust suppression or the like, or may contain higher quantities of water from rain.

[0023] The fragmented material may be of any suitable size. For instance, in one or all embodiments of the disclosure, the material may be in the form such that the material sizes in a given sample of fragmented material may be from powder form to over 1000mm, or 3000mm or more.

[0024] The one or more ore characteristics may be of any suitable form. For instance, the one or more ore characteristics may include the size, hardness, lustre, colour, streak, specific gravity, cleavage, fracture, tenacity, opacity transparency, translucency, radio-frequency resonant response signal magnitude, magnetism, shape, volume, mass, fluorescence, temperature and/or moisture content and so on of the fragmented material. For example, at least one of the one or more ore characteristics is the mineralogical or elemental grade of the fragmented material.

[0026] The measurement zone may be of any suitable form. For example, the measurement zone may comprise an area or region in which the measurement of the one or more ore characteristics is possible using the one or more measurement sensors. The measurement zone may be of any size or shape, although it is envisaged that the measurement zone may define a space suitable to at least partially receive a vehicle.

[0027] According to one or all embodiments, the measurement zone includes an entrance and an exit. According to one or all embodiments, a vehicle enters the measurement zone via the entrance and leaves the measurement zone via an exit. According to one or all embodiments, the entrance and exit are at opposed ends of the measurement zone such that a vehicle can drive continuously in a forward direction through the measurement zone. However, the skilled addressee will appreciate that the entrance and exit may be the same site such that a vehicle can enter the measurement zone and reverse out of the measurement zone.

[0028] According to one or all embodiments, the measurement zone is defined by physical features. According to one or all embodiments, the measurement zone is defined by an area mapped by a computer.

[0029] The measurement zone may comprise an area of unimproved ground, although it will be understood that the measurement zone may be substantially cleared of obstacles that may damage the vehicle or reduce the ability of the vehicle to access the measurement zone. In one or all embodiments, the measurement zone may include a slab, pad, or other ground modification. The measurement zone may include one or more reflectors, lights or railings. In one or all embodiments, the one or more reflectors, lights or railings may define at least a portion of the periphery of the measurement zone. It is envisaged that, by defining at least a portion of the periphery of the measurement zone, the operator of the vehicle may be provided with a visual indication of the location and extent of the measurement zone.

[0030] In one or all embodiments, the measurement zone may be raised above ground level. For example, one or more ramps, lifts or the like may be provided to enable the vehicle to access the measurement zone.

[0031] The measurement zone may include a structure, such as a building or the like. In one or all embodiments, the measurement zone may include a building frame, the building frame comprising a plurality of pillars, posts or the like. In on embodiments, the structure may include walls and a roof. For example, the structure is a roofed structure supported by pillars, without walls. The measurement zone may include a void, tunnel, or other horizontal or vertical excavation in an underground mine.

[0032] The structure may be transportable, such that it may be installed and/or configured at a convenient location. For instance, the structure may be positioned at a point between a vehicle loading point and a vehicle unloading point. In this way, the vehicle is not required to travel a significant additional distance to pass through the measurement zone. In other embodiments, the measurement zone may be located remotely to the vehicle loading point and/or the vehicle unloading point.

[0033] In one or all embodiments, the measurement zone includes one or more mechanical adjustors. For instance, the measurement zone may be provided with a conveyor system, lift, hoist, winch or the like for positioning a vehicle. The measurement zone may include a rotatory system (such as a turntable or the like) to enable the orientation of a vehicle to be altered. The measurement zone may further include a stop/go indicator. It will be understood that the purpose of the stop/go indicator may be to signal to the driver of the vehicle when to enter and/or exit the measurement zone. The stop/go indicator may be of any suitable form, and may include one or more visual signal generators, one or more audio signal generators, or a combination thereof. Preferably, the stop/go indicator is a traffic light system. In use, a vehicle may enter the measurement zone upon receiving a green signal, or other indicator. A stop indicator may indicate when a vehicle is in the correct place for measurement. An amber light may indicate that a vehicle should slow down.

[0034] It is envisaged that the stop/go indicator may be used to assist a vehicle in exiting the measurement zone. In this embodiment, the vehicle may exit the measurement zone upon receiving a green signal, or other indicator.

[0035] According to one or all embodiments, the method may also include determining the position of the vehicle and/or the ore within the measurement zone using one or more positioning sensors. Similarly, the system may further include one or more positioning sensors for determining the position of the vehicle within the measurement zone. According to one or all embodiments, the one or more positioning sensors are associated with the measurement zone. For example, the one or more mechanical adjusters are configured to be actuated to move the vehicle in response to measurements of the position of the vehicle measured by the one or more positioning sensors. Alternatively, the driver of the vehicle may be required to move the vehicle in response to measurements of the position of the vehicle measured by the one or more positioning sensors.

[0036] In one or all embodiments, a metal or weight detection system may be located in or adjacent to, or be otherwise associated with, the measurement zone. In one or all embodiments, the metal or weight detection system is associated with an auditory or visual alert system to alert a vehicle driver when the vehicle is in a desired position. Optionally, the auditory or visual alert system may direct a vehicle driver continually while in the measurement zone and may include instructions and procedural steps. In embodiments in which a vehicle entering the measurement zone has several ore compartments (such as that of a B-double truck), the auditory or visual alert system may provide for instructions to enter the measurement zone partially and slowly progress forward so that measurement may be taken for each ore compartment.

[0037] In one or all embodiments, the measurement zone may include passive traffic management systems such as painted markings on the ground, or wheel wells/guides to direct a vehicle driver to a desired location within the measurement zone.

[0038] The vehicle may be any suitable vehicle for carrying ore. Preferably, the vehicle has one or more receptacles for carrying ore. For example. the one or more receptacles are uncovered.

[0039] In one or all embodiments, the vehicle may comprise a haul vehicle, such as a haul truck. In one or all embodiments, the haul vehicle may include ultra-class and rear- eject trucks. The vehicle may have any suitable payload. For example, the present disclosure may be used with vehicles having payloads of 5 tonnes or less or in excess of 350 tonnes of ore.

[0040] In one or all embodiments, the vehicle may be a front-end loader such as a bogger, slusher or load haul dump. In one or all embodiments, the vehicle may include several receptacles linked together, such as a B-double truck.

[0041] according to one or all embodiments, the vehicle is a wheeled vehicle, however it will be understood that the vehicle may be moveable on tracks, skids or continuous treads.

[0042] according to one or all embodiments, the vehicle may comprise a train hopper wagon, utility vehicle or a trailer.

[0043] The one or more positioning sensors may be any suitable sensors for determining the position of the vehicle and/or the ore. For example, the positioning sensors measure the position and/or orientation of the vehicle in the measurement zone. Preferably, the one or more positioning sensors measure the size of the vehicle, type of vehicle, perimeter of the vehicle, and so on.

[0044] According to one or all embodiments, the one or more positioning sensors may also measure the arrangement of ore in the vehicle. In one or all embodiments, the one or more positioning sensors may measure the piling of the ore, the spread of the ore within the vehicle, the spacing of ore particles and so on. For example, the one or more positioning sensors may detect large gaps between the ore.

[0045] According to one or all embodiments, passive controls may be used to ensure that the ore is within tolerable parameters with respect to physical dimensions. Examples of passive controls may include physical barriers such as solid impassable barriers at a safe height which would make contact with the ore and indicate that the measurement zone should not be entered.

[0046] According to one or all embodiments, active barriers may be provided. The active barriers may be of any suitable form, and may include laser barriers or mechanical indicators which provide feedback to the driver of the vehicle indicating that it is not safe for the vehicle to enter the measurement zone (for instance, the ore is piled too high within the vehicle and so on).

[0047] According to one or all embodiments, at least a portion of the one or more positioning sensors may be located substantially above the vehicle and/or the ore when the vehicle is located within the measurement zone. For example, the one or more positioning sensors may be mounted to the structure associated with the measurement zone. The one or more positioning sensors may be movable relative to the structure, although, more preferably, the one or more positioning sensors may be located in a fixed position relative to the structure.

[0048] According to one or all embodiments, the one or more positioning sensors include point cloud data (LiDAR) sensors, weight sensors, ultrasonic sensors, radar sensors, infrared sensors, heat sensors, cameras (including RGB cameras, NIR cameras, optical cameras or the like) or any suitable combination thereof.

[0049] According to one or all embodiments, the operation of the one or more positioning sensors is not affected by adverse environmental or climatic conditions (such as wet or dusty conditions). However, in one or all embodiments of the disclosure, the one or more positioning sensors may be located within a housing. The housing may be provided in order to protect the one or more positioning sensors from damage and/or to act as shielding to protect workers from radiation emitted by the one or more positioning sensors. The housing may be of any suitable size, shape or configuration, and it will be understood that the exact configuration of the housing is not critical to the working of the disclosure.

[0050] In In or all embodiments two or more positioning sensors may be located within the same housing. In other embodiments, each positioning sensor may be provided with its own housing.

[0051] In one or all embodiments, the one or more positioning sensors may take one or more measurements at any suitable time interval. For example, the one or more positioning sensors may take measurements continuously. For example, the one or more positioning sensors are configured to take measurements from the time at which a vehicle enters the measurement zone until the vehicle leaves the measurement zone.

[0052] In one or all embodiments of the disclosure data generated by the measurements taken by the one or more positioning sensors may be communicated to a computing device. The computing device may be of any suitable form, and may comprise a computer, computing tablet or the like. The computing device may be located in close proximity to the one or more positioning sensors or may be located remotely to the one or more positioning sensors. According to an embodiment, the data may be communicated to the computing device wirelessly, such as by Wi- Fi, Bluetooth, Cloud computing or the like. Thus, in one or all embodiments, the one or more positioning sensors may be provided, or associated with, communications architecture. In one or all embodiments, one or more positioning sensors may be associated with the communications architecture. For example, all of the positioning sensors may be associated with the communications architecture. Preferably, the communications architecture is used to transmit the sensor data to the computing device.

[0053] In one or all embodiments, data from the one or more positioning sensors may be stored. The data may be stored in any suitable manner. For instance, the data may be stored in an electronic database associated with the computing device. Alternatively, the data may be stored on a cloud device. For example, one or more additional pieces of data (such as a time stamp and/or a vehicle identifier) may also be stored.

[0054] In one or all embodiments, the computing device may be configured to determine the mineral and/or elemental content of the ore. Alternatively, the computing device may be configured to analyse and/or interpret data (such as the strength of a response signal) received from the positioning sensors and/or the measurement sensors and determine the mineral and/or elemental content of the ore.

[0055] In one or all embodiments, the data generated by the one or more positioning sensors is processed using a sensor data processing algorithm. Position optimising algorithms may be run based on the data generated by the one or more positioning sensors.

[0056] In one or all embodiments, the computing device may include, or be associated with, one or more machine learning modules. In these embodiments of the disclosure, the data may be communicated to the one or more machine learning modules such that a machine learning algorithm may be used to optimise the three-dimensional positioning of the vehicle.

[0057] The one or more measurement sensors may be of any suitable form, and may be configured to measure any suitable properties of the ore.

[0058] In one or all embodiments, however, at least one of the one or more measurement sensors comprises a Magnetic Resonance (MR) sensor. The MR sensor may be configured to measure any suitable properties of the ore. For instance, the MR sensor may be configured to measure the grade of the ore. The grade of the ore may be measured using any suitable technique, although in one or all embodiments, the grade of the ore may be measured using zero field nuclear magnetic resonance and/or quadrupole resonance techniques. For example, the MR sensor uses non-ionizing radio waves. Furthermore, the MG sensor may have a rate of power of from about 60 kW to about 200 kW; from about 80kW to about 150 kW; or even from about 100kW to about 120 kW.

[0059] The skilled addressee will appreciate that a plurality of MR sensors may be employed at the measurement zone. In such instances, the MR sensors may be positioned at different locations of the measurement zone. In this embodiment of the disclosure, the MR sensors may be configured to measure different portions or sections of the ore carried by the vehicle. Thus, the ore grade determined by the present disclosure may be calculated based on a combination of data generated by the plurality of MR sensors.

[0060] It is envisaged that any suitable grade may be measured. For instance, the MR sensor may measure the grade of one or more elements within the ore. In other embodiments, the MR sensor may measure the grade of one or more compounds (i.e. mineralogical grade) within the ore. Any suitable elemental and/or compound grade may be measured, although it is envisaged that, when the ore comprises rock or a mineral ore, the elemental and/or compound (or mineralogical) grade may be related to the kind of ore deposit from which the ore is taken. For instance, in copper orebodies, the elemental grade may be the grade of copper and/or other associated elements such as iron and arsenic, while the compounds may include any suitable copper-bearing mineral (such as, but not limited to, chalcopyrite, chalcocite, bornite, covellite, digenite, cuprite).

[0061] Similarly, for ore taken from an iron ore deposit, the grades measured by the MR sensor may be the elemental iron grade, or the grade of iron-bearing minerals such as, but not limited to, hematite, magnetite, goethite.

[0062] According to one or all embodiments, the MR sensor measures the grade of one or more metals or minerals within the ore. The grade may be measured in any suitable form. For instance, the grade may be measured on a w/w basis, a w/v basis and so on.

[0063] In one or all embodiments, the MR sensor may be configured to measure the elemental grade of one or more elements (and particularly metallic elements) within the ore. For example, the elemental grade is measured directly (i.e. not calculated from a measurement of minerals containing the one or more elements), although the elemental grade may also be calculated from the mineralogical grade. The elemental grade of the one or more elements may be calculated directly due to deposit heterogeneity and/or through natural statistical fluctuations in the elemental grade within the ore.

[0064] The measurement sensors may comprise one or more auxiliary sensors. For instance, the auxiliary sensors may be configured to measure the grade of the fragmented material using X-ray diffraction (XRD), X-ray fluorescence (XRF), prompt gamma neutron activation analysis

(PGNAA), pulsed fast thermal neutron activation (PFTNA), or any suitable combination thereof. For example, the auxiliary sensors include hyperspectral, optical, near- infrared (NIR), inductance, capacitance, induced polarisation, and Laser Induced Breakdown Spectroscopy (LIBS) sensors.

[0065] The movement assembly may be of any suitable form. As previously stated, the measurement sensors are associated with the movement assembly, and it is envisaged that the measurement sensors may be associated with the movement assembly in any suitable manner. For instance, the movement sensors may be mounted to, or otherwise supported by, the movement assembly. For example, the movement assembly is located at least partially above the location of a vehicle and/or the ore within the measurement zone. In particular, it is envisaged that the measurement sensors may be supported by the movement assembly at a point above the ore. Thus, it is envisaged that the measurement sensors are positioned above the ore when the measurements of the ore characteristics are taken.

[0066] In one or all embodiments, the measurement sensors may be mounted to internal supports of the structure. In such embodiments, the measurement sensors may be configured to move along at least a portion of the length of the internal supports. The measurement sensors may move using any suitable movement members, such as one or more wheels, tracks, slides or the like.

[0067] In one or all embodiments, at least one of the one or more positioning sensors may be mounted to internal supports of the structure, and may be configured to move along at least a portion of the length of the internal supports in the same manner as the measurement sensors. Thus, the one or more positioning sensors may be configured for movement relative to the vehicle in order to determine the position of the vehicle in the measurement zone.

[0068] One or all embodiments, the measurement sensors may be mounted to an overhead gantry. For example, the overhead gantry may be associated with, and configured for movement relative to, the internal supports of the structure. For another example, the overhead gantry may be associated with one or more rail members. For example, a pair of rail members may be provided space apart from one another and the overhead gantry may be extended therebetween. In one or all embodiments, the pair of rail members may be located on opposed sides of the structure, and, for example mounted to, or otherwise associated with, an internal surface of the structure. For example, the overhead gantry may move relative to the rail members along at least a portion of the length thereof.

[0069] In one or all embodiments, the overhead gantry includes one or more bridge beams and a trolley associated therewith and configured for movement relative thereto. For example, the one or more measurement sensors may be mounted to the trolley. In this way, the measurement sensors may be configured for movement in both lateral and longitudinal directions relative to the vehicle via the movement assembly.

[0070] In one or all embodiments of the disclosure, at least one of the one or more positioning sensors may be mounted to the overhead gantry in the same manner as the measurement sensors. For example, the one or more positioning sensors may be configured for movement relative to the vehicle in order to determine the position of the vehicle in the measurement zone.

[0071] In one or all embodiments, the overhead gantry includes a dual winch system to allow an axis of rotation. The skilled addressee will appreciate that any suitable technique may be used to enable rotation of the measurement sensor. For example, the measurement sensor may be mounted to a swivel.

[0072] In one or all embodiments, the measurement sensor and/or at least one of the one or more positioning sensors may be associated with a suspension system (such as a cable driven parallel robot), an articulated robotic arm, or a fixed position sensor.

[0073] In one or all embodiments, the movement assembly also includes a cable management system. For example, the cable management system autonomously feeds multiple conduits to the measurement sensor to eliminate excess bending of the sensitive radiofrequency cables.

[0074] In one or all embodiments, the cable forms a single loop from a fixed suspended mounting point. In such instances, the cable loop length is managed such that the cable does not touch the ground or the vehicle while still allowing a complete range of motion.

[0075] In one or all embodiments, cable management is achieved using cable reel drums or festoon systems.

[0076] in one or all embodiments, the one or more positioning sensors are in electronic communication with the movement assembly using any suitable technique. For instance, the one or more positioning sensors and the movement assembly may be in electronic communication with one another via one or more electrical cables, cords or the like. For example, the one or more positioning sensors and the movement assembly may be in wireless communication with one another (for instance, by Wi-Fi, 3G, 4G, 5G, satellite and the like).

[0077] According to one or all embodiments, data generated by the one or more positioning sensors may be shared with the movement assembly.

[0078] According to one or all embodiments, the movement assembly may move automatically based on the data generated from the one or more positioning sensors (and/or the calculations based on the data performed by the computing device). In one or all embodiments, the movement assembly may be adjustable manually by an operator.

[0079] According to one or all embodiments, the data generated by the one or more positioning systems may be communicated to the computing device. For example, the computing device may calculate the position of the vehicle based on the data, and may actuate the movement assembly to move to a location relative to the vehicle at which the measurement sensors may generate an effective field of measurement of the ore.

[0080] It will be understood that the term "effective field of measurement of the ore" is intended to mean that the measurements taken by the one or more measurement sensors will include at least a portion of to substantially the entire load of ore carried by the vehicle. By ensuring that substantially the entire load of ore carried by the vehicle is measured by the one or more measurement sensors, the accuracy of the measurements of the ore characteristics may be improved.

[0081] The computing device may comprise a single device (such as a computer, server or the like), or a plurality of devices, such as, but not limited to, one or more computer servers, databases, data storage devices, queuing services and the like. For example, the plurality of devices may be in electronic communication with one another.

[0082] In one or all embodiments, the ore grade may be determined automatically based on predefined characteristic parameters. For example, if predefined ore characteristics are met, the ore will be classified into one of a plurality of categories (such as high, medium, or low grade). In one or all embodiments, the characteristics of the ore may be presented to a user and the user may be required to determine the category into which the ore should be classified based on the ore grade. This may be particularly useful where there are low quantities of metals which would otherwise not be sufficient to trigger a high grade for a large sample of ore.

[0083] It is envisaged that the calculation device may, on receipt of the data from the one or more positioning sensors, determine the optimum position of the measurement sensors and actuate the movement assembly to direct the measurement sensors to an optimum position. In this regard, the optimum position of the MR sensor is one where the effective field of measurement encompasses the entire vehicle load.

[0084] According to one or all embodiments, the measurement sensors are associated with a further computing device. The further computing device may be the same computing device used in relation to the one or more positioning sensors. In one or all embodiments the further computing device is different to the computing device used in relation to the one or more positioning sensors.

[0085] According to one or all embodiments, the further computing device uses the data from the measurement sensor to determine the mineral and/or elemental content of ore.

[0086] In one or all embodiments the data from the measurement sensor is paired with vehicle identifying data and such data is recorded on a database or blockchain. For example, it is envisioned that the logging of ore grade in relation to specific vehicles may be used to confirm that the vehicle has arrived at the appropriate processing location, for historical reporting, analysis or training databases.

[0087] In one or all embodiments, the data from the measurement sensor is used to assess the presence of metal debris in the ore load. In such instances, the measurement system may be associated with an alert recommending safe management of the metal debris.

[0088] Any of the features described herein can be combined in any combination with any one or more of the other features described herein within the scope of the disclosure.

BRIEF DESCRIPTION OF DRAWINGS

[0089] Embodiments and variations of the disclosure may be discerned from the following Detailed Description which provides sufficient information for those skilled in the art to perform the disclosure. The Detailed Description is not to be regarded as limiting the scope of the preceding Summary of Disclosure in any way. The Detailed Description will make reference to a number of drawings as follows:

[0090] Figures 1-3 illustrate steps in a method for the measurement of one or more ore characteristics according to an embodiment of the present disclosure.

[0091] Figure 4 illustrates a portion of a system for the measurement of one or more ore characteristics according to an embodiment of the present disclosure.

[0092] Figure 5 illustrates a schematic view of a method and system for the measurement of one or more ore characteristics according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0093] Figure 1 illustrates a first step in a method for the measurement of one or more ore characteristics according to an embodiment of the present disclosure. In this Figure, a vehicle in the form of a haul truck 10 is carrying a load of ore 11. The ore 11 is run-of-mine ore.

[0094] The truck 10 approaches a structure 12 in the form of a shed. The truck 10 enters the structure 12 through an entrance 13 therein and stops inside the structure 12. The interior of the structure comprises the measurement zone 14.

[0095] In Figure 2, the truck 10 is positioned within the structure and is therefore located in the measurement zone. Positioning sensors 15 in the form of LIDAR sensors are located within the measurement zone and are configured to detect the position of the truck 10 and the ore 11 within the measurement zone. The positioning sensors 15 may be fixed in place or may be movable relative to the truck 10.

[0096] Each LIDAR sensor 15 generates a field of vision 16 that encompasses at least a portion of the ore 11 (unless the truck 10 is positioned in such a manner that a LIDAR sensor 15 is too far away from the truck 10 to generate a field of vision 16 that encompasses a portion of the ore 11). The LIDAR sensors 15 generate a point cloud that allows a computing device (not shown) to determine the location of the truck 10 (and, more specifically, the ore 11) within the measurement zone.

[0097] In Figure 3, the position of the ore 11 within the measurement zone has been determined by the computing device (not shown) based on the data generated by the LIDAR sensors (not shown). A measurement sensor 17 in the form of a magnetic resonance (MR) sensor is moved into position above the truck 10 such that the field of vision of the measurement sensor 17 encompasses the entire load of ore 11 within the truck 10. The measurement sensor 17 is moved into position via an overhead gantry (not shown in this Figure) that moves the measurement sensor in both lateral and longitudinal directions relative to the truck 10 to accurately position the measurement sensor 17 relative to the ore 11. It will be understood that accurately positioning the measurement sensor 17 relative to the ore 11 means that the measurements sensor 17 is positioned in such a manner that when measurements are taken, substantially the entire load of ore 11 within the truck 10 falls within the effective field of measurement of the measurement sensor 17.

[0098] Figure 4 illustrates a portion of a system for the measurement of one or more ore characteristics according to an embodiment of the present disclosure. In this Figure, the structure 12 in which the measurement zone 14 is located may be more clearly seen.

[0099] The structure 12 includes a movement assembly 18 with which the measurement sensor 17 is associated. The movement assembly 18 comprises an overhead gantry which includes a bridge beam 19 and a trolley (obscured) to which the measurement sensor 17 is connected. The bridge beam 19 extends between rail members 20 located on opposed sides of the structure 12 and is configured for movement relative thereto. It is envisaged that movement of the bridge beam 19 relative to the rails members 20 results in movement of the measurement sensor 17 in a longitudinal direction within the measurement zone 14.

[0100] As previously stated, the measurement sensor 17 is mounted to a trolley (obscured) which is associated with the bridge beam 19. The trolley is configured for movement relative to the bridge beam 19 between the rail members 20. Thus, movement of the trolley relative to the bridge beam 19 results in movement of the measurement sensor 17 in a lateral direction within the measurement zone 14.

[0101] In the manner described above, the measurement sensor 17 may be moved within the measurement zone 14 so that the effective field of measurement of the measurement sensor 17 is configured to encompass an entire load of ore within a truck.

[0102] Figure 5 illustrates a schematic view of a method and system 21 for the measurement of one or more ore characteristics according to an embodiment of the present disclosure. In this Figure, a truck 10 enters a measurement zone, and one or more positioning sensors in the form of LIDAR sensors 15 measure the position of the truck 10 and the load of ore 11 carried by the truck 10.

[0103] The LIDAR sensors 15 generate a point cloud 22 of the truck 10 and the ore 11. The point cloud 22 is analysed by a computing device 23 to calculate the position of the truck 10 and the ore 11 within the measurement zone.

[0104] Once the position of the truck 10 and the ore 11 within the measurement zone is calculated by the computing device 23, the computing device 23 actuates movement of the measurement sensor 17 to a point in the measurement zone in which the effective field of measurement of the measurement sensor 17 encompasses the entire load of ore 11 within the truck 10.

[0105] Data generated by the measurement sensor 17 is analysed by the computing device 23, and the computing device 23 calculates the average grade 24 (elemental grade and/or mineral grade for one or more elements and/or minerals) within the ore 11.

[0106] The calculation of the average grade 24 may determine the destination of the ore 11. For instance, if the average grade 24 of the ore 11 (for one or more key elements and/or minerals) is below a predetermined value, the ore 11 may be diverted to waste rock. Alternatively, if the average grade 24 of the ore 11 (for one or more key elements and/or minerals) is above a predetermined value, the ore 11 may be sent for further processing (such as comminution, leaching, flotation and so on).

[0107] In one or all embodiments of the disclosure, the average grade 24 of the ore 11 (for one or more key elements and/or minerals) may be used to enable blending of ore 11 prior to further processing in order to achieve a substantially consistent feed grade of ore 11 to a processing plant (such as a concentrator).

[0108] In the present disclosure and claims (if any), the word *'comprising'* and its derivatives including *'comprises'* and *'comprise'* include each of the stated integers but does not exclude the inclusion of one or more further integers.

[0109] Reference throughout this specification to *'one embodiment'* or *'an embodiment'* means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Thus, the appearance of the phrases *'in one embodiment'* or *'in an embodiment'* in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more combinations.

[0110] In compliance with the statute, the disclosure has been described in language more or less specific to structural or methodical features. It is to be understood that the disclosure is not limited to specific features shown or described since the means herein described comprises preferred forms of putting the disclosure into effect. The disclosure is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims (if any) appropriately interpreted by those skilled in the art.

CLAIMS

What is claimed is:

1. A method for the measurement of one or more ore characteristics, the method comprising the steps of:

   positioning a vehicle carrying ore in a measurement zone;

   moving, based on the position of the vehicle and/or the ore, one or more measurement sensors relative to the vehicle such that the one or more measurement sensors are positioned to generate an effective field of measurement of the ore; and

   taking one or more measurements of the one or more ore characteristics using the one or more measurement sensors.
2. The method according to claim 1, further comprising determining the position of the vehicle and/or the ore within the measurement zone using one or more positioning sensors.
3. The method according to claim 1 or claim 2, wherein the ore is oxide ore, carbonate ore, sulphide ore, sulphate ore, halide ore, silicate or any combination thereof.
4. The method according to any one of claims 1 to 4, wherein the ore is fragmented.
5. The method according to claim 4, the fragmented ore includes at least one fragment over 1,000 mm.
6. The method according to any one of claims 1 to 5, wherein the ore characteristics include size, hardness, lustre, colour, streak, specific gravity, cleavage, fracture, tenacity, opacity transparency, translucency, radio-frequency resonant response signal magnitude, magnetism, shape, volume, mass, fluorescence, temperature, moisture, and any combination thereof.
7. The method according to any one of claims 1 to 6, wherein the one or more positioning sensors include point cloud data (LiDAR) sensors, weight sensors, ultrasonic sensors, radar sensors, infrared sensors, heat sensors, cameras, and any combination thereof.
8. The method according to any one of claims 1 to 7, wherein the one or more measurement sensors includes a magnetic resonance (MR) sensor,
9. The method according to claim 8, wherein the one or more measurement sensors also includes one or more of hyperspectral, optical, near- infrared (NIR), inductance, capacitance, induced polarisation, and Laser Induced Breakdown Spectroscopy (LIBS) sensors.
10. A system for the measurement of one or more ore characteristics, the system comprising:

    one or more measurement sensors configured to take one or more measurements of the one or more ore characteristics; and a movement assembly associated with the one or more measurement sensors, the movement assembly being configured to move the one or more measurement sensors relative to the vehicle in response to a position of the vehicle to position the one or more measurement sensors relative to the vehicle and/or the ore such that the one or more measurement sensors generate an effective field of measurement of the ore.

11. The system according to claim 10, further comprising one or more positioning sensors for determining the position of the vehicle within the measurement zone.
12. The system according to claim 10 or claim 11, wherein the ore is oxide ore, carbonate ore, sulphide ore, sulphate ore, halide ore, silicate or any combination thereof.
13. The system according to any one of claims 10 to 12, wherein the ore is fragmented.
14. The system according to claim 13, the fragmented ore contains at least one fragment over 1,000 mm.
15. The system according to any one of claims 10 to 14, wherein the ore characteristics include size, hardness, lustre, colour, streak, specific gravity, cleavage, fracture, tenacity, opacity transparency, translucency, radio-frequency resonant response signal magnitude, magnetism, shape, volume, mass, fluorescence, temperature, moisture, and any combination thereof.
16. The system according to any one of claims 10 to 15, wherein the one or more positioning sensors include point cloud data (LiDAR) sensors, weight sensors, ultrasonic sensors, radar sensors, infrared sensors, heat sensors, cameras, and any combination thereof.
17. The system according to any one of claims 10 to 16, wherein the one or more measurement sensors include a magnetic resonance (MR) sensor,
18. The system according to claim 17, wherein the one or more measurement sensors also includes one or more of hyperspectral, optical, near- infrared (NIR), inductance, capacitance, induced polarisation, and Laser Induced Breakdown Spectroscopy (LIBS) sensors.

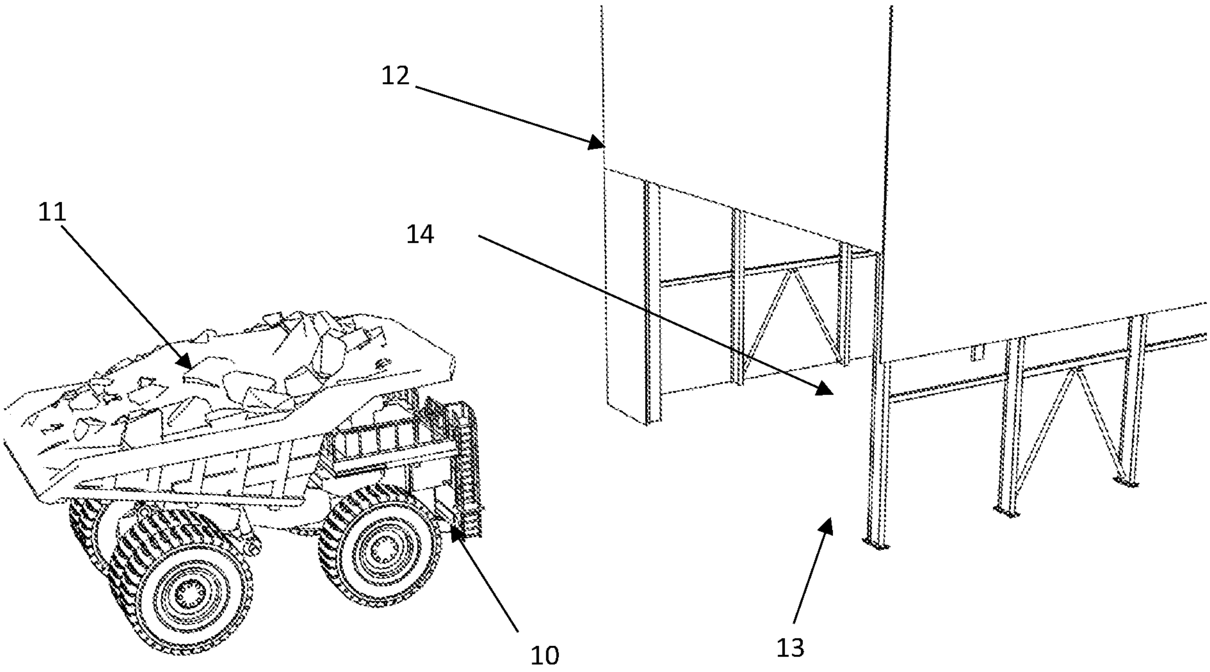

FIG 1

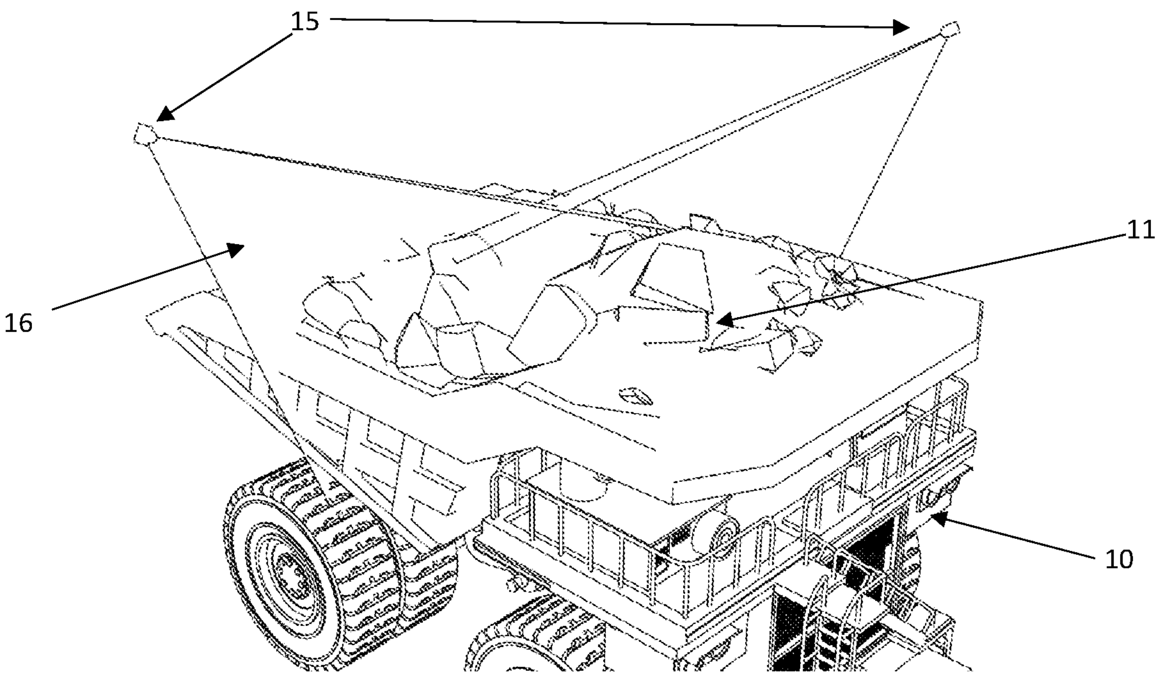

FIG 2

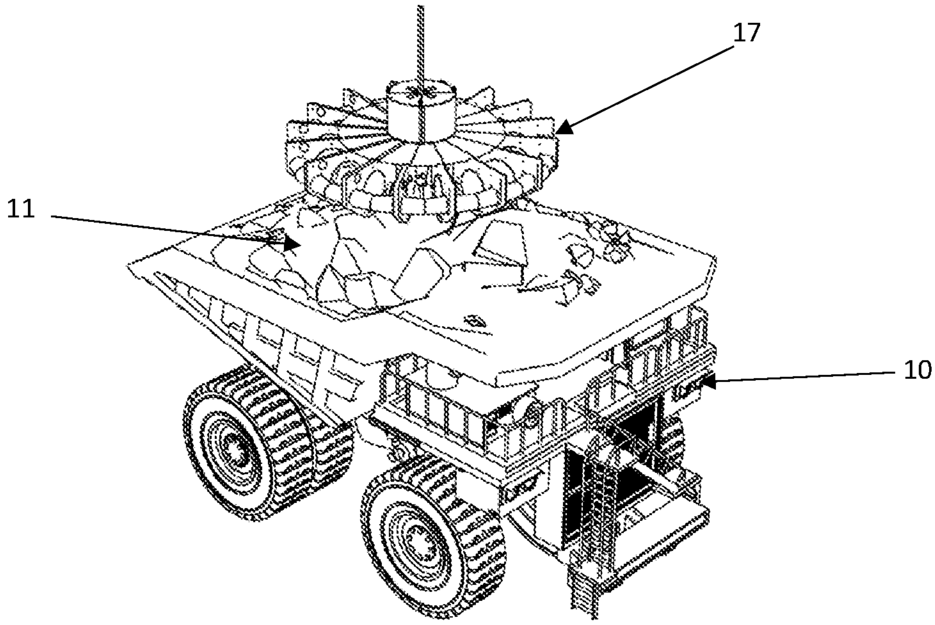

FIG 3

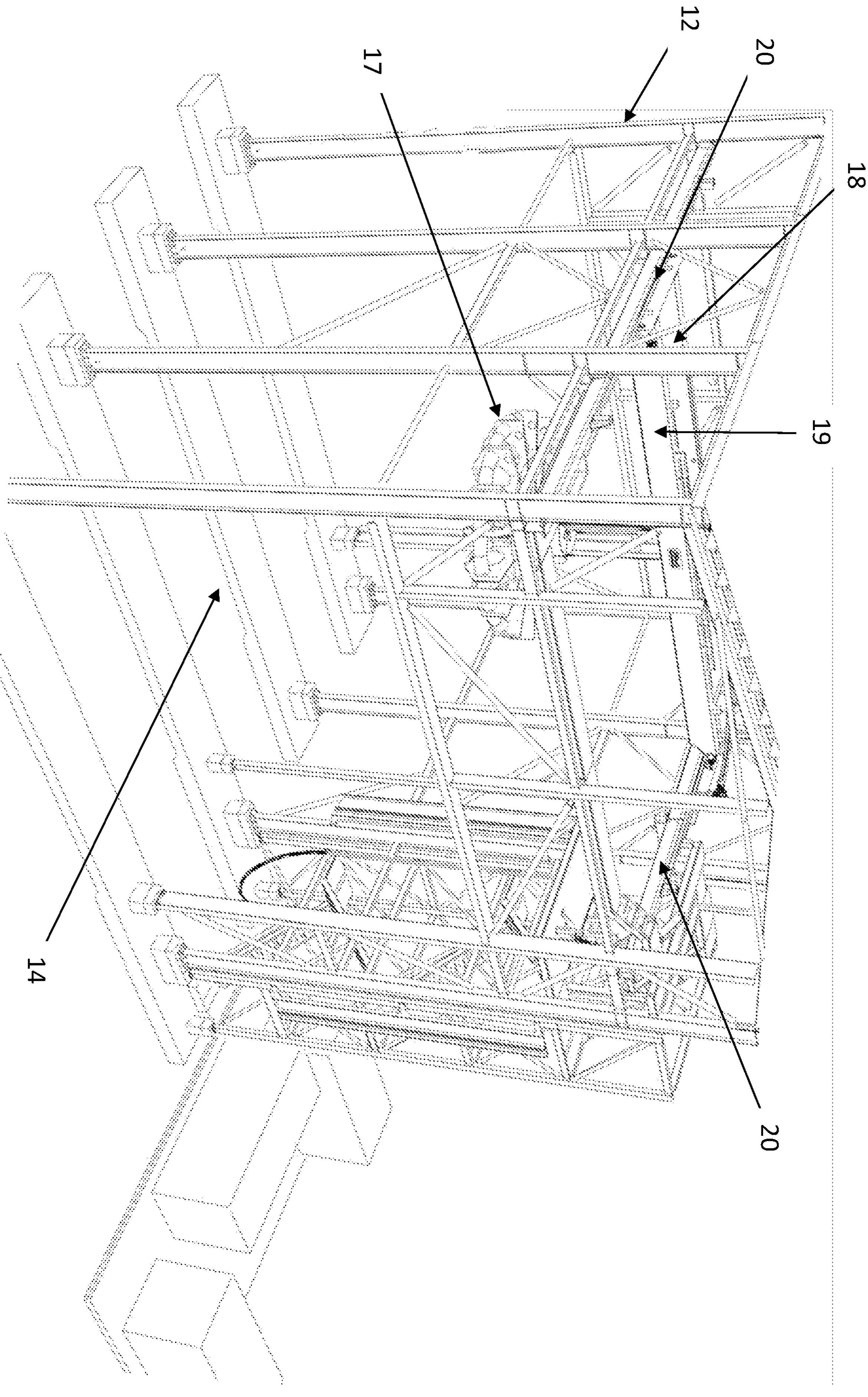

FIG 4

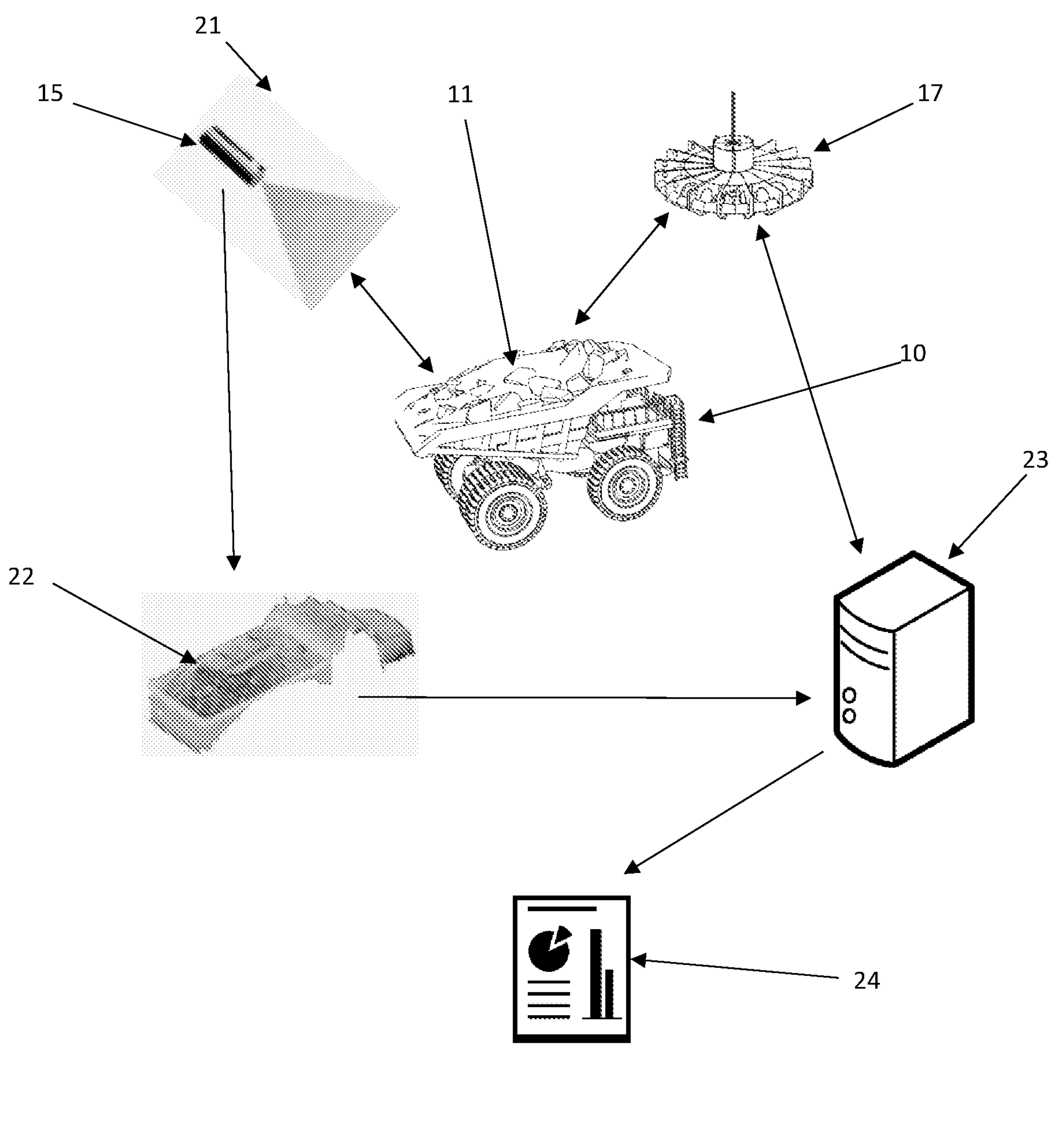

FIG 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2024/050110

A. CLASSIFICATION OF SUBJECT MATTER

G01V 3/14 (2006.01) G01R 33/20 (2006.01) G01V 3/12 (2006.01) G06Q 50/02 (2024.01)

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)

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)

EPOQUE (PATENW), Espacenet, Google Scholar using search terms such as: G01R33/12/LOW, G01R33/20, G01V3/14, G01N24/00/LOW, G01N27/00/IC/C/LOW, G01N[21,22,23,25,29,33,35]/00/LOW, G01N2223/616, B07C5/344/HIGH, G06Q50/02/, truck, haulage, vehicle, lorry, cart, enroute in transit, ore, material, load, minerals, elements, scan, sense, detect, composition, grade, quality, properties, characteristics, attributes, make up, content, move, position, align, gantry, crane, track, sensor, detector, antenna, magnetic resonance, NMR, MR, bulk ore sorting, sort, divert, waste, stockpile, gangue, mill, process, Christopher Beal, NEXTORE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[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
- "D" document cited by the applicant in the international application
- "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
24 April 2024	24 April 2024

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/0074619 A1 (MARTINEZ GODOY et al.) 31 March 2011 Whole document, in particular: Abstract; Figs 1 - 2; [0003], [0006], [0015], [0021] - [0022]	1, 3, 4 - 5, 8 - 10, 12 - 14, 17 - 18
X	WO 2019/046983 A1 (MAURIN GAUSSET) 14 March 2019 Whole document, in particular: Abstract; Page 7, Line 12 - Page 8, Line 7	1 - 4, 6 - 13, 15 - 18
A	WO 2020/049517 A1 (STONE THREE DIGITAL (PTY) LTD) 12 March 2020 Whole document	1 - 18
A	GIROUX et al., "In-truck ore grade estimation using apparent density measurements", *Journal of the Southern African Institute of Mining and Metallurgy,* 120.5, pp 327-332, 2020 Whole document	1 - 18
A	DUFFY et al., "In search of the Holy Grail—Bulk ore sorting", *Proceedings of the Austmine,* 2015 Whole document	1 - 18
A	LY, "Zero-field Nuclear Magnetic Resonance of Copper Minerals", *Diss. UNSW,* 2021 Whole document	1 - 18

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2024/050110**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
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		US 8284096 B2	09 Oct 2012
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WO 2020/049517 A1	12 March 2020	WO 2020049517 A1	12 Mar 2020
		AU 2019335607 A1	01 Apr 2021
		BR 112021004248 A2	18 May 2021
		CL 2021000547 A1	24 Sep 2021
		CL 2021003234 A1	26 Aug 2022
		CL 2021003235 A1	26 Aug 2022
		PE 20210695 A1	12 Apr 2021

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.