



(22) Date de dépôt/Filing Date: 2009/11/24

(41) Mise à la disp. pub./Open to Public Insp.: 2010/06/03

(45) Date de délivrance/Issue Date: 2013/01/29

(30) Priorité/Priority: 2008/12/03 (CA2,645,707)

(51) Cl.Int./Int.Cl. *G01C 7/06* (2006.01)

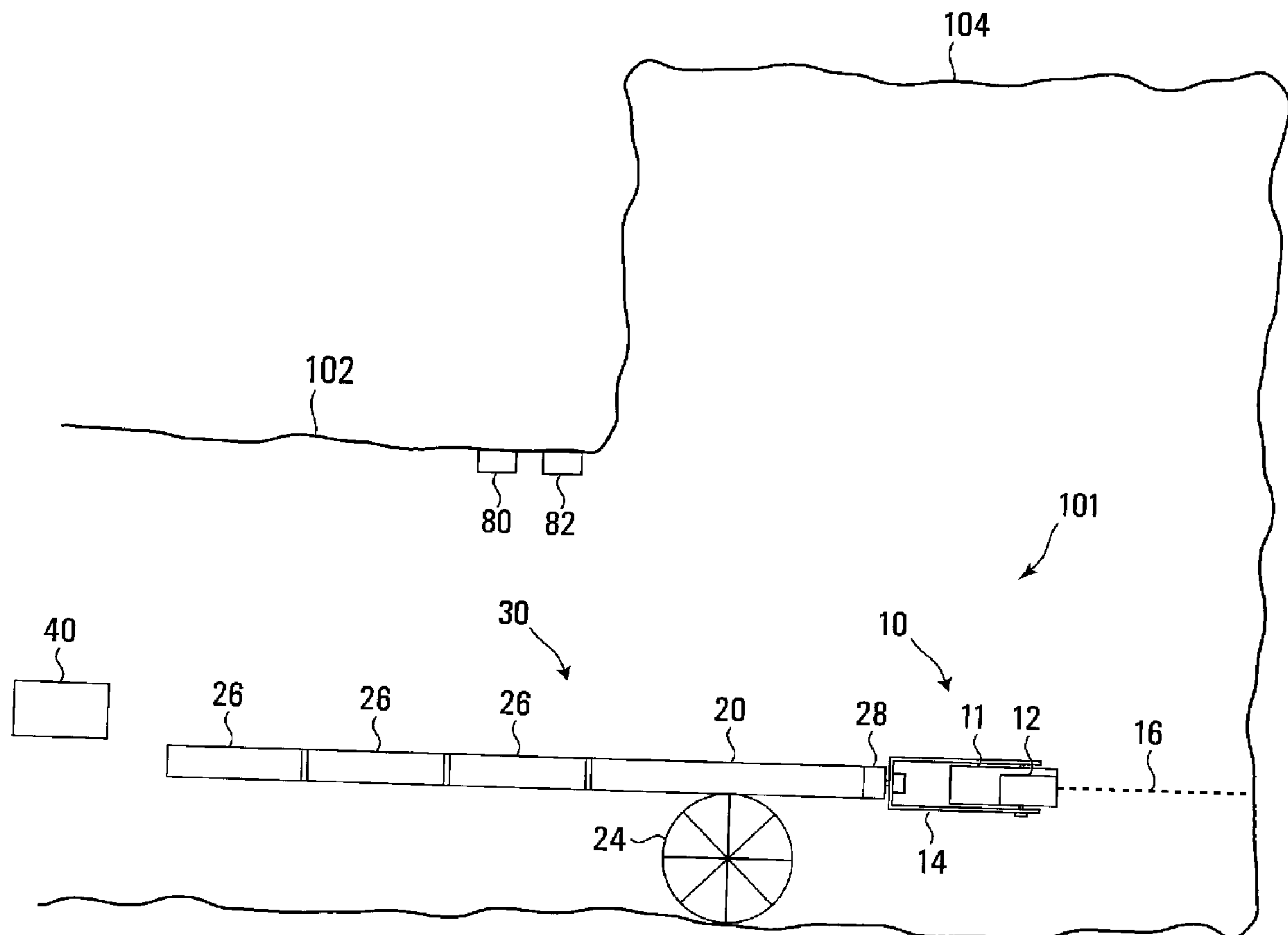
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(54) Titre : PROCEDE ET APPAREIL D'INSPECTION D'UNE CAVITE

(54) Title: METHOD AND APPARATUS FOR SURVEYING A CAVITY



(57) Abrégé/Abstract:

A flexible apparatus and method for remotely determining the dimensions of a cavity in a mine is disclosed. The apparatus and method do not require mechanical leveling prior to scanning a cavity. Additionally, the apparatus may operate in a variety of

(57) **Abrégé(suite)/Abstract(continued):**

challenging orientations and determine its position and azimuth using targets having known positions to facilitate a transformation of measured data into an existing coordinate system for display to a user. A digital compass may also optionally be used to determine the azimuth the apparatus.

ABSTRACT OF THE DISCLOSURE

A flexible apparatus and method for remotely determining the dimensions of a cavity in a mine is disclosed. The apparatus and method do not require mechanical leveling prior to scanning a cavity. Additionally, the apparatus may operate in a variety of challenging orientations and determine its position and azimuth using targets having known positions to facilitate a transformation of measured data into an existing coordinate system for display to a user. A digital compass may also optionally be used to determine the azimuth the apparatus.

METHOD AND APPARATUS FOR SURVEYING A CAVITY

FIELD OF THE INVENTION

[0001] The invention relates to apparatus and methods for surveying cavities. More particularly, the invention provides improved methods and apparatus for remotely surveying cavities in mines.

BACKGROUND

[0002] In modern mining methods cavity location, dimensions and volume are monitored. Accurate surveys may be required for various reasons including bonus systems, maintenance, structural analysis, economic analysis, etc. However, many cavities may not be accessed directly by surveyors due to safety concerns arising from the mining methods and cavity condition or the orientation of the cavities, for instance in the case of raises and ore passes.

[0003] Currently available cavity surveying equipment include systems that employ remote laser sensors on gimbals adapted to be placed in a cavity and operated from a remote position. However, equipment the inventor is aware of commonly being used for remotely surveying cavities, and in particular stopes in mines, is cumbersome and requires significant time for set-up and operation. Further, such systems are generally used with separate surveying equipment, typically a total station system, to provide coordinates and azimuth of the laser scanner, which is inconvenient. Difficulty may also be encountered in surveying ore passes or other cavities where there may be no sufficient line of sight available to establish accurate coordinates and azimuth of the laser scanner and where levelling of the scanner may be difficult or impossible due to the orientation of the cavity. Further, difficulty may be encountered with current systems when rapid scanning is required or when a user must deploy a scanner more than 100m away for long range scanning.

[0004] Accordingly, there is a need for improved methods and apparatus for remotely surveying cavities.

SUMMARY OF THE INVENTION

[0005] In accordance with an aspect of the invention there is provided an apparatus for surveying a cavity comprising a support structure; a scanner module having a mechanical home position mounted on the support structure, the module including a first motor mounted in the module adapted to rotate the module about a first axis; a laser scanner mounted in the module to scan along a scanning axis and measure distance to targets; inclinometers mounted in the module to measure the pitch and roll of the module in the mechanical home position; a second motor mounted in the module to rotate the module about a second axis, means to measure motor position data; scanner module control circuits and controllers adapted to receive commands from a remote station, actuate components of the apparatus, and communicate data received to the remote station; and a power source mounted in the module and wiring in the module to supply power to components of the module; the remote station including: a user interface for entering commands and reviewing measurements received from the scanner module; a processor adapted to receive commands from the user interface and to communicate them to the scanner module controllers, receive and store data from the scanner module controllers including data from measurements taken by the laser scanner without leveling thereof and scanner module mechanical home pitch and roll, azimuth and coordinates in an existing coordinate system, and motor position data measurements to facilitate preparation of an accurate representation of the cavity in the existing coordinate system.

[0006] In accordance with another aspect of the invention, it is provided that the support structure is a mobile support structure that further includes an axle generally transverse to said first axis having wheels rotatably mounted on each end and a longitudinal member mounted on said axle generally parallel to said

first axis; and wherein a support on of said module is mounted to said longitudinal support member for rotation about said first axis by said first motor; and said laser scanner is rotatably mounted on said support arm for rotation about said second axis by said second motor.

[0007] In accordance with another aspect of the invention there is provided a method of surveying a cavity comprising the steps of: positioning a support structure having a scanner module having a mechanical home position mounted thereon in the cavity, the scanner module including: a first motor mounted in the module adapted to rotate the module about a first axis; a laser scanner mounted in the module to scan along a scanning axis; inclinometers mounted in the module to measure the pitch and roll of the module in its mechanical home position; a second motor mounted in the module to rotate the module about a second axis, means to measure motor position data, scanner module control circuits and controllers adapted to receive commands from a remote station, actuate components of the scanner module and the first motor and communicate data received from the components to the remote station; and a power source mounted in the module and wiring in the module to supply power to the components of the module; operating controls on a user interface on a remote station to actuate the inclinometers, laser scanner and first and second motors and encoders to measure the pitch and roll of the module in the mechanical home position and the distance to the walls of the cavity at a plurality of positions and to communicate measurement and motor encoder information to the remote station; identifying the coordinates of the scanner module and the azimuth of the scanner module in its mechanical home position in an existing coordinate system and communicating same to the remote station; and processing the measurement information received from the laser scanner without leveling thereof using the pitch and roll, scanner module coordinates, azimuth and motor position data to prepare an accurate representation of the cavity in the existing coordinate system.

[0008] In accordance with another aspect of the invention there is provided a method of surveying a cavity comprising the steps of: positioning a laser scanner having an inclinometer module in a mechanical home position in the cavity; determining the pitch and roll of the laser scanner in the mechanical home position using the inclinometer module; selecting first and second targets, the first and second targets having known positions in an existing coordinate system; orienting the laser scanner towards the first and second targets and measuring target information; determining the position of the laser scanner in the existing coordinate system and the azimuth of the laser scanner in the mechanical home position in the existing coordinate system using the target information and the pitch and roll; orienting the laser scanner in a plurality of orientations to measure the distance from the laser scanner to the walls of the cavity at each of the plurality of orientations; and transforming the measurement information into the existing coordinate system using the position and the azimuth.

[0009] In accordance with another aspect of the invention there is provided a method of surveying a cavity comprising the steps of: positioning at an appropriate location in the cavity, a support structure having a scanner module having a mechanical home position mounted the support structure the module including: a first motor mounted in the module adapted to rotate the module about a first axis; a laser scanner mounted in the module to scan along a scanning axis and measure distance to targets; inclinometers mounted in the module to measure the pitch and roll of the module in the mechanical home position; a second motor mounted in the module to rotate the module about a second axis, means to measure motor position data, scanner module control circuits and controllers adapted to wirelessly receive commands from a remote station, actuate components of the module, and wirelessly communicate data received to the remote station; and a power source mounted in the module and wiring in the module to supply power to components of the module; selecting

first and second targets having known positions in the existing coordinate system; orienting the laser scanner towards the first and second targets and measuring the orientation of the laser scanner and distance from the laser scanner to the first and second targets to generate target information; operating controls on a user interface on a remote station to actuate the inclinometers, laser scanner and first and second motors and means for measuring motor position data to measure the pitch and roll of the scanning axis at the mechanical home position and the distance to the walls of the cavity at a plurality of positions; identifying the coordinates of the scanner module and the azimuth of the module in the mechanical home position in an existing coordinate system using the pitch and roll and the target information; and processing the measurement information received from the laser scanner without leveling thereof using the pitch and roll, the coordinates of the module, and the azimuth to prepare an accurate representation of the cavity in the existing coordinate system.

[0010] Other aspects and features of the present invention will become apparent to those of ordinary skill in the art upon review of the following

description of exemplary embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] In the figures which illustrate embodiments of the present invention by way of example only:

[0014] **FIG. 1** is a schematic depiction of an embodiment of the invention inside a cavity.

[0015] **FIG. 2** is side view of the scanner module of an embodiment of the invention.

[0016] **FIG. 3** is a side view of an embodiment of the scanner module in a first position.

[0017] **FIG. 4** is a side view of an embodiment of the scanner module in a second position.

[0018] **FIG. 5** is a schematic of an embodiment of a scanner module controller.

DETAILED DESCRIPTION

[0019] As noted, mining methods require accurate determination of the position and dimensions of cavities in mines. Scanning equipment that may be placed inside a cavity and remotely operated to scan the majority of the cavity without having personnel enter the cavity is advantageous. Providing flexible methods for transforming data received from such rapid scanning equipment in various cavity conditions and orientations is also advantageous. Exemplary embodiments of flexible apparatus and methods of the present invention are described.

[0020] With reference to Fig. 1, an exemplary cavity monitoring system 101 includes a scanner module 10 mounted on a mobile support structure 30 using a support arm 14 connected to mounting bracket 28 on longitudinal member 20. Rod sections 26 provide rigid extensions of longitudinal support member 20 to

allow remote positioning of the cavity monitoring system 101 in cavity 104.

[0021] Rod sections 26 and longitudinal support member 20 may be square aluminium rods. Rod sections 26 of approximately 5 feet in length configured for interconnection to form a rigid extension of known length have been found to facilitate accurate positioning of said cavity monitoring system 101 inside cavities having various orientations and configurations, including raises and ore passes.

[0022] The mobile support structure 30 may be mounted on wheels 24 for rotation about an axis transverse to longitudinal member 20 to facilitate cavity monitoring system 101 being positioned in a cavity 104 from a drift 102 or other safe access point. Such a configuration, used with support rods 26 as described, has been found to be effective in positioning the scanner module 10 up to 30 meters or more from the surveyor. Employing rod sections 26 that are rigid and of accurate lengths allows an accurate estimate of the position of scanner module 10 to be determined, which may be important in certain applications as noted below. However, the support method used to advance the cavity monitoring system (wheels, skids, levers, etc), and the particular configuration or number of axles or wheels is not essential to the invention in its broadest sense.

[0023] With reference to Fig. 2, a laser scanner 12 is mounted inside a protective housing 11 of scanner module 10. The laser scanner 12 emits a beam 16 that reflects from the walls of cavity 104 and records the distance to the reflection points using time of flight of beam 16. The laser scanner 12 may also measure the intensity of the returning beam 16 and preferably has a range of at least 150m.

[0024] In the exemplary embodiment illustrated, support arm 14 is mounted on longitudinal member 20 in mounting bracket 28 for 360 degree rotation about an axis X-X coincident with the longitudinal axis of longitudinal member 20. Support arm 14 may be mounted by securing shaft 70 to mounting bracket 28 in a suitable manner. Shaft 70 is operatively coupled to motor 72 that is in turn mounted on support arm 14 and adapted to rotate arm 14 about axis X-X. Motor 72 may include an encoder 74 to determine relative angular position of support arm 14 about axis X-X. Encoder 74 is preferably a precision encoder that provides high

resolution, for example of 100,000 or more points/scan, to facilitate accurate measurement of a cavity. Alternatively, motor 72 may be mounted inside mounting bracket 28 and operatively coupled to shaft 70 and in turn support arm 14 with appropriate modification in certain embodiments of the invention.

[0025] Protective housing 11, housing laser scanner 12 and other components, are mounted for rotation about a second axis Y-Y defined by shaft 50 that is generally perpendicular to axis X-X. Shaft 50 is mounted to support arm 14. Motor 52 is mounted inside protective housing 11 and is operatively coupled to shaft 50 for rotation of the housing 11 about axis Y-Y. Shaft 50 includes a slip ring or through-hole motor shaft (not shown) to allow the passage of wires to supply power from a power supply in the housing to motor 72 while permitting rotation about axis Y-Y. Preferably the housing 11 may be rotated 170 degrees from a mechanical home position to facilitate relatively complete scanning of a cavity by the laser scanner 12, as described below. However, a lesser degree of rotation may also be effectively employed, depending upon the application. It has been found that 150 degree rotation may advantageously used in most applications. An encoder 54 may be associated with motor 52 to determine the relative angular position of the laser scanner 12 about axis Y-Y. Encoder 54 is preferably a precision encoder, for instance providing resolution of at least 100,000 points/scan, to facilitate accurate measurement.

[0026] In the illustrated embodiment an inclinometer module 53 is mounted in protective housing 11. Inclinometer module 53 may include two inclinometers configured to determine the inclination (tilt) of laser scanner 12 relative to two different axes or a dual axis inclinometer having the same functionality. The inclinometer module is preferably capable of measuring inclinations from 0 to ± 90 degrees to allow for effective and accurate deployment in surveying cavities having steep inclinations such as ore passes or raises.

[0027] A digital compass 55 may also be mounted in housing 11 to facilitate determination of the azimuth of the scanning axis of laser scanner 12 as described below.

[0028] Protective housing 11 is preferably sealed to minimize egress of dust or

other contaminants. In a preferred embodiment, the protective housing 11 also has a power source, controllers and a communication module mounted in it. The scanner 12, inclinometer module 53, digital compass 55, power source, controllers and communication module are mounted and interconnected in any suitable configuration and known manner in the housing 11 allowing for operability (the last three components are not shown in Fig.1-3).

[0029] Rotation of an embodiment of scanner module 10 and laser scanner 12 is illustrated with reference to Figs. 3 and 4. In Fig. 3, laser scanner 12 is shown in its mechanical home position so that beam 16 extends along axis X-X and support arm 14 of scanner module 10 is in its initial position before rotation about axis X-X. Fig. 4 depicts the scanner module 10 rotated 180 degrees about axis X-X and rotated 90 degrees about axis Y-Y from its mechanical home position.

[0030] A schematic of a preferred embodiment of a scanner module controller 200 mounted in the protective housing 11 is shown in Figure 5. Scanner module controller 200 includes a single board computer 202 in communication with and having supervisory control over other system components. Scanner module controller as used herein refers to the general control and communications components of the scanner module and is not limited to any particular structure or configuration, provided similar functionality is provided.

[0031] In operation a user enters commands on remote station 40, via command interface 41, which are communicated by remote station 40 to scanner module 10 through communication module 214. Transmission between remote station 40 and communication module 214 may take place by way of wireless communication, such as a WiFi link, or RS422 communication where long range remote scanning is required. User commands are transferred from communication module 214 to single board computer 202 for processing. Single board computer 202 communicates as necessary with motor controllers 204 and 208 which control motors 52 and 72 in conjunction with encoder controllers 206 and 210 to control the orientation of scanner module 10 and laser scanner 12. Single board computer 202 may also communicate with inclinometer controller 212 to determine the pitch and roll of laser scanner 12. Single board computer 202 may also communicate with digital compass 55 to determine azimuth data of the

scanner module. Similarly, single board computer 202 may communicate with laser scanner controller 218 to actuate laser scanner 12.

[0032] Power management module 216 is preferably connected to a battery 220 housed in the protective housing 11 and adapted to provide power to the various components of the cavity monitoring system. In a preferred embodiment battery 220 is a 22.2V lithium ion battery configured to be charged by external cables and charger. However, other suitable battery types and charging methods, including induction, may also be effective. Electric connections are provided from the battery 220 to other components in the housing 11 and to external motor 72 and associated encoders and controllers.

[0033] In operation, scanner module 10 is advanced into cavity 104 on mobile support structure 30 to an appropriate position for the surveying task at hand by incremental attachment of rods 26 and manual advancement. Scanner module 10 and laser scanner 12 are set in the mechanical home position through initialization. The pitch and roll of laser scanner 12 in the mechanical home position is determined by inclinometer module 52 and stored in memory 222. In contrast to current popular cavity monitoring systems, no levelling of the laser scanner is performed, which may reduce the time required to scan a cavity and allow for a more accurate scan in practical operation. The azimuth or deviation from a horizontal axis in an existing coordinate system of the laser scanner 12 in the mechanical home position is also ascertained and stored in memory 222 as discussed below.

[0034] Dimensions of the cavity being surveyed are measured by orienting laser scanner 12 in a plurality of measurement positions to determine the distance to the walls of cavity 104 at various locations. More specifically, scanner module controller 200 causes motor 52 to rotate laser scanner 12 about axis Y-Y in conjunction with encoder 54 to a first angular position where the distance to the wall of cavity 104 is measured by laser scanner 12 and stored in memory 222. Scanner module controller 200 then causes motor 72 in conjunction with encoder 74 to rotate support arm 14 and to actuate laser scanner 12 to measure the distance to the walls of cavity 104 at different measurement positions around the 360 degree rotation about axis X-X and measurement data is stored in memory

222. Scanner module controller 200 then actuates motor 52 in conjunction with encoder 54 to rotate laser scanner 12 about axis Y-Y to a second angular position. Scanner module controller 200 again causes motor 72 in conjunction with encoder 74 to rotate support arm 14 about axis X-X 360 degrees and laser scanner 12 to measure the distance to the walls of cavity 104 at various points, the measurement data being stored in memory 222. This process is repeated while laser scanner 12 is rotated to various positions intermediate between 0 and 170 degrees relative to axis Y-Y and scanner module 10 is rotated from 0 to 360 degrees relative to axis X-X at each angular position of laser scanner 12 such that measurements are taken in concentric circles.

[0035] The azimuth (deviation from a horizontal axis) and position in an existing coordinate system, and orientation of the laser scanner must be ascertained in order to facilitate transformation of measurement data generated by laser scanner 12 to an existing coordinate system. The orientation is measured using the inclinometer module 52. The position and azimuth may be determined in different ways as discussed below.

[0036] A preferred method for determining position and azimuth employs targets 80 and 82 (see Fig. 1) secured at known positions in an existing coordinate system, for instance on the back of drift 102 leading to cavity 104 or at another appropriate known position in proximity to the cavity to be measured. Targets 80 and 82 may be comprised of a reflective material having greater reflectance than the walls of cavity 104, such as mini prisms or other targets suitable for use in mine surveying. The coordinates of targets 80 and 82 are known, for instance having been determined in the existing coordinate system when initially positioned, for example, by bolting to the in situ rock, or may be ascertained and stored for further use by conventional surveying techniques when the cavity is first surveyed. In the preferred process, targets 80 and 82 are selected so that a line of sight exists between targets 80 and 82 and laser scanner 12 when laser scanner 12 is placed inside cavity 104 in a position appropriate to measure the dimensions of cavity 104. Laser scanner 12 may emit a visual beam that a user may use to assist in orienting laser scanner 12 towards targets 80 and 82. The reflectance of targets 80 and 82 assist a user in determining that laser

scanner 12 is directed at targets 80 and 82. In preferred embodiments where the laser scanner measures the intensity of the returning beam 16, the laser scanner 12 preferably includes a locate function which facilitates the laser scanner automatically locating targets.

[0037] Remote station 40 may provide a user interface to allow easy selection of targets 80 and 82 having known positions in an existing coordinate system to facilitate determination of the azimuth and position of laser scanner 12 by cavity monitoring system 101. For instance, remote station 40 may store and display identification details of targets available in the vicinity and the user may select targets appropriately positioned for the task at hand. In a preferred embodiment of the invention, remote station 40 presents a graphical representation of available targets to facilitate location and selection of appropriate targets by the user. The user inputs the identification of the selected targets into remote station 40. To obtain azimuth and position information for the laser scanner the operator directs the laser scanner 12 to point at each target and measures distance to the target from the scanner. Target information is stored, including the orientation of laser scanner 12 relative to its home position and distance from laser scanner 12 to each target. Only two targets are required to determine the position and azimuth of laser scanner 12 in the mechanical home position in preferred embodiments of the invention due to the orientation information provided by the inclinometer module 52. Moreover, a total station is not required to determine the position and azimuth of laser scanner 12 so long as the scanner 12 has line of sight to two targets, thereby reducing the equipment required to survey the cavity. In a further preferred embodiment, the scanner module 10 may be used to set and record target points, for instance when advancing down a portion of a drift being scanned that does not have sufficient targets. The coordinates of a target point are determined using the scanner module 10, stored as an identified reference point and a target is affixed to the point for subsequent referencing by the scanner.

[0038] Once the location of targets 80 and 82 relative to the laser scanner have been determined, the position of laser scanner 12 in an existing coordinate system and the azimuth of laser scanner 12 may be determined using resection

according to known methods. Using targets and resection allows for a relatively fast and accurate determination of the position and azimuth of laser scanner 12 increasing surveying efficiency and minimizing inconvenience. If three or more targets are within range, triangulation may be utilized if desired.

[0039] A second method for determining position and azimuth of laser scanner 12 is to use a total station apparatus (not shown). The total station apparatus is set up at a known position in an existing coordinate system. Two targets (not shown) are placed at different known locations on mobile support structure 30 along axis X-X. A surveyor may then determine the position of the targets on the mobile support structure using the total station apparatus, and the position and azimuth of laser scanner 12 in its mechanical home position may be calculated and transformed into the existing coordinate system.

[0040] A third method for determining position and azimuth of laser scanner 12 may be utilized where there is insufficient line of sight to accurately determine the position and azimuth of the scanner module 10 or support structure 30. In particular, that situation may occur when surveying cavities having steep inclines and bends, most commonly encountered in raises and ore passes. In such situations, the azimuth of the laser scanner 12 in its mechanical home position may be provided by the digital compass 55. The position of the laser scanner 12 in the existing coordinate system may then be estimated based on the known length of longitudinal member 20 and extensions thereof through rod sections 26 and inclinometer measurements to determine the relative position of a point on a rod section 26 from a point having known coordinates in the existing coordinate system.

[0041] In most circumstances, information received from the digital compass 55 will not be necessary to carry out the survey. However, the information may be used to confirm azimuth information otherwise obtained. Further, in a preferred embodiment, the remote station 40 may be used to process the measurement data generated and may provide a three dimensional display of cavity 104 in the existing coordinate system. Such a display will provide the surveyor with an ability to check the accuracy of the survey undertaken while still at the site, which is

obviously beneficial. For example, it allows a surveyor to analyse the orientation of a cavity relative to other nearby features, such as drifts. The display may also display a representation of the measured azimuth in the existing coordinate system in order to verify that the position and azimuth are correctly determined prior to scanning the cavity.

[0042] It will be understood that operation of scanner module 10 is controlled by the user via the remote station 40. Commands entered into the remote station 40 via interface 41 are communicated to scanner module controller 200 to implement the desired command. Similarly, after a measurement is taken by the scanner, inclinometer module or digital compass measured data, and information relating to scanner module 10 positioning from encoders 54 and 74 is transmitted to remote station 40 through communication module 214. That information may be stored in memory in remote station 40 for processing on surface. However, preferably the information is processed in the manner referred to in the preceding paragraph to provide an onsite check for errors and accuracy. The data received is processed using known algorithms to transform the raw distance data from the scanner 12 to coordinates in the existing coordinate system using the azimuth, position and pitch and roll data of the laser scanner 12.

[0043] The above described embodiments are intended to be illustrative only and in no way limiting. The described embodiments of carrying out the invention, are susceptible to many modifications of form, arrangement of parts, details and order of operation. The invention is intended to encompass all such modification within its scope, as defined by the claims.

WHAT IS CLAIMED IS:

1. An apparatus for surveying a cavity comprising:
 - (a) a support structure;
 - (b) a scanner module having a mechanical home position mounted on said support structure, said module including:
 - (i) a first motor mounted in said module adapted to rotate said module about a first axis;
 - (ii) a laser scanner mounted in said module to scan along a scanning axis and measure distance to targets;
 - (iii) inclinometers mounted in said module to measure the pitch and roll of said module in said mechanical home position;
 - (iv) a second motor mounted in said module to rotate said module about a second axis,
 - (v) means to measure motor position data;
 - (vi) scanner module control circuits and controllers adapted to receive commands from a remote station, actuate components of the apparatus, and communicate data received to the remote station; and
 - (vii) a power source mounted in said module and wiring in said module to supply power to components of said module;
 - (c) said remote station including:
 - (i) a user interface for entering commands and reviewing measurements received from said scanner module;
 - (ii) a processor adapted to receive commands from said user interface and to communicate them to said scanner module controllers, receive and store data from said scanner module controllers including data from measurements taken by said laser scanner

without leveling thereof and scanner module mechanical home pitch and roll, azimuth and coordinates in an existing coordinate system, and motor position data measurements to facilitate preparation of an accurate representation of said cavity in said existing coordinate system.

2. The apparatus of claim 1 wherein said control circuits include a computer board mounted in said module having supervisory control over other components of said scanner module.
3. The apparatus of claim 1 or 2 wherein said power source is a battery.
4. The apparatus of any one of claims 1-3 wherein said processor is adapted to receive data from said scanner module controllers and to process said data to transform measurements taken by said laser scanner using said measured pitch and roll, azimuth in said mechanical home position, scanner module coordinates and motor position data measurements to prepare an accurate representation of said cavity in an existing coordinate system.
5. The apparatus of any one of claims 1-4 wherein said module further includes a digital compass adapted to measure said azimuth of said module in said mechanical home position.
6. The apparatus of any one of claims 1-5 wherein said means to measure motor position data are motor encoders.
7. The apparatus of any of claims 1 - 6 wherein said support structure is a mobile support structure that further includes:

- (a) an axle generally transverse to said first axis having wheels rotatably mounted on each end;
- (b) a longitudinal member mounted on said axle generally parallel to said first axis;

wherein a support arm of said module is mounted to said longitudinal support member for rotation about said first axis by said first motor; and said laser scanner is rotatably mounted on said support arm for rotation about said second axis by said second motor.

8. The apparatus of claim 7 wherein said module may be rotated between 0 and 360 degrees relative to said first axis and said laser scanner may be rotated at least between 0 and 150 degrees around said second axis.

9. The apparatus of claim 7 wherein said support structure is manually advanced into said cavity using rod sections of known length releasably and rigidly connected together as the structure is advanced.

10. The apparatus of any one of claims 1-9 wherein said scanner module further includes a communication module adapted for wireless communication between said scanner module and said remote station.

11. The apparatus of any one of claims 1 - 10 wherein said inclinometers are capable of measuring pitch and roll between 0 and ± 90 degrees from horizontal.

12. A method of surveying a cavity comprising the steps of:

- (a) positioning a support structure having a scanner module having a mechanical home position mounted thereon in said cavity, said scanner module including:

- (i) a first motor mounted in said module adapted to rotate said module about a first axis
 - (ii) a laser scanner mounted in said module to scan along a scanning axis;
 - (iii) inclinometers mounted in said module to measure the pitch and roll of said module in its mechanical home position;
 - (iv) a second motor mounted in said module to rotate said module about a second axis,
 - (v) means to measure motor position data,
 - (vi) scanner module control circuits and controllers adapted to receive commands from a remote station, actuate components of said scanner module and said first motor and communicate data received from said components to said remote station; and
 - (vii) a power source mounted in said module and wiring in said module to supply power to the components of said module;
- (b) operating controls on a user interface on a remote station to actuate said inclinometers, laser scanner and first and second motors and encoders to measure the pitch and roll of said module in said mechanical home position and the distance to the walls of the cavity at a plurality of positions and to communicate measurement and motor encoder information to said remote station;
 - (c) identifying the coordinates of said scanner module and the azimuth of said scanner module in its mechanical home position in an existing coordinate system and communicating same to said remote station; and
 - (d) processing said measurement information received from said laser scanner without leveling thereof using said pitch

and roll, scanner module coordinates, azimuth and motor position data to prepare an accurate representation of said cavity in said existing coordinate system.

13. The method of claim 12, wherein said coordinates and said azimuth of said scanner module in said home position are determined by steps including:
 - (a) selecting first and second targets having known positions in said existing coordinate system;
 - (b) orienting said laser scanner towards said first and second targets and measuring the orientation of said laser scanner and distance from said laser scanner to said first and second targets; and
 - (c) determining the coordinates of said scanner module and said azimuth in its mechanical home position using said orientation and said distance of said first and second targets.
14. The method of claim 12, wherein said module further includes a digital compass adapted to measure said azimuth of said module in said mechanical home position and the azimuth of said scanning axis.
15. The method of any one of claims 12-14 wherein said means to measure motor position data are motor encoders.
16. The method of claim 14 or 15 wherein said control circuits include a computer board having supervisory control over other components of said scanner module.
17. The method of any one of claims 14-16 wherein said power source is a battery.

18. The method of any one of claims 12-17 wherein said support structure is a mobile support structure that further includes:

- (a) an axle generally transverse to said first axis having wheels rotatably mounted on each end;
- (b) a longitudinal member mounted on said axle generally parallel to said first axis;

wherein a support arm of said scanner module is mounted to said longitudinal support member for rotation about said first axis by said first motor; and said laser scanner is rotatably mounted on said support arm for rotation about said second axis by said second motor.

19. The method of any one of claims 12-18 wherein said scanner module may be rotated 360 degrees around said first axis and said laser scanner may be rotated at least between 0 and 150 degrees around said second axis.

20. The method of claim 18 wherein said support structure is manually advanced into said cavity using rod sections of known length releasably and rigidly connected together as the structure is advanced.

21. The method of any one of claims 12-20 wherein said scanner module further includes a communication module adapted for wireless communication between said scanner module and said remote station.

22. The method of any one of claims 12-21 wherein said inclinometers are capable of measuring pitch and roll between 0 and ± 90 degrees.

23. The method of claim 14, wherein identifying said coordinates of said module includes:

- (a) advancing said module a known distance into said cavity;

- (b) determining the coordinates of a first point in said existing coordinate system, said first point a known distance from said module; and
 - (c) estimating the coordinates of said module based on the position of said first point.
24. The method of claim 12, wherein identifying said coordinates and said azimuth of said module includes:
- (a) advancing said module a known distance into said cavity;
 - (b) determining the coordinates of a first point in said existing coordinate system, said first point a known distance from said module;
 - (c) determining the coordinates of a second point on said support structure in said existing coordinate system; and
 - (d) determining the coordinates and the azimuth of said module based on the coordinates of said first and second points.
25. A method of surveying a cavity comprising the steps of:
- (a) positioning a laser scanner having an inclinometer module in a mechanical home position in said cavity;
 - (b) determining the pitch and roll of said laser scanner in said mechanical home position using said inclinometer module;
 - (c) selecting first and second targets, said first and second targets having known positions in an existing coordinate system;
 - (d) orienting said laser scanner towards said first and second targets and measuring target information;
 - (e) determining the position of said laser scanner in said existing coordinate system and the azimuth of said laser scanner in said mechanical home position in said existing coordinate system using said target information and said pitch and roll;

- (f) orienting said laser scanner in a plurality of orientations to measure the distance from said laser scanner to the walls of said cavity at each of said plurality of orientations; and
- (g) transforming said measurement information into said existing coordinate system using said position and said azimuth.

26. A method of surveying a cavity comprising the steps of:

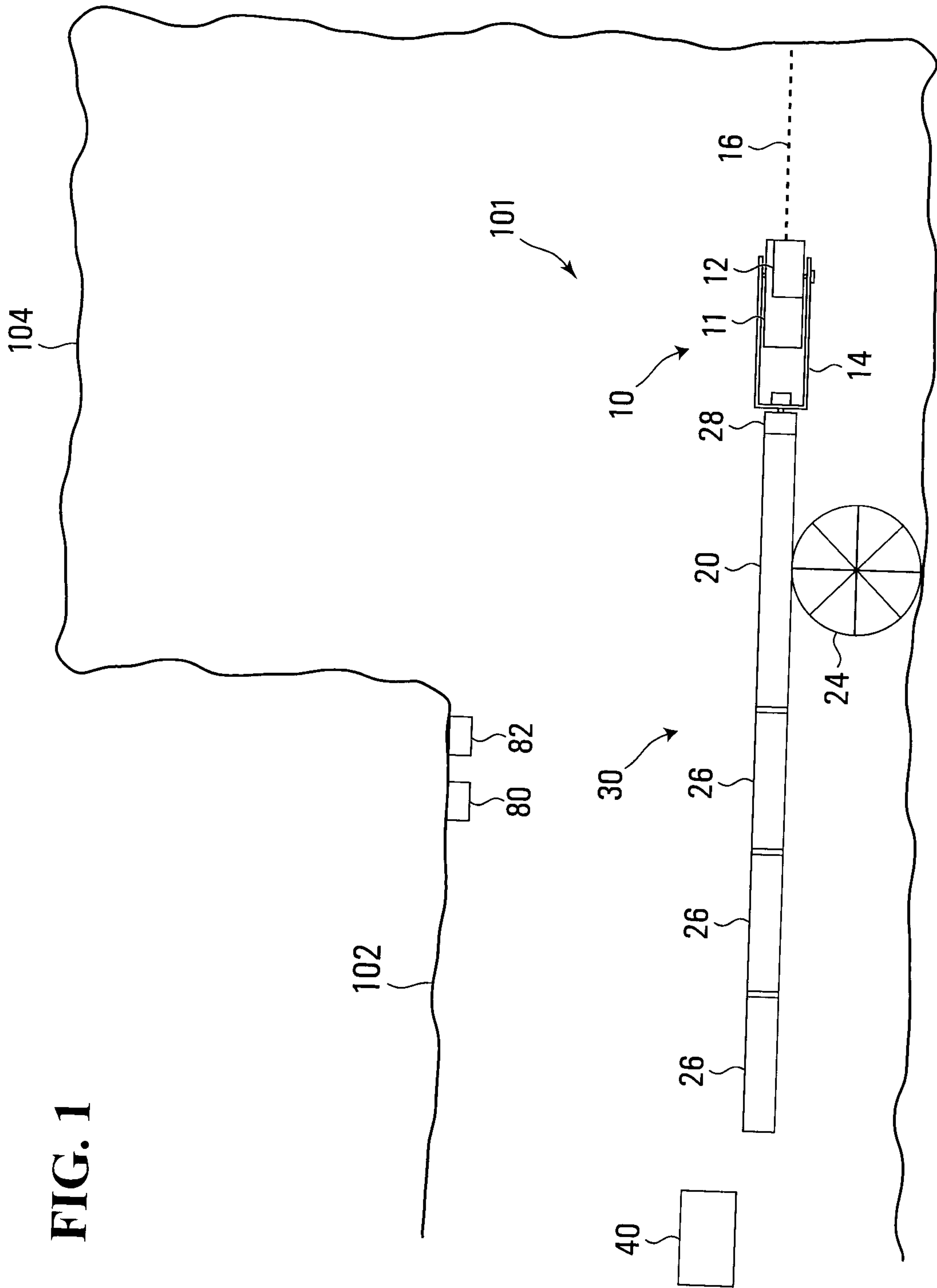
- (a) positioning at an appropriate location in said cavity, a support structure having a scanner module having a mechanical home position mounted said support structure said module including:
 - (i) a first motor mounted in said module adapted to rotate said module about a first axis;
 - (ii) a laser scanner mounted in said module to scan along a scanning axis and measure distance to targets;
 - (iii) inclinometers mounted in said module to measure the pitch and roll of said module in said mechanical home position;
 - (iv) a second motor mounted in said module to rotate said module about a second axis,
 - (v) means to measure motor position data,
 - (vi) scanner module control circuits and controllers adapted to wirelessly receive commands from a remote station, actuate components of said module, and wirelessly communicate data received to the remote station; and
 - (vii) a power source mounted in said module and wiring in said module to supply power to components of said module;
- (b) selecting first and second targets having known positions in said existing coordinate system;

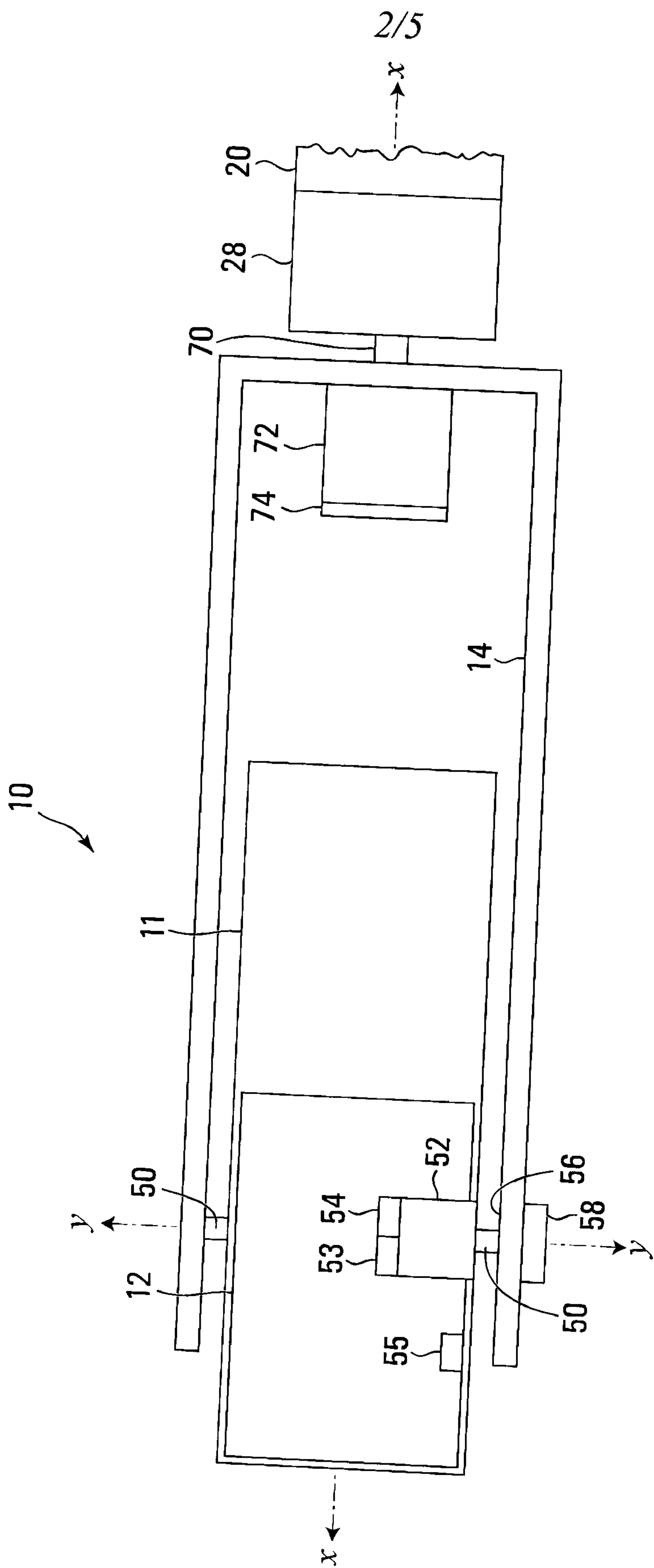
- (c) orienting said laser scanner towards said first and second targets and measuring the orientation of said laser scanner and distance from said laser scanner to said first and second targets to generate target information;
- (d) operating controls on a user interface on a remote station to actuate said inclinometers, laser scanner and first and second motors and means for measuring motor position data to measure the pitch and roll of said scanning axis at said mechanical home position and the distance to the walls of the cavity at a plurality of positions;
- (e) identifying the coordinates of said scanner module and the azimuth of said module in said mechanical home position in an existing coordinate system using said pitch and roll and said target information; and
- (f) processing said measurement information received from said laser scanner without leveling thereof using said pitch and roll, said coordinates of said module, and said azimuth to prepare an accurate representation of said cavity in said existing coordinate system.

27. The method of claim 13 including the further step of recording and separately storing coordinates of target positions on the walls of the cavity using the scanner module and marking said target positions for future use.

28. The apparatus of any one of claims 1 - 11 wherein said laser scanner uses time of flight to calculate distances from said laser and measures light intensity data for assisting in locating reflective targets.

FIG. 1





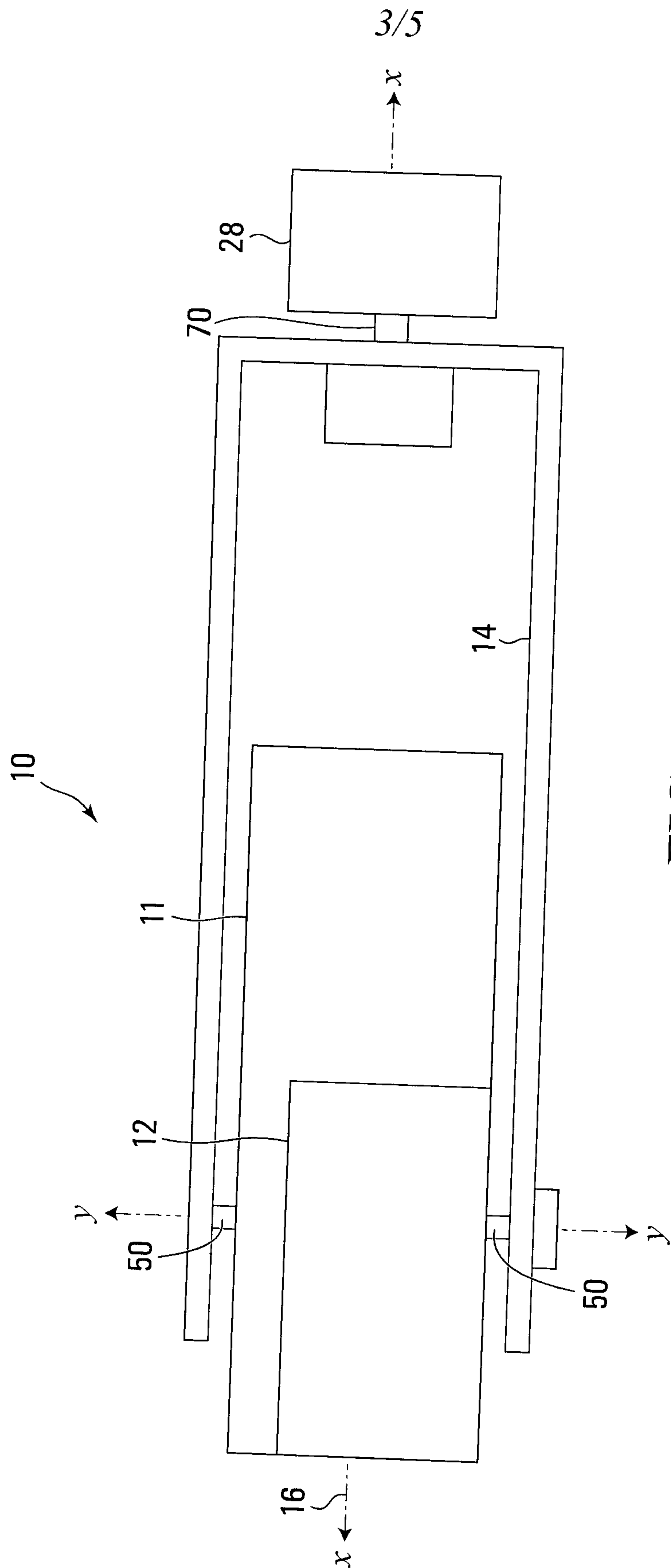
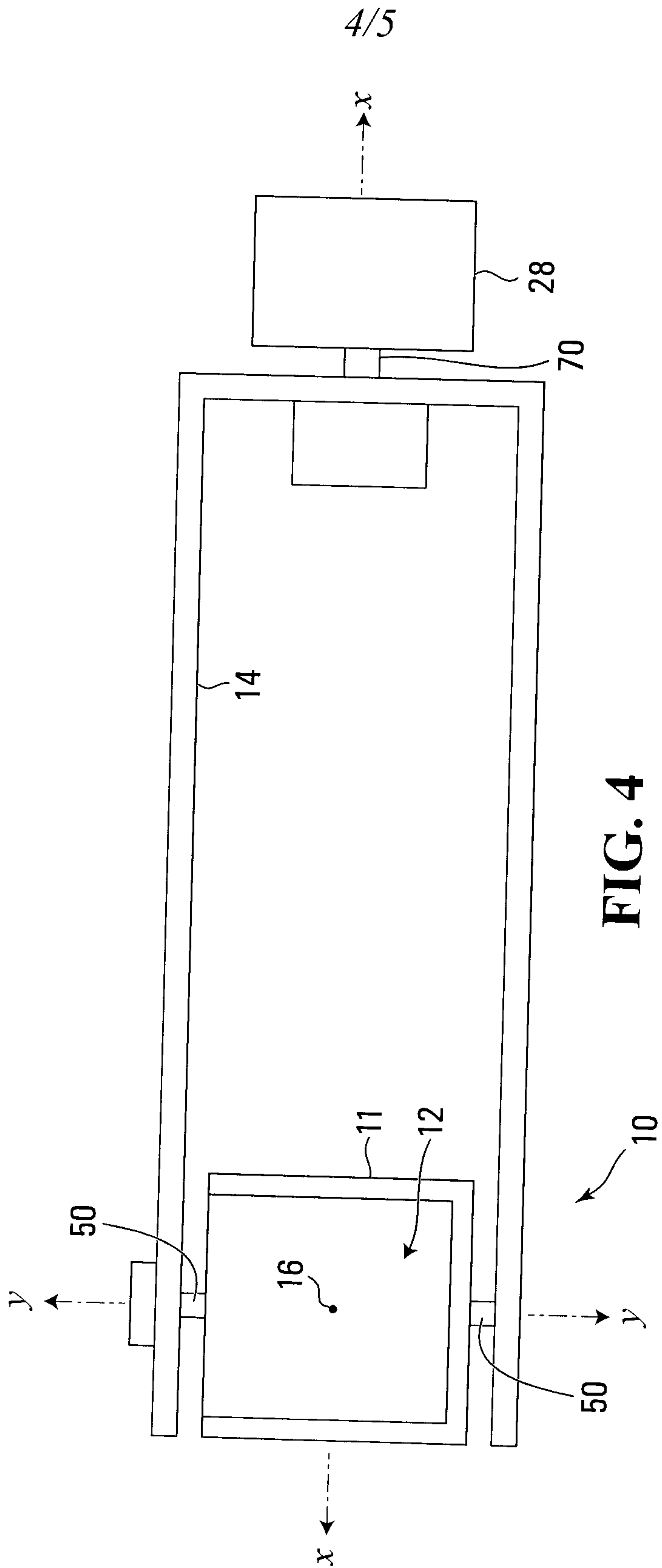
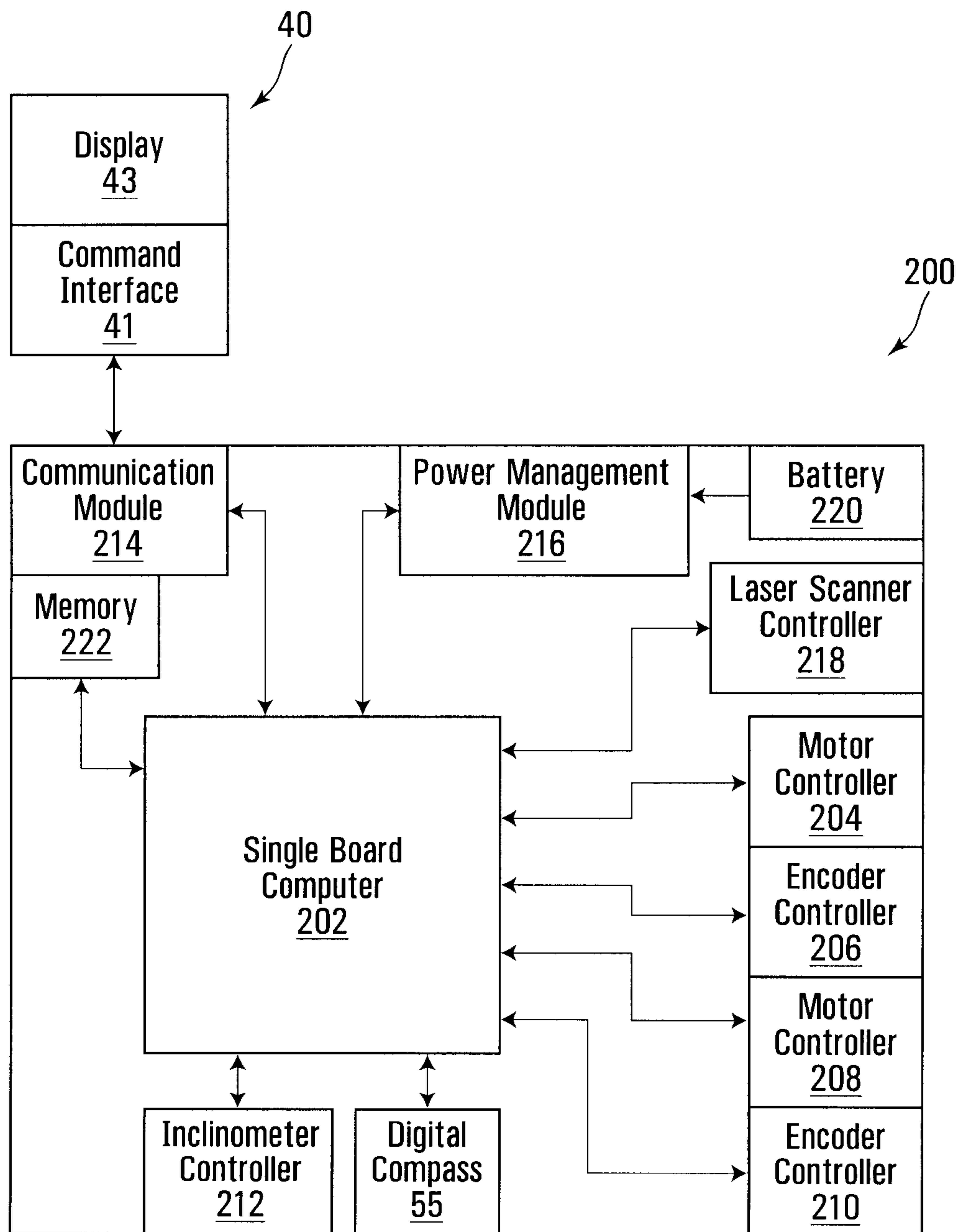


FIG. 3



5/5

**FIG. 5**

