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(54) Benævnelse: **JORDFLYTNINGSMASKINE, AFSTANDSMÅLERANORDNING OG FREMGANGSMÅDE TIL 3D-SCANNING**

(56) Fremdragne publikationer:
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DESCRIPTION

BACKGROUND OF THE INVENTION

[0001] The invention relates to an earth moving machine.

[0002] The invention further relates to a method for 3D scanning.

[0003] Document US 2016/0104289 A1 discloses a work machine on a worksite having a range map generation system. Document WO 2015/041689 A1 discloses a method for determining a position of a machine in a worksite. The method comprises determining input data associated with a Lidar survey, by a Lidar unit on the machine at the position in the worksite. Documents JP 2016 008484 A, US 2007/181810 A1, US 2016/154094 A1 and US 2009/112472 A1 disclose also similar type of arrangements.

BRIEF DESCRIPTION OF THE INVENTION

[0004] An object of the invention is to provide a new earth moving machine and a new method for 3D scanning.

[0005] The invention is characterized by the features of the independent claims. Embodiments of the invention are disclosed in the dependent claims.

[0006] The range finder device is durable and inexpensive. The movable machine element provides enlarged degree of freedom for the movement of the range finder device thereby providing an expanded angle of view and wide scanning beam.

[0007] According to an embodiment the control unit is configured to determine 3D position and orientation of the range finder device and to provide the point cloud with 3D coordinates in response to the input data.

[0008] According to an embodiment the range finder device is arranged to the movable machine element at a known location on the movable machine element; the location of the range finder device and a kinematic model of the movable machine element are input to the control unit; and the control unit is configured to calculate the position and orientation of the range finder device in response to the input data. In this embodiment the 3D positioning system is arranged separately relative to the range finder device.

[0009] According to an embodiment the range finder device comprises positioning means for determining 3D position and orientation of the range finder device.

[0010] According to an embodiment the receiving unit of the range finder device comprises at least one single photon detector for receiving the reflecting signals.

[0011] According to an embodiment the receiver unit comprises one or more time-gated single photon avalanche detector elements.

[0012] According to an embodiment the receiving unit comprises at least one detector element arranged to form an array of n*m, wherein n and m can be any number.

[0013] According to an embodiment the array of detector elements of the receiver unit comprise a matrix with several elements arranged in n rows and m columns.

[0014] According to an embodiment the array of detector elements of the receiver unit comprise a row with several elements. Thereby, the range finder may have horizontal bar-like configuration.

[0015] According to an embodiment the array of detector elements of the receiver unit comprise a column with several elements. Thereby, the range finder may have vertical bar-like configuration.

[0016] According to an embodiment the range finder device comprises one single detector element, whereby the receiver unit has point form configuration.

[0017] According to an embodiment the at least one machine element is a boom; and the at least one range finder is arranged to the boom, whereby the at least one range finder is moved together with the boom.

[0018] According to an embodiment the boom is provided with at least two range finder devices arranged to different locations on the boom and thereby have different angles of view.

[0019] According to an embodiment the boom is articulated and comprises two or more boom parts and joints between them; and at least two range finder devices are arranged on separate boom parts.

[0020] According to an embodiment a distal end portion of the boom is provided with at least one working tool; and the at least one range finder device is directed to produce point cloud data on the working tool.

[0021] According to an embodiment the earth moving machine is an excavator comprising a boom and a bucket at a free end of the boom; and the at least one range finder device is directed to produce point cloud data on the bucket.

[0022] According to an embodiment the at least one machine element is a bulldozer blade; at least one range finder is arranged to the blade or to supporting elements of the blade for producing point cloud data on the blade. Alternatively, or in addition to, the scanning data comprises data on topography of the ground in front of the blade, or processed material facing the frontal face of the blade during the operation.

[0023] According to an embodiment the at least one machine element is a control cabin provided with a moving arrangement allowing vertical position of the control cabin to be adjusted relative to the carrier; and the at least one range finder device is configured to produce cloud data on the vertical position of the control cabin.

[0024] According to an embodiment the range finder device is a laser range finder device, wherein the transmitting unit comprises at least one laser transmitter.

[0025] According to an embodiment the laser range finder comprises at least one laser light sources for producing a laser beam, which is directed at desired point at a work site. The device comprises at least one detector device that receive the laser beams after reflection off the target point of the work site. Based on the time between generating the laser beam and receiving, the control unit may determine a distance between the target point and the range finder device. Thus, the distance measurement is based on time-of-flight measurement principle. On the basis of the distance measurements 3D point cloud data is generated of part of the work site that is detected by the range finder device. Each data point of the 3D point cloud includes a distance from the range finder device to the detected point of the work site.

[0026] According to an embodiment the range finder device is a LiDAR instrument. LiDAR is a laser radar device, which uses ultraviolet, visible, or near infrared light from lasers.

[0027] According to an embodiment the range finder device is a radar instrument based on use of radio waves.

[0028] According to an embodiment the range finder device is a sound based time-of-flight camera or image sensor.

[0029] According to an embodiment the positioning system for determining 3D position and orientation data of the earth moving machine comprises a satellite-based positioning system (GNSS).

[0030] According to an embodiment the positioning system for determining 3D position and orientation data on the earth moving machine comprises a total station.

[0031] According to an embodiment the positioning system for determining 3D position and orientation data on the earth moving machine comprises an SLAM system (simultaneous localization and mapping). The SLAM system is configured to produce point cloud of the surrounding of the earth moving machine at an initial location and is configured to create a map of the surrounding. The system may simultaneously use the created map to determine its own location within that space. The SLAM system may be used to secure that primary position and orientation data produced by means of another system is reliable by comparing the primary position and orientation data to the created map.

[0032] According to an embodiment the at least one sensing device for determining position and orientation of the movable machine element comprises at least one Inertia Measurement Unit (IMU) for producing data on orientation; and the control unit is configured to determine orientation of the range finder device in response to the data received from the Inertial Measurement Unit.

[0033] According to an embodiment the range finder device comprises the IMU.

[0034] According to an embodiment the IMU comprises one or more devices which provide measurement of angular position, rates or acceleration. The IMU may comprise an accelerometer, a gyroscope and/or an inclinometer.

[0035] According to an embodiment one or more sensing devices are configured to monitor joints or moving actuators of the movable machine element, and the control unit is configured to calculate the position and orientation in response to the monitoring. Thus, the sensing device may be a linear movement sensor or a rotary encoder, for example.

[0036] According to an embodiment the system is configured to execute surveying and to collect information relating to the environment where the earth moving machine is operating. The system may collect information relating to a surface over which the earth moving machine is moving. Thus, the system may determine ground surface, ground level and other topographic features of the ground of the work site. Topography of ground surface in front of the earth moving tool is also useful information.

[0037] According to an embodiment the system is configured to execute surveying of the environment where the earth moving machine is operating, and is configured to update a pre-designed or previous three dimensional environmental model created of the work site.

[0038] According to an embodiment the system is configured to execute surveying of the environment where the earth moving machine is operating, and is configured to determine surface profiles of the environment. The system may be utilized to execute periodic scanning of the work site and may compare gathered surface data to the previous point cloud output. The control unit may calculate volume of the removed or filled material and surface changes at the operated areas in response to the comparison. The system may also update the production or terrain model and map of the work site. The system may determine changes in surface profiles of the work site and the operator may be able to view live cut/fill volumes and surface changes inside the control cabin. The created point clouds may be transformed into 3D models for volume calculations and terrain models. Further, the created and updated 3D models and maps may be shared with two or more earth moving machines operating at the same work site, whereby collaborated 3D models and maps may be used. Further, the data may be used to automatically monitor and record the realized measures executed at the work site.

[0039] According to an embodiment the system is configured to determining position and orientation of a working tool of the earth moving machine. Further, the determined position and orientation data may be compared to position and orientation data gathered from one or more sensing devices arranged on the boom. The boom sensors may be calibrated on the basis of the comparison data. The system may also be used for detecting possible failures in the primary sensing means of the instrumented boom.

[0040] According to an embodiment one or more range finder devices are configured to scan a bucket or a transport platform and material loaded therein. Based on the scanned data volume and centre of gravity of the loaded material may be determined. The determined data may be used in weighing the loaded material and for determining the caused loading to the machine, for example.

[0041] According to an embodiment the system is configured to generate a tree dimensional model of one or more machine elements or working tools. Thereby, the bucket, the transport platform or the boom may be modelled. The generated model may be compared to a previously created, or to an initial model made for manufacture of the component, and deviations between the models are being detected. Thereby, wear, failures and deformations of the component can be noted. The system may provide information for a condition monitoring system.

[0042] According to an embodiment the system is configured to determine where the potential obstacles exist in the environment and where the earth moving machine is in relation to the detected potential obstacles. Thus, the control system of the machine may utilize the point cloud data in obstacle detection and avoidance. The point cloud data may also be used for access control and for creating safety zones around the machine.

[0043] According to an embodiment the system may determine linear and rotational velocities of the earth moving machine on the basis of the generated point cloud data. Thus, the point cloud data may be used for odometry, wherein change in position over time is determined. The earth moving machine may comprise one or more disclosed range finder devices arranged to detect movements of one or more moving means, such as tracks or wheels, of the earth moving machine. Travelled distance and speed may be measured based on the created point cloud data.

BRIEF DESCRIPTION OF THE DRAWINGS

[0044] Some embodiments are described in more detail in the accompanying drawings, in which

Figure 1 is a schematic side view of an excavating machine provided with a range finder device, and

Figure 2 shows schematically some components of the range finder arrangement.

[0045] For the sake of clarity, the figures show some embodiments of the disclosed solution in a simplified manner. In the figures, like reference numerals identify like elements.

DETAILED DESCRIPTION OF SOME EMBODIMENTS

[0046] Figure 1 shows an excavator E comprising a movable carrier 1 on which a boom 2 is arranged. The excavator is one example of a mobile earth moving machine. The carrier 1 may comprise an under carrier 1a and an upper carrier 1b. The upper carrier 1b may be connected to the under carrier 1a by means of a rotating axle 3. The upper carrier 1b may be rotated R around a rotating axis 4 of the rotating axle 3. The boom 2 is arranged to turn together with the upper carrier 1b. The boom 2 may comprise a first boom part 2a and a second boom part 2b. The first boom part may be connected to the carriage 1 by means of first joint, which is not shown. The second boom part 2b may be connected to the first boom part 2a by means of a second joint 5. At a distal end of the second boom part 2b is a working tool, in this case a bucket 6, and between the bucket 6 and the second boom part 2b may be a third joint 7. In connection with the third joint 7 may also be joints or mechanisms allowing the bucked to be tilted in a sideward direction.

[0047] On the carrier 1 is a control cabin 8 for an operator. The control cabin 8 may be provided with a moving arrangement allowing vertical position of the control cabin 8 to be adjusted relative to the carrier 1.

[0048] The excavator E is provided with a range finder arrangement comprising one or more control units 9 and one or more range finder devices 10. The range finder device 10 may be arranged to the boom 2, whereby the range finder device 10 is moved together with the boom 2. The boom 2 may be provided with at least two range finder devices 10 arranged to different locations on the boom 2 and thereby having different angles of view. It is also possible to arrange one range finder device 10 to the first boom part 2a and another range finder device 10 to the second boom part 2b. The boom 2 or each boom part 2a and 2b also comprise at least one sensing device 14 for determining position and orientation data of the boom 2 or boom part 2a and 2b. Also the range finder device 10 may comprise the sensing device 14.

[0049] The excavator E may also be provided with a GNSS satellite positioning system, comprising one or more satellite receiving devices SN for receiving signals from satellites S. The receiving device SN may be placed on the carrier 1 and the control unit may calculate position of the excavator E on the basis of the received satellite based position data. Alternatively, the excavator E may be equipped with another onboard position measuring device, such as a total station TS.

[0050] The data of the position measuring device, the sensing device 14 and range finder device 10 are transmitted to the control unit 9. The control unit 9 processes the data and provides point cloud output of an object detected by the range finder device 10.

[0051] Figure 2 discloses some components and features of the disclosed range finder arrangement. These issues have already been disclosed above in this application. The range finder device 10 may comprise the sensing device 14. The sensing device 14 may comprise at least one Inertia Measurement Unit (IMU) for producing data on orientation. The range finder device 10 comprises a transmitting unit 11 transmitting time-of-flight signals and a receiving unit 12 comprising at least one detector 13 receiving reflecting signals. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

REFERENCES CITED IN THE DESCRIPTION

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

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- WO2015041689A1 **[0003]**
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- US2016154094A1 **[0003]**
- US2009112472A1 **[0003]**

Patentkrav

1. Mobil jordflytningsmaskine omfattende:

et understel (1);

mindst et maskinelement, der er bevægeligt i forhold til understellet (1);

et positioneringssystem til bestemmelse af 3D-positions- og orienteringsdata for jordflytningsmaskinen på et arbejdssted;

mindst en detekteringsindretning (14) til bestemmelse af positions- og orienteringsdata for det bevægelige maskinelement;

mindst en afstandsmålerindretning (10) til detektering af mindst et objekt i et felt af den mindst ene afstandsmålerindretning (10) og tilvejebringelse af punktsky-output af det mindst ene objekt; og

mindst en styreenhed (9) konfigureret til

at modtage som inputdata i det mindste 3D-positions- og orienteringsdata for positioneringssystemet, positions- og orienteringsdata for det bevægelige maskinelement og punktskyen for det mindst ene objekt og behandle de genererede inputdata; hvorved

den mindst ene afstandsmålerindretning (10) er en faststof-indretning uden indre bevægelige mekaniske elementer, hvorved den mindst ene afstandsmålerindretning (10) er uden internt scanningsudstyr og er forsynet med en begrænset synsvinkel;

den mindst ene afstandsmålerindretning (10) er anbragt på et bevægeligt maskinelement og er konfigureret til at blive bevæget sammen med det bevægelige maskinelement for at udvide synsvinklen af den mindst ene afstandsmålerindretning (10);

den mindst ene afstandsmålerindretning (10) er konfigureret til at generere punktsky-output baseret på en flyvetid for signaler sendt af mindst en sendeenhed (11) og til at reflektere signaler modtaget af mindst en modtageenhed (12) omfattende mindst en detektor (13); og

den mindst ene styreenhed (9) er konfigureret til at bestemme 3D-position og -orientering af den mindst ene afstandsmålerindretning (10) på arbejdsstedet og til at tilvejebringe punktskyen som svar på inputdataene.

2. Jordflytningsmaskinen ifølge krav 1, hvor
styreenheden (9) er konfigureret til at bestemme 3D-position og -orientering af den mindst ene afstandsmålerindretning (10) og til at forsyne punktskyen med 3D-koordinater som svar på inputdataene.

3. Jordflytningsmaskinen ifølge krav 1 eller 2, hvor
modtageenheden (12) omfatter mindst et detektor- (13) element, der er indrettet til at danne et array af n*m detektorelementer, hvor n og m kan være et hvilket som helst tal.

4. Jordflytningsmaskinen ifølge et hvilket som helst af de foregående krav 1 til 3, hvor

det mindst ene maskinelement er en udligger (2); og
den mindst ene afstandsmålerindretning (10) er anbragt på udliggeren (2), hvorved den mindst ene afstandsmålerindretning (10) bevæges sammen med udliggeren (2).

5. Jordflytningsmaskinen ifølge et hvilket som helst af de foregående krav 1 til 4, hvor
afstandsmålerindretningen (10) er en laserafstandsmålerindretning, hvor sendeenheden (11) omfatter mindst en lasersender.

6. Jordflytningsmaskinen ifølge et hvilket som helst af de foregående krav 1 til 5, hvor
positioneringssystemet til bestemmelse af 3D-positions- og orienteringsdata for jordflytningsmaskinen omfatter et satellitbaseret positioneringssystem (GNSS).

7. Jordflytningsmaskinen ifølge et hvilket som helst af de foregående krav 1 til 6, hvor

den mindst ene detekteringsindretning (14) til bestemmelse af position og orientering af det bevægelige maskinelement omfatter mindst en inertimåleenhed (IMU) til frembringelse af data om orientering; og
styreenheden (9) er konfigureret til at bestemme orienteringen af den mindst ene afstandsmålerindretning (10) som svar på data modtaget fra inertimåleenheden.

8. Fremgangsmåde til 3D-scanning på et arbejdssted for en jordflytningsmaskine, hvor jordflytningsmaskinen omfatter et understel (1) og mindst et maskinelement, der er bevægeligt i forhold til understellet (1);
hvilken fremgangsmåde omfatter:

bestemmelse af 3D-positions- og orienteringsdata for jordflytningsmaskinen på arbejdsstedet;

generering af scanningsdata for jordflytningsmaskinens omgivelser ved hjælp af mindst en afstandsmålerindretning (10) anbragt på jordflytningsmaskinens mindst ene bevægelige maskinelement, hvor det scannede data omfatter mindst en punktsky af mindst et objekt detekteret i et felt af den mindst ene afstandsmålerindretning (10);

indlæsning af de genererede scannede data og de bestemte positions- og orienteringsdata til mindst en styreenhed (9) og beregning af tredimensionelle koordinater for mindst et målpunkt af de genererede scannede data;

udførelse af scanningen ved hjælp af den mindst ene afstandsmåler-indretning (10) som er en faststof-indretning uden indre bevægelige mekaniske elementer, hvorved afstandsmålerindretningen er uden internt scanningsudstyr og er forsynet med en begrænset synsvinkel;

udvidelse af synsvinklen af den mindst ene afstandsmålerindretning (10), som er anbragt på det bevægelige maskinelement, ved at bevæge afstandsmålerindretningen (10) ved hjælp af det bevægelige maskinelement;

bestemmelse af afstanden mellem den mindst ene afstandsmålerindretning (10) og det mindst ene objekt ved hjælp af flyvetidsmåling, og indlæsning af dataene til den mindst ene styreenhed (9);

bestemmelse af 3D-position og -orientering af den mindst ene afstandsmålerindretning (10) og indlæsning af dataene til styreenheden (9); og

beregning af tredimensionelle koordinater for punktskyen som svar på inputdataene.

DRAWINGS

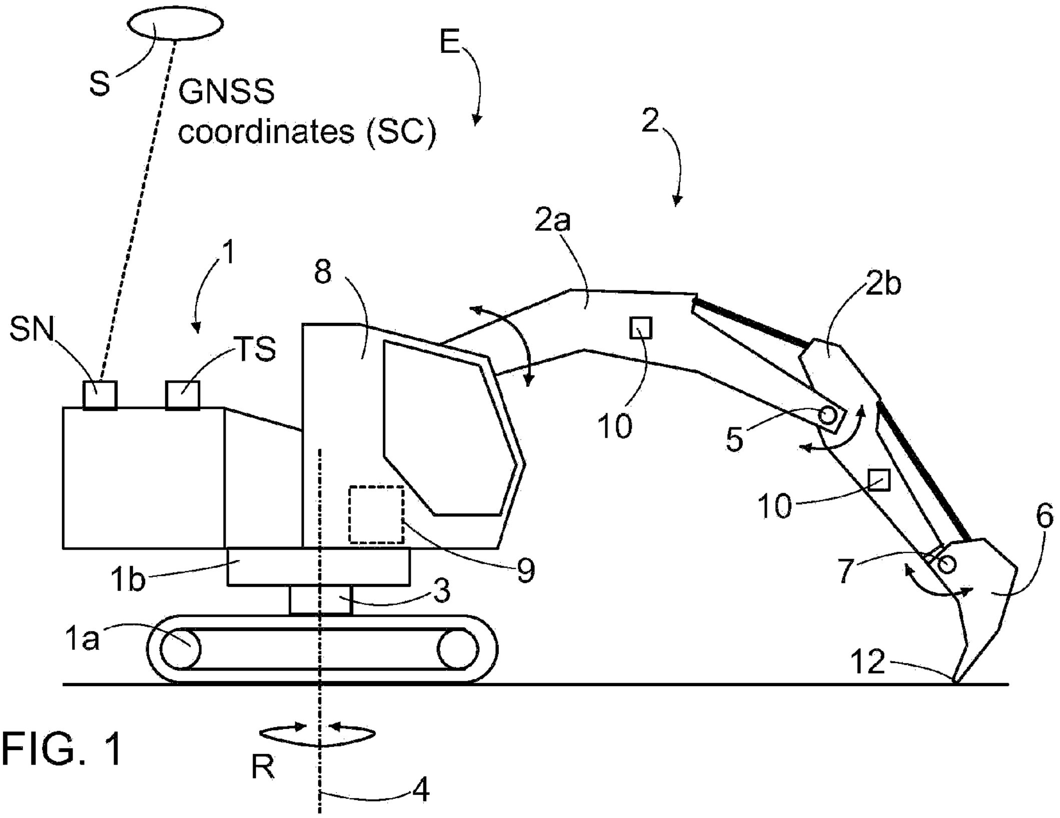

FIG. 1

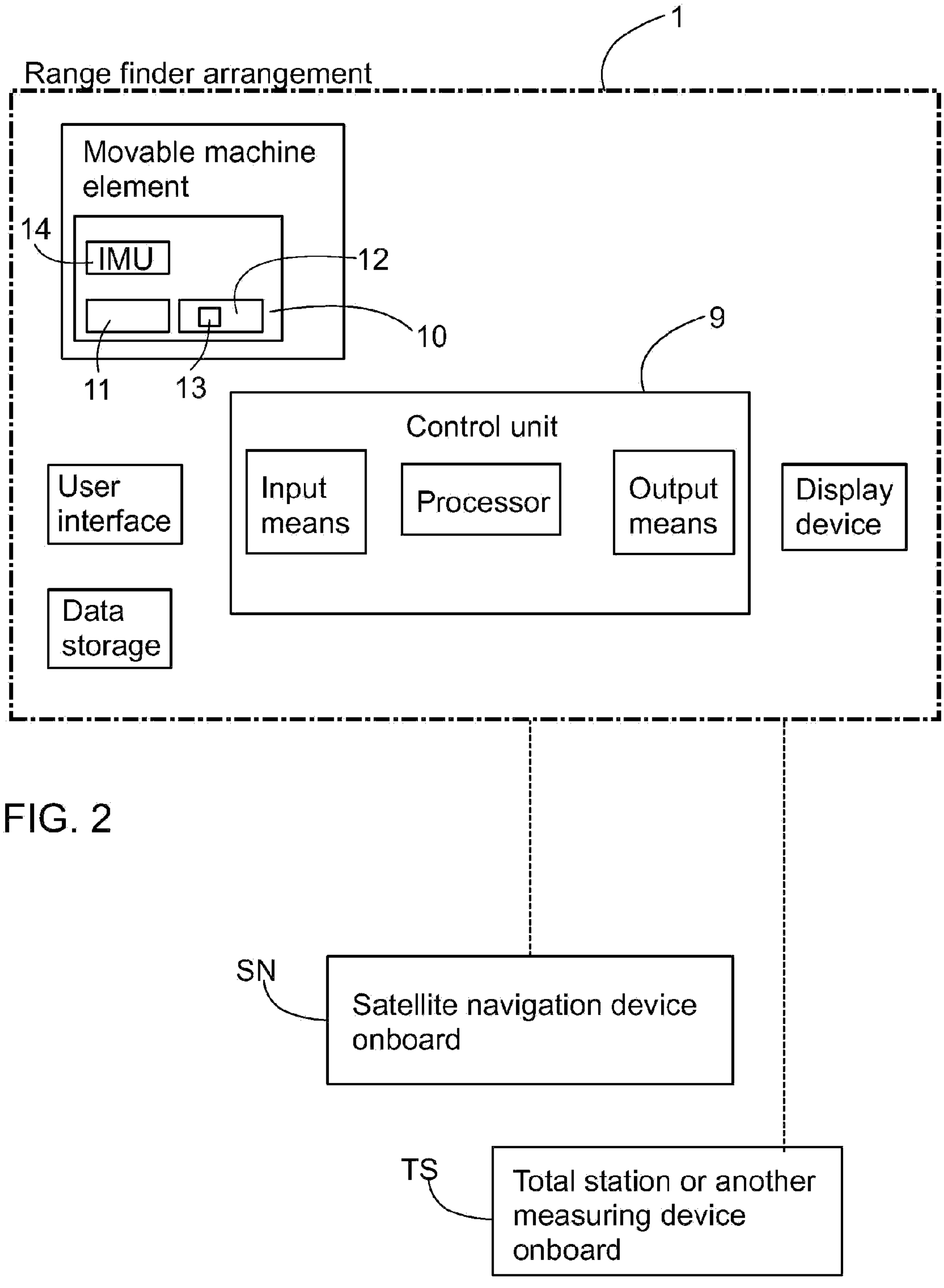
1
Range finder arrangement
Movable machine element
14
IMU
12
10
11
13
9
Control unit
User interface
Input means
Processor
Output means
Display device
Data storage
SN
Satellite navigation device onboard
TS
Total station or another measuring device onboard

FIG. 2