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(54) Title: METHOD FOR OPTICALLY SCANNING AND MEASURING AN ENVIRONMENT

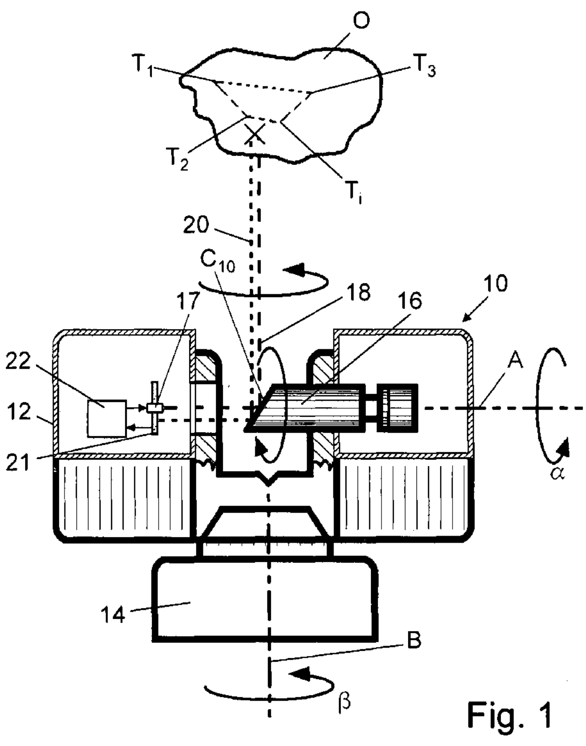

Fig. 1

(57) Abstract: With a method for optically scanning and measuring an environment of a laser scanner (10), which comprises a measuring head (12) with a light emitter (17) and a light receiver (21), a mirror (16), which is rotatable about a first axis (A) relative to the measuring head (12), a base (14), relative to which the measuring head (12) is rotatable about a second axis (B), a control and evaluation unit (22), and a center (Ci0), which, for a scan, defines the stationary reference system of the laser scanner (10) and the center of this scan, wherein the light emitter (17) emits an emission light beam (18), the mirror (16) reflects the emission light beam (18) into the environment and makes several complete revolutions during the rotation of the measuring head (12), the light receiver (21) receives a reception light beam via the mirror (16), which reception light beam is reflected by an object (O) in the environment of the laser scanner (10) or scattered otherwise, and the control and evaluation unit (22) determines, for a multitude of measuring points (X) of the scan, at least the distance (d) of the center (Ci0) to the object (O), the measuring head (12) makes more than half a revolution for the scan, wherein at least some measuring points (X) are doubly determined.

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Method for optically scanning and measuring an environment

The invention relates to a method having the features of the generic term of Claim 1.

By means of a device such as is known for example from DE 20 2006 005 643 U1, which device is designed as a laser scanner, a method of the kind mentioned in the introduction can be carried out. Due to damage on the laser scanner or to other error sources, the scans get incorrect.

The invention is based on the object of improving a method of the type mentioned in the introduction. This object is achieved according to the invention by means of a method comprising the features of Claim 1. The dependent claims relate to advantageous configurations.

By turning the measuring head for more than the necessary half turn, at least some measuring points are doubly determined. Then such a point is determined twice using different mechanical arrangements of the laser scanner – another combination of horizontal and vertical angles points to the same point in space . Although it is still the same laser scanner, the two different arrangements result in two different scans, i.e. two different scans like produced by two different laser scanners. However, the two different scans are correlated in a defined manner.

The additional information, obtained from the doubly determined measuring points, can be used for error correction. The coordinates of the measuring points, i.e. their angle coordinates with priority, can thus be corrected. The more double measuring points are available, the better can correction take place. Depending on the kind of error, a single calibration of the laser scanner, which is used further for subsequent scans without double measuring points, is sufficient. Dynamic errors can be corrected as well, however. The method can also be used for verifying data: The measured data are verified, if they are consistent, i.e. if, with the double measuring points, there are no and/or sufficiently small deviations.

As distinct from measuring in two circles positions which, for example, is used for determining tilting-axes errors, in the present invention it is not the same point at the firmament which is measured, but measuring takes place twice with - theoretically - identical coordinates, and a potential error is determined from the coordinates of the doubly measured objects.

The invention is explained in more detail below on the basis of an exemplary embodiment illustrated in the drawing, in which

Fig. 1 shows a schematic illustration of the optical scanning and measuring of an environment of a laser scanner - shown in partially sectional view -, and

Fig. 2 shows an illustration of the axes and angles.

A laser scanner 10 is provided as a device for optically scanning and measuring the environment of the laser scanner 10. The laser scanner 10 has a measuring head 12 and a base 14. The measuring head 12 is mounted on the base 14 as a unit that can be rotated about a vertical axis. The measuring head 12 has a mirror 16, which can be rotated about a horizontal axis. The horizontal axis of the mirror 16 is designated first axis A, the assigned rotational angle of the mirror 16 first angle α, the vertical axis of the measuring head 12 second axis B, the assigned rotational angle of the measuring head 12 second angle β, and the intersection point of the first axis A with the second axis B center C_{10} of the laser scanner 10.

The measuring head 12 is further provided with a light emitter 17 for emitting an emission light beam 18. The emission light beam 18 is preferably a laser beam in the visible range of approx. 340 to 1000 nm wave length, such as 790 nm, on principle, also other electro-magnetic waves having, for example, a greater wave length can be used, however. The emission light beam 18 is amplitude-modulated, for example with a sinusoidal or with a rectangular-waveform modulation signal. The emission light beam 18 is emitted by the light emitter 17 onto the mirror 16, where it is deflected and emitted to the environment. A reception light beam 20 which is reflected in the environment by an object O or scattered otherwise, is captured again by the mirror 16, deflected and directed onto a light receiver 21. The direction of the emission light beam 18 and of the reception light beam 20 results from the angular positions of the mirror 16 and the measuring head 12, i.e. the two angles α and β, which depend on the positions of their corresponding rotary actuators which, again, are registered by one encoder each. A control and evaluation unit 22 has a data connection to the light emitter 17 and to the light receiver 21 in measuring head 12, whereby parts of it can be arranged also outside the measuring head 12, for example a computer connected to the base 14. The control and evaluation unit 22 determines, for a multitude of measuring points X, the distance d between the laser scanner 10 and the (illuminated point at) object O, from the propagation time of emission light beam 18 and reception light beam 20. For this purpose, the phase shift between the two light beams 18 and 20 is determined and evaluated.

Scanning takes place along a circle by means of the (quick) rotation of the mirror 16 about the first axis A, i.e. the first angle α each time makes a revolution (360°), wherein, however, an angle range of approximately 40° cannot be used, since the emission light beam 18, within this angle range, is directed onto the base 14 and onto the part of the measuring head 12 which is mounted on it. By virtue of the (slow) rotation of the measuring head 12 about the second axis B, relative to the base 14, the whole space is scanned step by step, by means of the circles. The mirror 16 at the same time carries out several complete revolutions, while the measuring head 12 rotates. The entity of measuring points X of such a measurement is designated scan. For such a scan, the center C_{10} of the laser scanner 10 defines the stationary reference system of the laser scanner 10, in which the base 14 rests. Further details of the laser scanner 10 and particularly of the design of measuring head 12 are described for example in US 7,430,068 B2 and DE 20 2006 005 643 U1, the respective disclosure being incorporated by reference.

Due to its design, the laser scanner 10 defines a spherical-coordinate system with the center C_{10}, the distance d as radius and the two angles α and β. In spherical coordinates, however, in principle one angle makes a complete revolution, and the other angle runs only half as far. Since, in the laser scanner of the present invention, the first angle α already makes complete revolutions, a complete scan - with regard to the coordinates - has been made, when the second angle β has run from 0° to 180°, i.e. when the measuring head 12 has carried out half a turn.

The initial position (β = 0°) of the measuring head 12 defines two hemispheres separated by a vertical plane. When second angle β is 180°, one hemisphere has been scanned with a laser beam spot (of the emission light beam 18) running from the bottom to the top, and the other one with a laser beam spot (of the emission light beam 18) running from the top to the bottom. In the present invention, the measuring head 12, however, makes more than half a revolution (β > 180°), particularly one complete revolution. Although the mirror 16 is still rotating in the same direction, the spot of the emission light beam 18 is now running in the opposite direction in each hemisphere. The same laser scanner 10 is scanning with the opposite (inverse) mechanical arrangement. Another combination of first angle α and second angle β points to the same point in space, i.e. the same point in space is described by two different combinations of first angle α and second angle β.

Several, particularly all, measuring points X are thus determined twice. If the laser scanner 10 were in perfect state as well as perfectly set up, the double measuring points X would be identical. However, damage to the laser scanner 10, for example bent bearings of mirror and/or measuring head, might lead to the two axes A and B no longer intersecting in the center C_{10} and/or no longer being exactly perpendicular to each other. In case of such errors, the double measuring points X deviate from each other, i.e. actually corresponding measuring points X have deviating coordinates. These deviations (inconsistence of measuring points X) can now be used for calibrating the laser scanner 10 and thus for correcting the measuring points X. When doing so, the measuring points X can be reduced again, so that all corrected measuring points X are available only once.

In order to search for corresponding measuring points X, methods can be used, for example, as they have been developed for joining together several scans. Before making the scan, several targets T_1, T_2,... can be suspended in the environment, i.e. special objects O or special parts of an object O. Due to the rotation of measuring point 12 by a second angle β of more than 180°, at least one area of the scan overlaps in such a way that some (preferably at least three) targets T_1, T_2,... are doubly registered. Spheres or checkerboard patterns have turned out to be particularly suitable (and therefore preferred) targets T_1, T_2,... . The targets T_1, T_2,... must then be localized and identified in the scan. The deviations of the measuring points X which correspond to each other result from the deviations of the coordinates of the targets T_1, T_2,... .

Since the deviations (of the coordinates) of the measuring points X should not be too big, the measuring points X which correspond to each other, can be looked for also by means of error-correction methods, for example by means of least square error method.

The more the measuring head 12 turns, i.e. the bigger the second angle β gets within the range of 180° and 360° is, the better becomes calibration. For recognizing dynamic errors, it might even be sensible if the measuring point 12 carried out more than one complete revolution.

The data is checked with respect to inconsistencies. If there are no or only sufficiently small deviations or other inconsistencies at the measuring points X, the method according to the invention - nearly automatically - supplies a verification of the data. If the inconsistencies exceed a certain limit, severe errors might be detected, for example, if the orientation of the laser scanner 10 changes during the scan, due to a strike.

Preferably, the laser scanner 10 comprises various sensors, e.g. thermometer, inclinometer, altimeter, compass, gyro compass, GPS etc., which are preferably connected to the control and evaluation unit 22. By means of said sensors, the operating conditions of the laser scanner 10, defined by certain parameters like geometrical orientation or temperature, are monitored. If one or more parameters show a drift, the associated sensors will detect the drift, which may be compensated by the control and evaluation unit 22. By means of said sensors, a sudden change of the operating conditions can also be detected, e.g. a strike changing the orientation of the laser scanner 10, or a shift of the laser scanner 10. If the amount of said change cannot be detected exactly enough, the scanning operation will be interrupted or aborted. If the amount of said change of the operating conditions can be roughly estimated, the measuring head 12 may turn back some degrees (until an overlap with the region scanned before the sudden change is available), and the scanning operation is continued. The two different parts of the scan may be combined by evaluating the overlapping region.

The method according to the invention also allows to discard the part of the scan before or after the sudden change of the operating conditions, i.e. the smaller part.

List of Reference Symbols

10	laser scanner
12	measuring head
14	base
16	mirror
17	light emitter
18	emission light beam
20	reception light beam
21	light receiver
22	control and evaluation unit
A	first axis
α	first angle
B	second axis
β	second angle
C_{10}	center of the laser scanner
d	distance
O	object
T_i	target
X	measuring point

Claims

1. Method for optically scanning and measuring an environment of a laser scanner (10), which comprises a measuring head (12) with a light emitter (17) and a light receiver (21), a mirror (16), which is rotatable about a first axis (A) relative to the measuring head (12), a base (14), relative to which the measuring head (12) is rotatable about a second axis (B), a control and evaluation unit (22), and a center (C_{10}), which, for a scan, defines the stationary reference system of the laser scanner (10) and the center of this scan, wherein the light emitter (17) emits an emission light beam (18), the mirror (16) reflects the emission light beam (18) into the environment and makes several complete revolutions during the rotation of the measuring head (12), the light receiver (21) receives a reception light beam via the mirror (16), which reception light beam is reflected by an object (O) in the environment of the laser scanner (10) or scattered otherwise, and the control and evaluation unit (22) determines, for a multitude of measuring points (X) of the scan, at least the distance (d) of the center (C_{10}) to the object (O), characterized in that the measuring head (12) makes more than half a revolution for the scan, wherein at least some measuring points (X) are doubly determined.

2. Method according to Claim 1, characterized in that the measuring head (12) makes a full revolution for the scan, determining all measuring points (X) twice.

3. Method according to Claim 1 or 2, characterized in that deviations of the double measuring points (X) are determined and used for calibration and compensation of the laser scanner (10).

4. Method according to Claim 3, characterized in that the deviations of the double measuring points (X) are used for correction of all measuring points (X).

5. Method according to Claim 3 or 4, characterized in that, as deviations, the deviations of the coordinates of those measuring points (X) which actually correspond to each other are determined.

6. Method according to Claim 5, characterized in that the deviations of the coordinates of the measuring points (X) which actually correspond to each other are determined by error-correction methods.

7. Method according to any of the preceding claims, characterized in that the environment of the laser scanner (10) is provided with targets (T_1, T_2,...).

8. Method according to Claim 7, characterized in that, due to the rotation of the measuring head (12), areas of the scan overlap in such a way that some targets (T_1, T_2,..) are doubly registered.

9. Method according to any of the preceding claims, characterized in that a verification of the data is carried out by means of the measuring points (X) doubly determined.

10. Laser scanner (10) for carrying out the method according to any of the preceding claims.

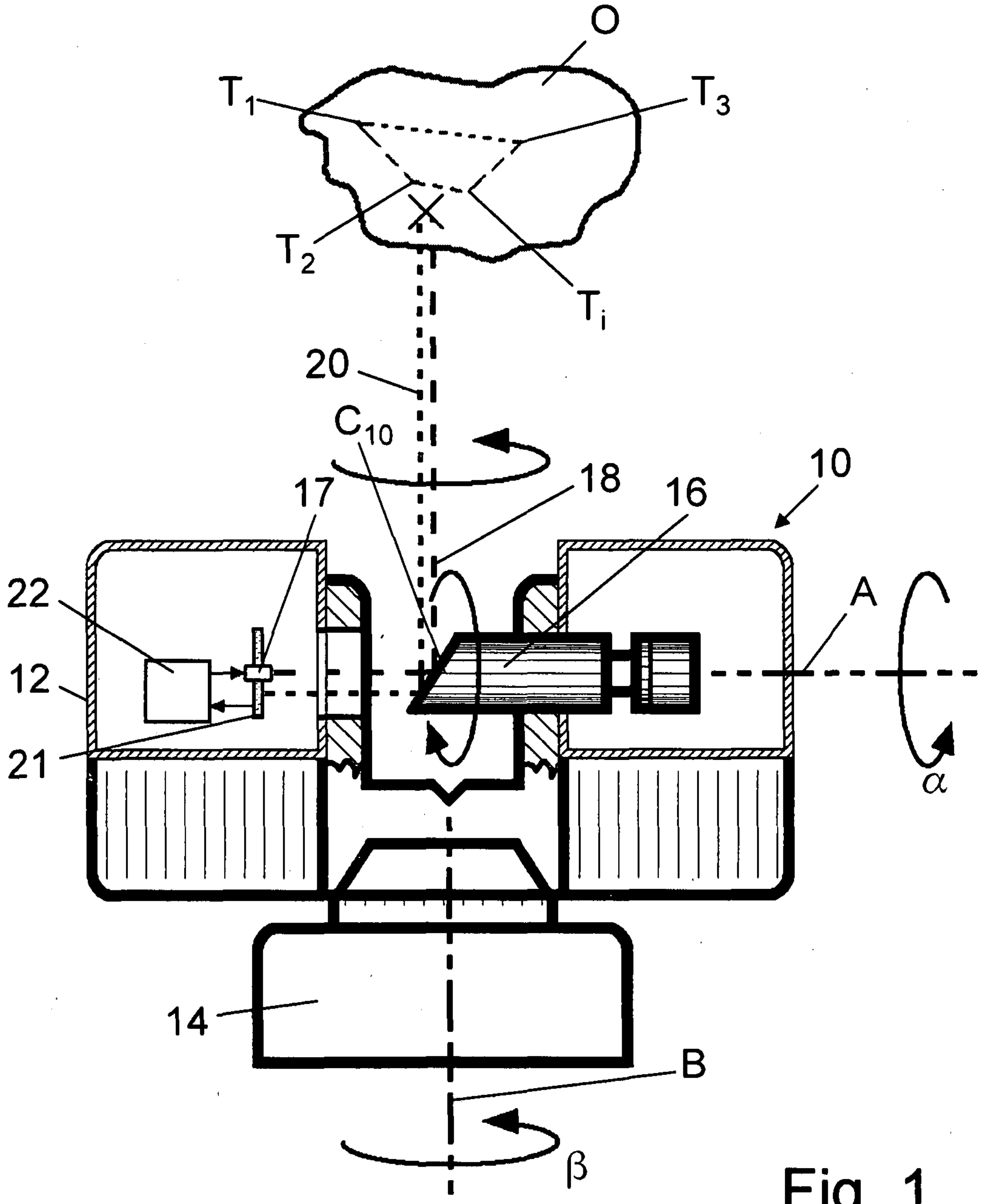

Fig. 1

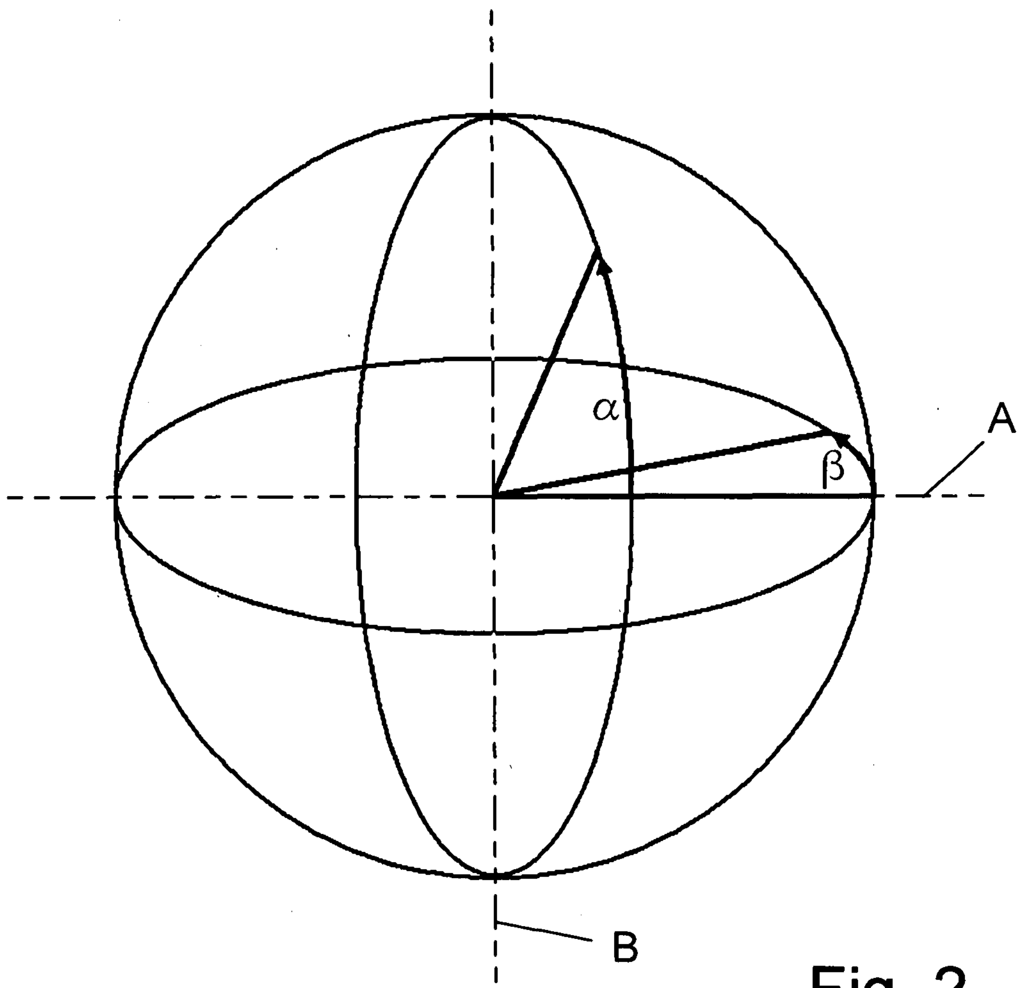

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2010/002258

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S7/497 G01S17/89
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01S

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 practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	DE 20 2006 005643 U1 (FARO TECH INC [US]) 6 July 2006 (2006-07-06) cited in the application paragraphs [0001], [0059], [0060], [0067]; figure 1 -----	1,2,10 3-9
Y	WO 2005/059473 A2 (TRIMBLE JENA GMBH [DE]; VOGEL MICHAEL [DE]) 30 June 2005 (2005-06-30) page 6, line 33 - page 7, line 9 page 12, line 37 - page 13, line 3 page 13, lines 7-10 page 21, line 36 - page 22, line 7 page 23, line 25 page 36, line 30 - page 37, line 2 page 40, lines 4-9 page 47, lines 15-18 ----- -/--	3-9

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

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
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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.
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