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(54) Title: METHOD FOR OPTICALLY SCANNING AND MEASURING A SCENE

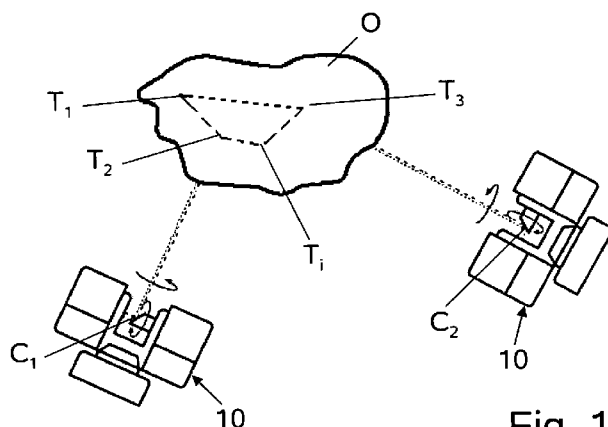


Fig. 1

(57) Abstract: The invention provides a method for optically scanning and measuring a scene by means of a laser scanner (10) which, for making a scan having a certain center (C), optically scans and measures its environment provided with targets (T), whereby two adjacent scans having different centers and scanning the same scene overlap within a range of measuring points (X) so that some targets are scanned by any of the two scans, whereby, for registering the two adjacent scans, the targets are localized in the measuring points during a first step and, during a second step, candidates of correspondence among the localized targets if the two adjacent scans are looked for and, during a third step, a test registration of the two adjacent scans is made which, if there is a sufficient compliance if the measuring points within the overlapping range, is taken over for registration, thus identifying the targets.

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5 Method for optically scanning and measuring a scene

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

10 By means of a laser scanner such as is known for example from US 7,430,068 B2, the surroundings of the laser scanner can be optically scanned and measured. To scan a larger scene, it might be necessary to make several scans from various positions, i.e. with different centers. Targets, which have been installed before, and which are present in overlapping areas of two adjacent scans, are localized by a user
15 and identified in the two adjacent scans.

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.
20

The method according to the invention makes it possible to automatically localize and identify the targets, in order to register the adjacent, overlapping scans of the scene together. To reduce the number of combination possibilities, preferably similar geometries are looked for, in which the targets are embedded, and which are
25 preferably defined by few further targets, for example by the three closest targets, so that quadrangles result. A pair of potentially candidates of correspondence has been found, if two targets from different, adjacent scans are embedded in similar geometries. With the test registration, the two scans are superimposed on a trial
30 basis.

The present method is a global method which even succeeds if the scans are far away from each other, because it is based on the geometry between the targets, i.e. the geometrical relationship between the targets. Therefore, the present method may be used for rough registration as well as for fine registration. Known methods, like
5 "iterative closest points" or other gradient-based dynamics, are local methods which only succeed if the scans are close enough together. Those known methods can only be used for a fine registration (when no secondary minima exist).

In addition to the scans, it is also possible to use data from further measuring units,
10 which are then linked with the scans. This may be an integrated measuring unit such as an inclination sensor or a compass, or an external measuring unit which, for example, carries out a conventional measurement. The registration results can thus be improved and/or the number or required targets can be reduced. It is, for example, also possible to determine the position of one or several targets by means of such
15 measuring units. This facilitates localization of the targets in the scans or defines this localization.

During every step, there will be the problem that, due to the noise level or similar, there is no exact compliance of the measuring points. It is, however, possible to determine threshold values and/or intervals, which serve for discrimination and defini-
20 tion of precision. Formation of gradients, the search for extrema and statistical methods might be applied as well.

The invention is explained in more detail below on the basis of an exemplary embodiment illustrated in the drawing, in which
25

Figure 1 shows a schematic illustration of the registration of a scene by means of several scans,

30 Figure 2 shows a schematic illustration of a laser scanner, and

Figure 3 shows a sectional detail view of the laser scanner.

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
5 be rotated around a vertical axis. The measuring head 12 has a mirror 16, which can be rotated around a horizontal axis. The intersection of the two rotational axes is herein designated center C_i of the laser scanner 10.

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. 300 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. The emission light beam 18 is amplitude-modulated, for example with
15 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 by the mirror 16, deflected and directed onto a light receiver 21. The direction of the emission light
20 beam 18 and of the reception light beam 20 results from the angular positions of the mirror 16 and the measuring head 12, which depend on the positions of their corresponding rotary drives which, in turn, are registered by one encoder each. A control and evaluation unit 22 has a data connection to the light emitter 17 and the light receiver 21 in measuring head 12, whereby parts of those can be arranged also outside
25 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.
30

Scanning takes place along a circle by means of the (quick) rotation of the mirror 16. By virtue of the (slow) rotation of the measuring head 12 in relation to the base 14, the whole space is scanned step by step, by means of the circles. The entity of measuring points X of such a measurement is designated scan. The center C_i of the laser scanner 10 defines the stationary reference system of the laser scanner 10 for such a scan, 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.

10

A scan of a certain scene is made by optically scanning and measuring the environment of the laser scanner 10. Scenes, which cannot be registered with one single scan, such as a framework structure or objects O with many undercuts, are possible. For this purpose, the laser scanner 10 is set up at different positions, and the scanning and measuring process is repeated, i.e. one scan is made with a defined center C_i , which always registers the same scene, but from a different viewing angle. The different scans of the same scene must be registered in a joined coordinate system, which is designated registering (visual registering).

Before a scan is made, several targets $T_1, T_2, \dots$, i.e. special objects O are suspended in the environment. The laser scanner 10 is then set up in a new position for several times, i.e. a new center C_i is defined, and a scan is made for each position. The whole scene is then registered by several scans having different centers C_1, C_2 . Adjacent scans overlap so that several (preferably at least three) targets $T_1, T_2 \dots$ are registered by two adjacent scans each. Spheres and checker-board patterns have turned out to be particularly suitable (and therefore preferred) targets.

25

Until now, the targets $T_1, T_2, \dots$ have been localized and identified manually in the scans, in order to register the measurements. According to the invention, registration takes place automatically.

30

For this purpose, the targets $T_1, T_2, \dots$ are localized in the scans, as a first step. In the case of a sphere, this information can be gained from the distances d , which join together to a uniformly bent, round shape, i.e. to a hemisphere. In the case of the checker-board pattern, gradients can be recognized in two directions. It makes sense to have several measuring points X , for example at least 50 - 100, for each target T_i , in order to avoid errors in localizing the targets $T_1, T_2, \dots$. Filters with threshold values can help to avoid further localization errors. In addition, data from further measuring units, which are incorporated in the laser scanner 10, or from external measuring units can be used, which facilitate or define localization in the scans for one or several targets $T_1, T_2, \dots$.

In a second step, potentially candidates of correspondence are looked for. For each scan, the distances (or alternatively the angles) for several localized targets T_i between the corresponding target T_i and the other (or at least the closest) targets $T_1, T_2, \dots$ is determined from the distances d , resulting in certain geometries, in which the corresponding targets T_i are embedded, for example three-dimensional quadrangles together with the three closest targets $T_1, T_2, \dots$. Similar geometries are looked for when comparing with the adjacent scans. As soon as two targets T_i , which come from two different adjacent scans, are embedded in a similar geometry, i.e. the distances at least to the closest targets $T_1, T_2, \dots$ correspond to each other within a certain precision interval, a pair of candidates of correspondence has been found.

In a third step, a test registration is carried out, i.e. the adjacent scans are transformed in relation to each other by translation and rotation, until the candidates of correspondence and the geometries, in which they are embedded, show a minimum distance. Then, all measuring points X , which must be present in both scans, i.e. which are within the overlapping range of the two scans, are compared by means of statistical methods. It is possible, for example, to determine the distances, and the sum of the distances could be a measure of the (missing) compliance. If the statistically gained compliance exceeds a certain threshold value, the targets $T_1, T_2, \dots$ have

been identified, and the test registration is taken over for registration. If the compliance is not sufficient, the pair of candidates of correspondence is rejected, and identification of the targets $T_1, T_2, \dots$ by means of the second and the third step is repeated.

5

Since the search for candidates of correspondence, particularly in the case of many targets $T_1, T_2, \dots$, might create problems due to non-linearity, it makes sense to use only few targets $T_1, T_2, \dots$, i.e. small embedded geometries for the search for candidates of correspondence, and to undertake the test registration with all targets $T_1,$

10 $T_2, \dots$. This increases the performance of the whole method.

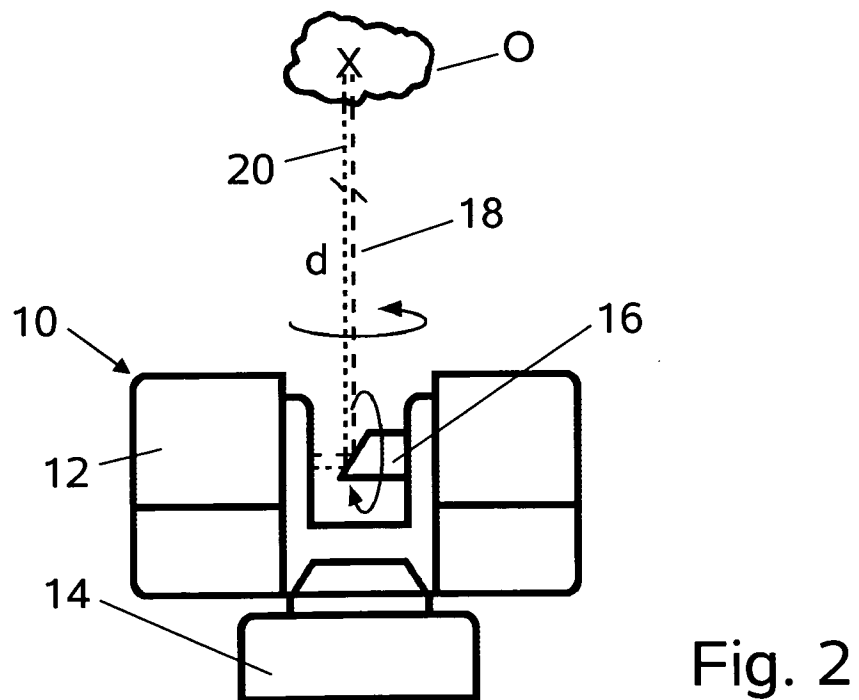
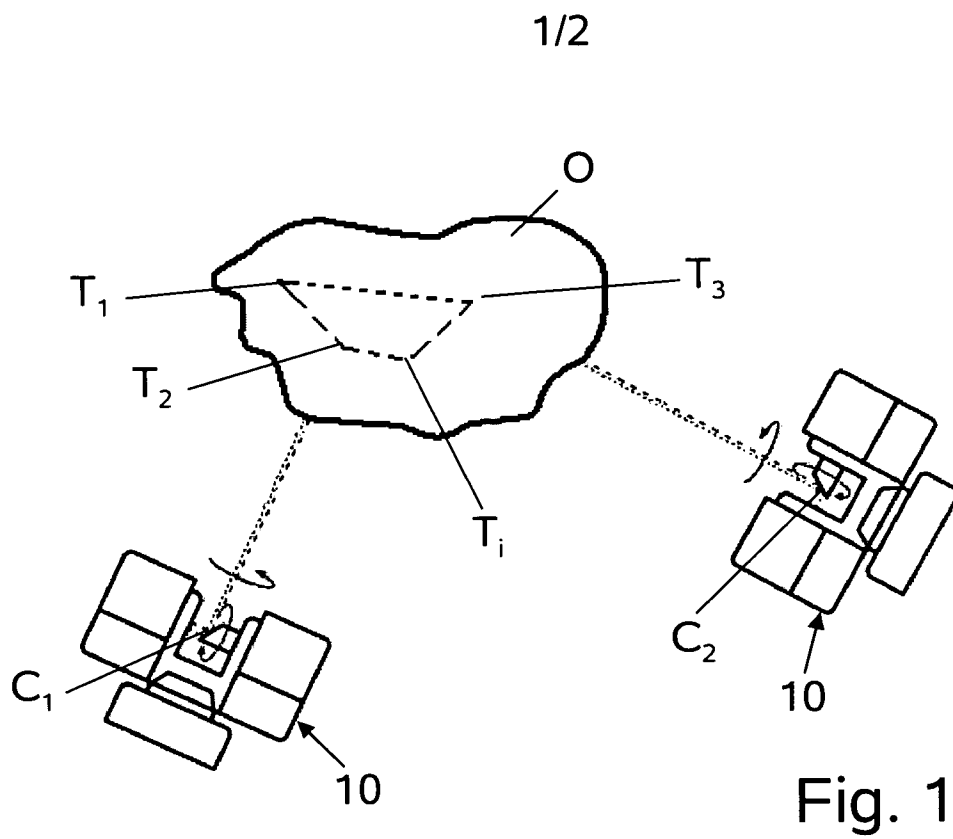
List of Reference Symbols

10	laser scanner
12	measuring head
14	base
16	mirror
17	light emitter
18	emission light beam
20	reception light beam
21	light receiver
C_i	center
d	distance
O	object
T_i	target
X	measuring point

Claims

1. Method for optically scanning and measuring a scene by means of a laser
5 scanner (10), which, for making a scan which shows a certain center (C_i), optically scans and measures its environment which is provided with targets ($T_1, T_2, \dots$), whereby two adjacent scans having different centers ($C_1, C_2, \dots$) and scanning the same scene overlap within a range of measuring points (X), so that some targets ($T_1, T_2, \dots$) are scanned by any of the two scans,
10 whereby, for registering the two adjacent scans, the targets ($T_1, T_2, \dots$) are localized in a first step in the measuring points (X) of the scans, in order to subsequently identify them, characterized in that, in a second step, candidates of correspondence are looked for among the localized targets ($T_1, T_2, \dots$) of the two adjacent scans and, in a third step, a test registration of the two adjacent
15 scans is made which, if there is a sufficient compliance of the measuring points (X) within the overlapping range, is taken over for registration, thus identifying the targets ($T_1, T_2, \dots$).
2. Method according to Claim 1, characterized in that the targets ($T_1, T_2, \dots$)
20 are localized by virtue of their shape and/or their gradients during the first step.
3. Method according to any of the preceding claims, characterized in that, during the second step, the geometry, in which the target (T_i) is embedded and
25 which results from the closest targets ($T_1, T_2, \dots$), is determined for at least one localized target (T_i) in any of the two scans.
4. Method according to Claim 3, characterized in that similar geometries are
30 looked for among the geometries of the two adjacent scans embedding the localized targets ($T_1, T_2, \dots$).

5. Method according to Claim 4, characterized in that a pair of candidates of correspondence is found, as soon as two targets (T_i), which stem from different of the two adjacent scans, are embedded in a similar geometry.
- 5 6. Method according to any of Claims 3 to 5, characterized in that the embedding geometry results from determined distances and/or angles between the localized target (T_i) and the closest targets ($T_1, T_2, \dots$).
7. Method according to Claims 4 and 6, characterized in that the embedding
10 geometries are similar, if the distances between the localized target (T_i) and the closest targets ($T_1, T_2, \dots$) correspond to each other within a certain precision interval.
8. Method according to any of the preceding claims, characterized in that during
15 test registration in a third step the two adjacent scans are transformed in relation to each other, so that the candidates of correspondence show a minimum distance.
9. Method according to Claim 8, characterized in that the measuring points (X)
20 within the overlapping range are compared by means of statistical methods, if the candidates of correspondence show a minimum distance.
10. Method according to any of the preceding claims, characterized in that the
25 laser scanner (10) is set up at different positions for optically scanning and measuring the scene, in order to make one scan each, whereby the laser scanner (10) defines the corresponding center (C_i) of the scan in each position.
11. Laser scanner (10) for carrying out a method according to any of the preceding claims.



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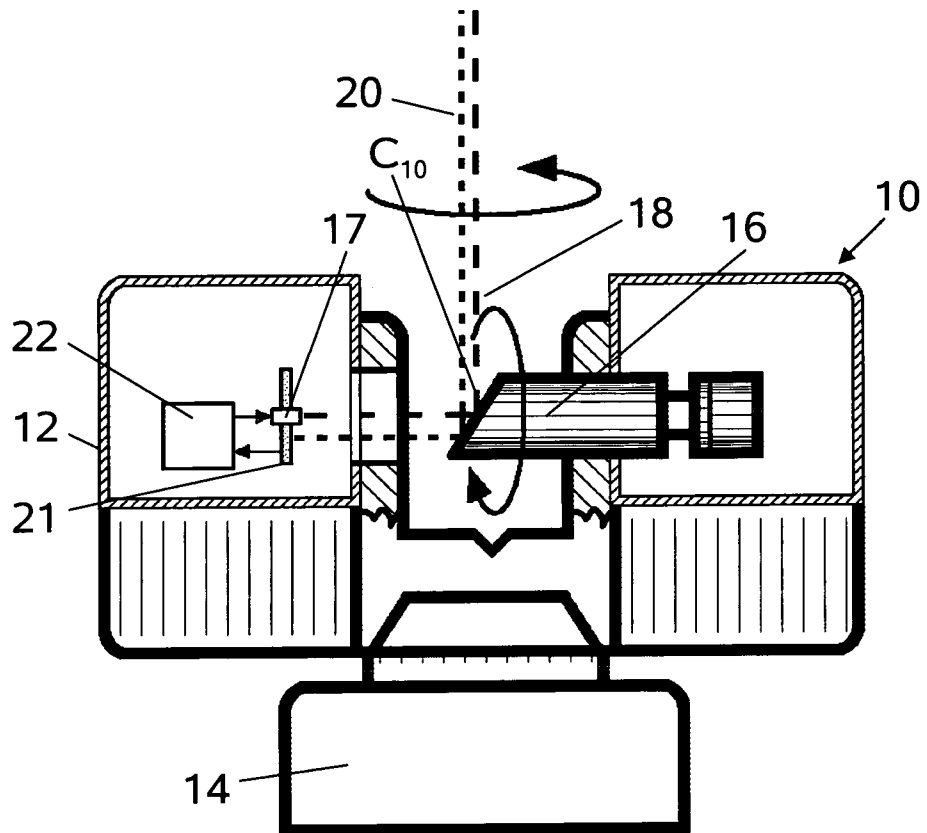


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/001781

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01C3/06 G01C15/00 G01S17/06 G01S17/89 G06T7/00
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)

G01C G01S G06T

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 A	US 2005/190384 A1 (PERSI FRED M [US] ET AL) 1 September 2005 (2005-09-01) figure 4 paragraphs [0001] - [0003], [0010], [0011] paragraphs [0054] - [0068], [0090], [0097] paragraphs [0146] - [0149], [0185], [0186] ----- -/--	1,2,8-11 3-7



Further documents are listed in the continuation of Box C.



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

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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)

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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.

G document member of the same patent family

Date of the actual completion of the international search

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Date of mailing of the international search report

22/07/2010

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/001781

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DEVIRIM AKCA: "Full automatic registration of laser scanner point clouds" OPTICAL 3D MEASUREMENT TECHNIQUES, vol. VI, 2003, XP002590305 ETH, Swiss Federal Institute of Technology Zurich, Institute of Geodesy and Photogrammetry DOI: 10.3929/ethz-a-004656666 the whole document -----	1-11
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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