(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 March 2002 (21.03.2002)

PCT

(10) International Publication Number
WO 02/23127 A1

(51) International Patent Classification[7]: G01C 15/02, 11/00, G01B 11/26, G06K 19/06

(21) International Application Number: PCT/CH01/00539

(22) International Filing Date:
6 September 2001 (06.09.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
00810817.7 11 September 2000 (11.09.2000) EP

(71) Applicant *(for all designated States except US)*: **LEICA GEOSYSTEMS AG** [CH/CH]; Mönchmattweg 5, CH-5035 Unterentfelden (CH).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **CLARKE, Timothy, Alan** [GB/GB]; No 1 Grange Road, Bishop's Stortford, Hertfordshire CM23 5N6 (GB). **WANG, Xinchi** [CN/GB]; 29A Green Hill Parade, Great North Road, New Barnet, Hertfordshire EN5 1EU (GB).

(74) Agent: **FREI PATENTANWALTSBÜRO**; Postfach 768, CH-8029 Zürich (CH).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

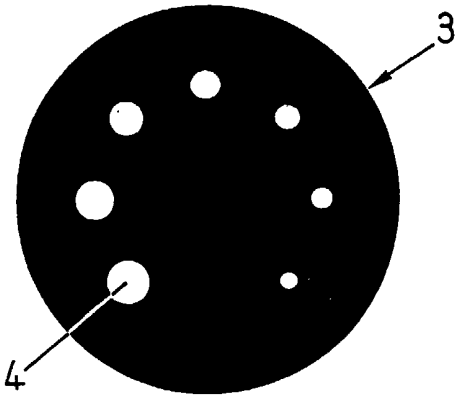
(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/23127 A1

(54) Title: METHOD FOR IDENTIFYING MEASURING POINTS IN AN OPTICAL MEASURING SYSTEM



(57) Abstract: In an optical measuring system for e.g. determining spatial position and orientation of objects a plurality of measuring point on the object is registered by cameras, laser measuring devices or a combination thereof. For identifying the measuring points, one target of a specific intensity and/or size or a predetermined pattern (3) of a plurality of targets (4) having specific differing intensities and/or sizes is associated to each measuring point. The intensities and/or sizes of the targets are detected e.g. in a pixel image of the target (4) by summing up intensities sensed by pixels being comprised in the image of the target. The targets are e.g. light emitting means consuming differing amounts of energy, reflecting, black or white spots of differing diameter or spots of differing shades of gray or other suitable color. Three to five grades of intensity and/or size can be realized easily. The advantage compared with known binary segment or dot codes used for measuring point identification in optical measuring systems is the fact that in systems with a small amount of measuring points one target per measuring point is sufficient and that when using patterns (3) of targets (4) each target can be used as measuring point and can supply in addition to identification information further useful information.

METHOD FOR IDENTIFYING MEASURING POINTS IN AN OPTICAL MEASURING SYSTEM

The invention is in the field of metrology and relates to a method according to the generic part of the first independent claim. The method serves for identification of measuring points in an optical measuring system.

Optical measuring systems are used in particular for determining position and orientation of objects in a three dimensional space but also e.g. for determining two dimensional deformation or three dimensional shape. For this purpose, optical measuring devices, e.g. cameras, laser measuring devices (e.g. laser trackers) or combinations thereof are aimed towards the object to be subjected to the measurement and the spatial position of selected points (measuring points) on the object surface are registered. The data gained from such registration is then subjected to suitable computation from which data regarding the spatial position of the selected points are determined from which information regarding position and orientation of the object or other information is deduced.

The selected points on the object are usually marked with targets. These targets may be active, i.e. light emitting targets (e.g. light emitting diodes), or passive, i.e. light reflecting targets (e.g. reflectors, white spots on black background, black spots on white background or light spots projected onto the object).

As in most cases a plurality of points is needed for getting enough data for enabling computation of the desired information, it is important that registrations of measuring points can be correlated unequivocally to real measuring points. This correlation can be realized by sequential measurement of selectively illuminated targets, by image matching carried out by an operator, or by giving to each measuring point a unique, machine readable identity. Such machine readable identities may be the position of a measuring point in a predetermined geometric pattern of measuring points or it may be associated to the target marking the measuring point.

According to the state of the art target associated identification is e.g. realized by code patterns e.g. in black and white arranged in the vicinity of the target and usually decoded by template matching (image matching). Such code patterns are e.g. circular segment codes or circular dot codes which codes are binary, i.e. for each code feature position presence of the code feature (e.g. segment or dot) means "one", absence of the code feature means "zero".

Such identification systems have some disadvantages. As the codes are binary, the number of permutations is relatively small such necessitating large numbers of code features (segments or dots) for identifying large numbers of targets. In order to prevent misidentification, the code features must be arranged such that they can be recorded separately, i.e. large numbers of such features need a large amount of space. i.e. restrict target density. As the code features are either present or absent only present targets can be used for measurement. Machine reading of such identification patterns necessitates recordation and analysis of a large number of features (e.g. code segments or dots). Furthermore, decoding by template matching needs considerable computing capacity.

It is the object of the invention to provide a method for measuring point identification in an optical measurement system which measuring point identification method allows to reduce the disadvantages as described above for target associated identification using known patterns of code features. In particular, the inventive measuring point identification method is to be very universally applicable, it is to be easily adaptable for supplying besides identification information further useful information and it is to be "readable" not only by template matching methods but also by other, less computation intensive methods.

This object is achieved by the method for measuring point identification in an optical measuring system as defined by the claims.

According to the inventive method the measuring points are marked with the aid of one or more targets each, wherein each target has a specific intensity and/or size. This means that each measuring point is identified either by intensity and/or size of a target positioned substantially in the measuring point or by a plurality of targets arranged in a predefined pattern, the pattern of targets being positioned in a predefined relation to the measuring point and encoding the identity of the measuring point by their differing intensities and/or sizes.

Targets with differing intensity are realized e.g. as light emitting means emitting differing amounts of energy or as passive targets with differing brightness (shades of gray instead of or in addition to black and white, differing intensities of specific color). Targets with differing size are realized e.g. as active targets consisting of an accumulation of light emitting means or as passive targets in the form of reflecting or white on black or black on white spots of differing sizes.

The targets are recorded by a pixel detector (e.g. CCD-detector), i.e. as pixel images comprising advantageously between about 10 and 100 pixels. Intensity and/or size of a target may be determined by summing up the intensities of all the pixels comprised in the pixel image of the target (showing an intensity above or below a predetermined limit), the size of a target may be determined by counting the pixels comprised in the image of the target and the intensity may be determined by determining the intensity sensed by the one pixel of the image showing the maximum (or minimum) intensity.

In the case of a photogrammetric method, all data to be recorded for determination of the intensity and/or size of a target need to be recorded also for determining the center of gravity of the image representing the exact position of the target image on the pixel detector. This means that identification is possible without additional data acquisition.

Pixel images of identification encoding patterns of a plurality of targets having differing intensities and/or sizes can also be decoded by template matching in the same way as done with images of known code patterns associated with measuring points. Identification "by hand" is possible also.

The advantages of the inventive measuring point identification method over known measuring point identification methods are in particular due to the fact that firstly no target needs ever to be absent (zero intensity or zero size are preferably not used) and to the fact that more than two grades of intensity and/or size are possible resulting in more than binary codes and therefore, larger numbers of permutations.

From the above short description it can be gathered that the inventive method for target identification is very widely applicable. Each measuring point can be marked with one target of a specific intensity and/or size or by a plurality of targets arranged in a predetermined pattern wherein each target has a specific intensity and/or size and wherein the pattern encodes the identity of the measuring point. All the targets of an encoding target pattern can represent measuring points such that the pattern as a whole constitutes a suitable means for supplying apart from identification information further useful information, e.g. regarding the spatial orientation of the measuring point or of the surface on which it is positioned respectively.

The inventive measuring point identification method is further described in connection with the following Figures, wherein:

Figure 1 illustrates the determination of intensity and/or size of a target from a pixel image of such a target;

Figure 2 shows four code patterns each comprising seven passive identification targets with differing sizes;

Figure 3 shows an example of an arrangement of passive targets for encoding the identity of a measuring point and further defining the spatial position and orientation of the measuring point;

Figure 4 shows an example of an arrangement of active targets encoding the identity of a measuring point substantially in the same way as the pattern according to Fig. 3.

Figure 1 shows above a bright spot 1 on a darker background 2 representing the image of a target with a specific intensity and size and below the intensity

distribution I across the image of the target and intensities I_i sensed by pixels P_i of a pixel detector in the area of the target image. As mentioned above, intensity and/or size of the image may be determined by analysis of the intensities I_i of the pixels P_i comprised within the spot image. For determining size only the number of the pixels P_i within the spot image can be determined and for determining the intensity only it may be sufficient to register the maximum intensity I_M sensed by pixel P_M.

Figure 2 shows four exemplified circular arrangements 3 of identification targets 4 around a central target 5 marking a measuring point. The identification targets 4 have three different sizes such allowing 3^7, i.e. 2187 permutations. Without complication the central target 5 may also be included in the identification code by having differing sizes in differing patterns 3 instead of having always the same size as shown in Fig. 2.

It is not necessary that the code dot patterns in a set of arrangements of such code dots is always the same as this may be concluded from the set of arrangements as shown in Fig. 2. It is quite possible that one set of arrangements comprises differing patterns.

The patterns as shown in Fig. 2 are realized e.g. as stickers showing the pattern in black and white, in white and black or in suitably contrasting colors or the code dots may be made of a reflecting material.

Figure 3 shows a similar identification pattern 3 with seven identification targets 4 as Fig. 2 in which however, the central target (5) marking the measuring point is missing. Besides determination of the measuring point identity, the data acquired from a pixel image of the arrangement may further serve for determining the spatial

position of the arrangement center (measuring point) as well as the orientation of the arrangement (spatial orientation of the measuring point or spatial orientation of a surface on which the measuring point is positioned respectively) if the identification targets 3 are handled like measuring point targets.

Figure 4 shows a further exemplified embodiment of a target arrangement to be used in the inventive measuring point identification method. This target arrangement comprises light emitting diodes 10 arranged in a ring and wired in parallel with resistors 11 of differing size. Application of three different resistor types results in three different intensities of light emission by the diodes. Use of the arrangement as shown in Fig. 4 can achieve the same effect as the arrangement shown in Fig. 3.

CLAIMS

1. Method for identification of measuring points in an optical measuring system in which system a plurality of active or passive targets is used for marking measuring points, **characterized** in that one or a plurality of targets (4, 10) is associated to each measuring point, the targets having differing intensities and/or differing sizes and that for identification of the measuring points the intensities and/or sizes of the targets (4, 10) are registered.

2. Method according to claim 1, **characterized** in that the targets (4, 10) are imaged in pixel images (1) and that intensities and/or sizes of the pixel images (1) are determined by summing-up intensities (I_i) sensed by pixels (P_i) comprised in the image (1) of a target, by counting the pixels (P_i) comprised in the image (1) of a target or by determining the maximum intensity (I_M) sensed by one of the pixels (P_M) comprised in the image (1) of a target.

3. Method according to one of claims 1 or 2, **characterized** in that the targets (10) are light emitting means emitting differing amounts of light energy.

4. Method according to one of claims 1 or 2 **characterized** in that the targets (4) are light reflecting spots or white spots on black background or black spots on white background and that the spots have differing sizes.

5. Method according to one of claims 1 or 2 **characterized** in that the targets are spots of differing shades of gray on a white or black background or spots of differing intensity of at least one color.

6. Method according to one of claims 1 to 5 **characterized** in that to each measuring point one target is associated and that the measuring point identity is encoded by the specific intensity and/or size of the target associated with the measuring point.

7. Method according to one of claims 1 to 5, **characterized** in that to each measuring point a plurality of targets (4, 10) is associated, the plurality of targets (4, 10) being arranged in a predetermined pattern (3) and that the measuring point identity is encoded by specific intensities and/or sizes of the targets (4, 10) in the pattern (3).

8. Method according to claim 7, **characterized** in that for computing the spatial position and/or orientation of a measuring point, the spatial position of the targets (4, 10) in the target pattern (3) associated with the measuring point are determined.

9. Set of arrangements of a plurality of targets (4, 10) each serving for identifying measuring points in an optical measuring system, **characterized** in that the targets (4, 10) of each arrangement are arranged in the same pattern (3) or in differing patterns and that the targets (4, 10) have differing intensities and/or sizes.

10. Set of arrangements according to claim 9, **characterized** in that the target pattern (3) is a circle.

11. Set of arrangements according to one of claims 9 or 10, **characterized** in that the targets (10) are light emitting means emitting differing amounts of light energy.

12. Set of arrangements according to one of claims 9 or 10, **characterized** in that the targets (4) are light reflecting spots of differing sizes.

13. Set of arrangements according to one of claims 9 or 10, **characterized** in that the targets (4) are black spots on a white background or white spots on a black background and have differing sizes.

14. Set of arrangements according to one of claims 9 or 10, **characterized** in that the targets are spots of differing gray shades on a white or black background or spots of at least one specific color in differing intensities.

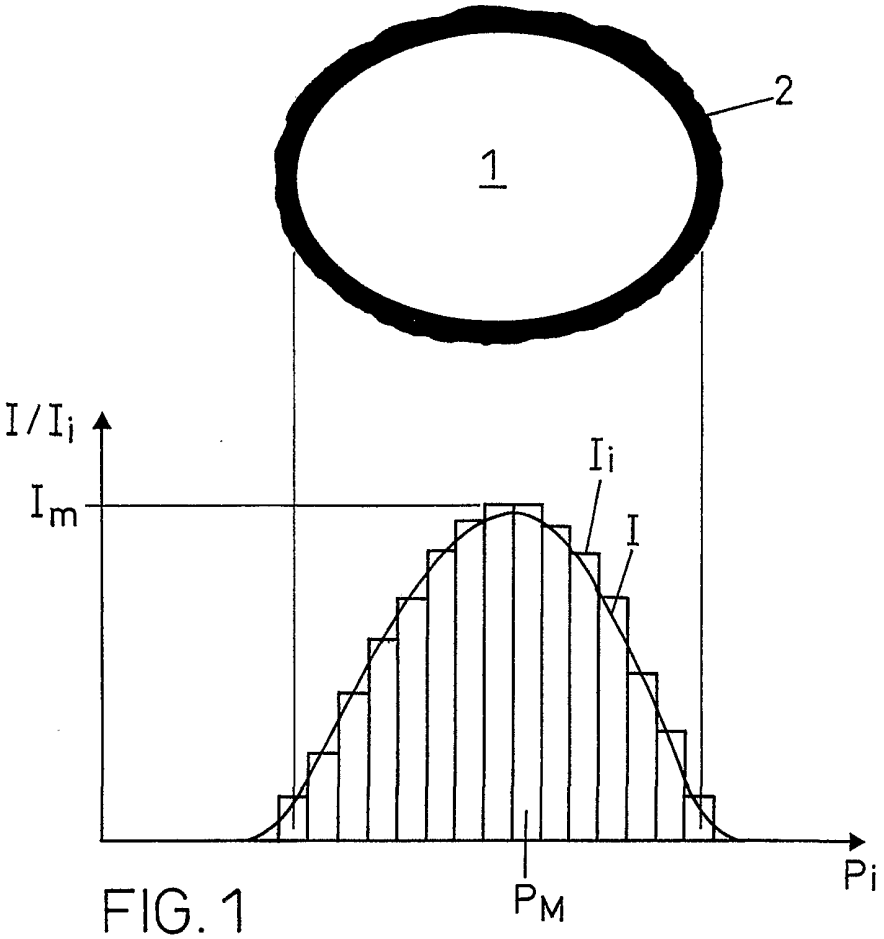


FIG. 1

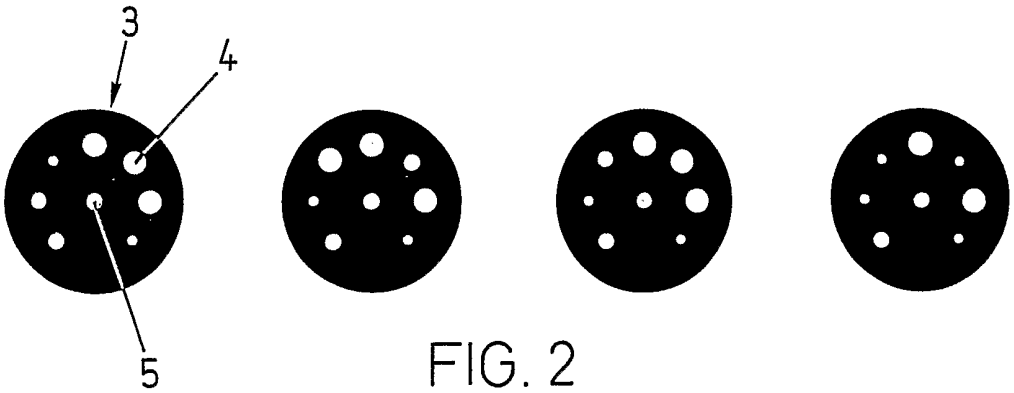


FIG. 2

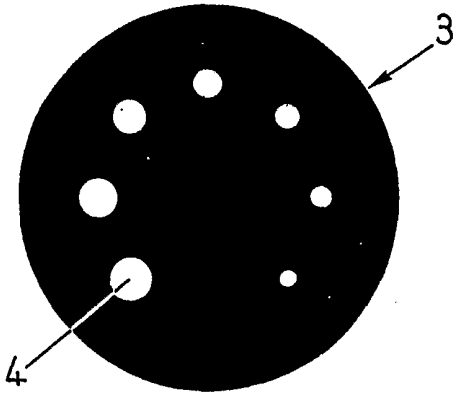


FIG. 3

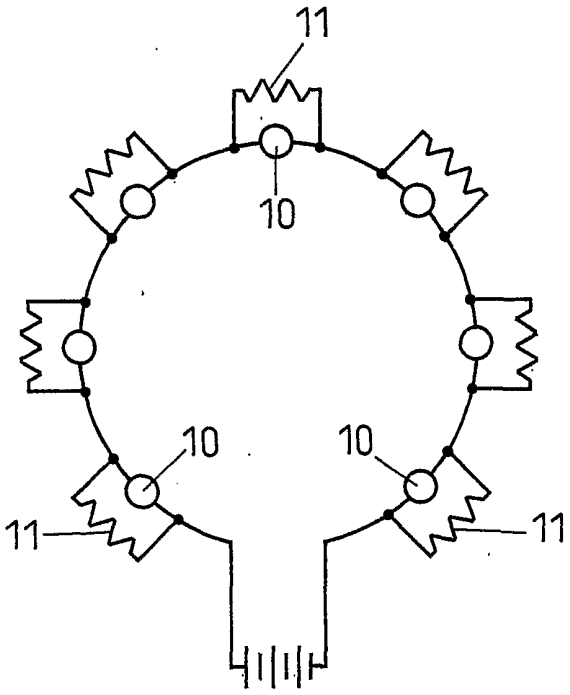


FIG. 4

INTERNATIONAL SEARCH REPORT

In tional Application No
PCT/CH 01/00539

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01C15/02 G01C11/00 G01B11/26 G06K19/06

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)
IPC 7 G01B G06K G01C

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, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 943 783 A (JACKSON BERNIE FERGUS) 31 August 1999 (1999-08-31) column 9, line 50 - line 60 column 13, line 33 - line 37; figure 3	1,9
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A	US 4 863 819 A (DREXLER ET AL.) 5 September 1989 (1989-09-05) column 3, line 55 -column 4, line 18; figure 2	1,9

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 November 2001	06/12/2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/CH 01/00539

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