

(19)



(11)

EP 2 944 285 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:

18.10.2017 Bulletin 2017/42

(51) Int Cl.:

A61B 1/313 (2006.01)

(86) International application number:

PCT/KR2014/000131

(21) Application number: **14737829.3**

(22) Date of filing: **07.01.2014**

(87) International publication number:

WO 2014/109520 (17.07.2014 Gazette 2014/29)

(54) TRACKING SYSTEM AND METHOD FOR TRACKING BY USING SAME

VERFOLGUNGSSYSTEM UND VERFAHREN ZUR VERFOLGUNG DAMIT

SYSTÈME DE SUIVI ET PROCÉDÉ DE SUIVI AU MOYEN DE CE SYSTÈME

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **10.01.2013 KR 20130002841**

(43) Date of publication of application:

18.11.2015 Bulletin 2015/47

(73) Proprietors:

- **Koh Young Technology Inc.**
Seoul 153-706 (KR)
- **Kyungpook National University**
Industry-Academic
Cooperation Foundation
Daegu 702-701 (KR)

(72) Inventors:

- **HONG, Jong-Kyu**
Gwangju-si
Gyeonggi-do 464-892 (KR)

• **LEE, Hyun-Ki**

Daegu 706-760 (KR)

• **CHUNG, Jae-Heon**

Gwangmyeong-si

Gyeonggi-do 423-030 (KR)

• **KIM, Min-Young**

Daegu 706-014 (KR)

(74) Representative: **Zardi, Marco**

M. Zardi & Co. SA

Via Pioda 6

6900 Lugano (CH)

(56) References cited:

WO-A1-02/02028	JP-A- 2006 284 442
JP-A- 2007 130 398	KR-A- 20110 118 640
KR-B1- 100 835 186	US-A- 5 394 875
US-A1- 2003 209 096	US-A1- 2005 015 005
US-A1- 2007 183 041	US-A1- 2012 330 154

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 2 944 285 B1

Description

TECHNICAL FIELD

5 **[0001]** Exemplary embodiments of the present invention relate to a tracking system and tracking method using the same. More particularly, exemplary embodiments of the present invention relate to a tracking system and tracking method using the same for surgery capable of detecting a spatial and a direction information of a target by tracking coordinates of markers attached on the target, in which the target are markers attached on a patient or a surgical instrument.

10 BACKGROUND

[0002] Recently, a robot surgery have been studied and introduced to reduce pain of patients and to recover faster in an endoscopic surgery or an otolaryngology surgery (ENT surgery).

15 **[0003]** In such a robot surgery, in order to minimize a risk of the surgery and to operate the surgery more precisely, a navigation system is used to navigate to an exact lesion of a patient by tracking and detecting a spatial position and a direction of a target such as lesion portion or surgical instrument.

[0004] The navigation system described above includes a tracking system which is capable of tracking and detecting a spatial position and direction of a target such as lesion or surgical instrument.

20 **[0005]** The tracking system described above includes a plurality of markers attached on a lesion or a surgical instrument, a first and second image forming units to form images of lights emitted from the markers, and a processor calculating three-dimensional coordinates of the markers which are connected to the first and second image forming units and calculating a spatial position and a direction of the target by comparing pre-stored information of straight lines connecting the markers adjacent to each other and angle information formed by a pair of straight lines adjacent to each other to the three-dimensional coordinates of the markers.

25 **[0006]** Herein, in order to calculate the three-dimensional coordinates of the markers, conventionally, two detectors are required to calculate the three-dimensional coordinates of each markers through a processor, a trigonometry is used in an assumption that a coordinate of marker which is emitted from one marker and formed image in a first image forming unit and a coordinate of marker which is emitted from one marker and formed image in a second image forming unit are identical.

30 **[0007]** Conventional tracking system requires two image forming units to form images of lights which are emitted from each markers positioned different to each other, a manufacturing cost increases as well as a whole size also increases, therefore, a restriction of surgical space is generated.

[0008] Examples of tracking systems and method according to the prior art are known from WO 02/02028.

35 SUMMARY

[0009] Therefore, the technical problem of the present invention is to provide a tracking system and method using the same capable of reducing a manufacturing cost as well as minimizing a restriction of a surgical space by achieving compact of a system through calculating three-dimensional coordinates of each of markers by using only one image forming unit.

40 **[0010]** In one embodiment of the present invention, a tracking system includes at least three markers which are attached on a target to emit lights or reflect lights emitted from a light source, a reflector which reflects light emitted from the makers or reflected light from the markers, an image forming unit which forms a direct image by directly receiving lights emitted from the markers and, at the same time, forming a reflection image by receiving lights reflected from the reflector after being emitted from markers, and a processor which calculates three-dimensional coordinates of each markers by using the direct image and the reflection image formed on the image forming unit, compares the three-dimensional coordinates of the markers to pre-stored geometric information of the markers which are adjacent to each other, and calculates a spatial position and a direction of the target, the system further comprising the features as recited in claim 1.

50 **[0011]** In one embodiment, the reflector may be a mirror to form a reflection image by reflecting the emitted light from the markers to the image forming unit.

[0012] In one embodiment, the reflector is positioned on the same optical path as the image forming unit, changes at least one of a position, an angle and a shape of a reflection surface under the control of the processor, and changes an image forming position of the reflection image.

55 **[0013]** In one embodiment, the image forming unit may be a camera capable of forming image by receiving a direct light emitted from the markers and a reflected light reflected by the reflector.

[0014] Meanwhile, geometric information of the markers may be length information coupling markers adjacent to each other and angle information formed by a pair of straight lines adjacent to each other.

[0015] In one embodiment of the present invention, a tracking method includes forming a direct image on an image forming units by directly receiving lights emitted from at least three markers which are attached on a target and, at the same time, forming a reflection image on the image forming unit by receiving lights which are reflected from the reflector, the reflector is installed on a specific position and reflects lights emitted from the markers, calculating three-dimensional coordinates of each markers by using the direct image and the reflection image of the markers formed on the image forming unit through the processor, and calculating a spatial position and a direction of the target by comparing the three-dimensional coordinates of the each markers to pre-stored geometric information of markers which are adjacent to each other, the method further comprising the features as recited in claim 1.

[0016] Herein, the geometric information of the markers may be length information coupling markers which are adjacent to each other and angle information formed by a pair of straight lines adjacent to each other.

[0017] Meanwhile, forming the reflection image on the image forming unit comprises controlling at least one of an installation position, an angle, and a shape of a reflection portion of the reflector through the processor to change an image forming position of the reflection image on a same optical path.

[0018] In one embodiment, the process of calculating the three-dimensional coordinates of the marker may further include calculating two-dimensional coordinates of the direct image and reflection image which are formed on the image forming unit through the processor, and calculating the three-dimensional coordinates of the markers by using the two-dimensional coordinates of the direct image and reflection image of the markers

ADVANTAGEOUS EFFECTS

[0019] Thus, according to an embodiment of the present invention, in a tracking system and tracking method using the same, lights emitted from each of the markers are directly flowed to an image forming unit and, at the same time, lights reflected by the reflector are directly flowed to the image forming units. In other words, lights emitted from each of the markers are flowed to the image forming unit through two paths (first path: marker -> image forming unit, second path: marker -> reflector -> image forming unit), an image sensor of the image forming unit forms images of the markers according to the two paths, and therefore, it is possible to calculate a spatial position and a direction of the markers attached on the target by using only one image forming unit.

[0020] Therefore, there is an effect of reducing manufacturing cost of the tracking system, making small and lightweight, and relatively low restriction of a surgical space compared to the conventional tracking system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a schematic diagram of a tracking system according to an embodiment of the present invention.

FIG. 2 is an example diagram of markers attached on a target.

FIG. 3 is an example diagram explaining a position change of a reflection image when a position of the marker is changed on a same optical path as a lens.

FIG. 4 is a block diagram explaining a tracking method according to an embodiment of the present invention.

FIG. 5 is a block diagram explaining a method of calculating three-dimensional coordinates.

FIG. 6 is an example diagram of an image sensor of the image forming unit in which a coordinate of a direct image and coordinate of a reflection image is virtually divided.

FIG. 7 is a diagram explaining a relationship between two-dimensional coordinates and three-dimensional coordinates of a real marker.

DETAILED DESCRIPTION

[0022] The present invention is described more fully hereinafter with reference to the accompanying drawings, in which example embodiments of the present invention are shown. The present invention may, however, be embodied in many different forms and should not be construed as limited to the example embodiments set forth herein. Rather, these example embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present invention to those skilled in the art. In the drawings, the sizes and relative sizes of layers and regions may be exaggerated for clarity.

[0023] It will be understood that, although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, or section discussed below could be termed a second element, component, or section without departing from the teachings of the present invention.

[0024] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting of the present invention. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof

[0025] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0026] Hereinafter, with reference to the drawings, preferred embodiments of the present invention will be described in detail.

[0027] In a tracking system and method using the same according to an embodiment of the present invention, at least three markers are attached and three-dimensional coordinates of the markers are calculated, geometric information of markers adjacent to each, which are pre-stored in a processor, are compared to the three-dimensional coordinates of the markers through the processor, and therefore, it is capable of calculating a spatial position and a direction of a target such as a lesion or surgical instrument. Detailed description is explained with referencing the figures.

[0028] FIG. 1 is a schematic diagram of a tracking system according to an embodiment of the present invention, FIG. 2 is an example diagram of markers attached on a target, and FIG. 3 is an example diagram explaining a position change of a reflection image when a position of the marker is changed on a same optical path as a lens.

[0029] For the convenience of description, a marker is shown in FIGS. 1 and 3, however, in a tracking system according to an embodiment of the present invention, at least three markers 110, 111 and 112 are attached on a target 200 such as a lesion or a surgical instrument.

[0030] Referring to FIGS. 1 to 3, a tracking system according to an embodiment of the present invention includes at least three markers 110, 111 and 112, a reflector 120, an image forming unit 130, and a processor 140.

[0031] At least three markers 110, 111 and 112 are attached on the target 200 such as a lesion or a surgical instrument. Herein, the at least three markers 110, 111 and 112 are separated to each other in a predetermined interval, the markers are attached on the target 200 such as a lesion or a surgical instrument to form specific angles A1, A2 and A3 which are formed by a pair of straight lines of the adjacent markers, in which the straight lines L1, L2 and L3 virtually connect the adjacent markers 110, 111 and 112.

[0032] Herein, geometric information between the markers 110, 111 and 112 which are adjacent to each other, in other words, length information of straight lines L1, L2 and L3 which connect the markers 112 which are adjacent to each other and angle information A1, A2 and A3 formed by a pair of the straight lines, are stored in a memory 141 of the processor 140.

[0033] For example, the markers 110, 111 and 112 may be attached on the target 200 such as a lesion and a surgical instrument in a triangle shape, and straight line information L1, L2 and L3 forming sides of the triangle in which the markers are used as vertices and angle information A1, A2 and A3 in which angles are formed by a pair of straight lines coupling each of the markers 110, 111 and 112 may be pre-stored in the memory 141 of the processor 140.

[0034] Meanwhile, the markers 110, 111 and 112 may be active markers which emit lights by themselves. As described above, when an active marker is used for the markers 110, 111 and 112, a light source is not needed.

[0035] Alternatively, the markers 110, 111 and 112 may be passive markers which reflect a light emitted from at least one light source 150. As described above, when passive markers are used as the markers 110, 111 and 112, at least one light source 150 may be arranged close to the image forming unit 130. For example, a pair of light source 150 may be arranged on both sides of the image forming unit 130.

[0036] The reflector 120 reflects lights emitted from the markers 110, 111 and 112 or lights reflected by the markers 110, 111 and 112. For example, the reflector 120 reflects lights emitted from the markers 110, 111 and 112 or re-reflects lights reflected by the marker 110, 111 and 112 which are emitted from the light source 150.

[0037] Herein, the reflector may be a mirror which reflects lights emitted from the markers 110, 111 and 112 to form an image of a reflection image on the image forming unit 130. For example, the reflector 120 may be a spherical mirror. Thus, when a spherical mirror is used for the reflector 120, since a θ value is reduced when a marker changes its position on a same optical path AX1 as the image forming unit 130 as shown in FIG. 3, a position of a marker is calculated based on the θ value.

[0038] Meanwhile, by changing an installation position, an installation angle, or a shape of a reflection surface, the reflector may change an image formation position of a reflection image formed on the image forming unit 130. In other words, it is possible to vary a measurement range by changing an installation position, an installation angle, or a shape of a reflection surface.

[0039] Herein, changing the position, the angle, or the shape of the reflection surface of the reflector may be controlled

by the processor 140 which is interlocked in a wired/wireless network. Thus, it is capable of changing an optical path as the reflection image by moving the reflector 120 when the optical path is screened by a stand of a surgical robot, an arm, a doctor or a nurse, etc.

[0040] Or, when the reflection image is not received in a certain period of time after the processor directly receives an image of the markers 110, 111 and 112, then, the processor decides that there is an obstacle in an optical path, and in such a case, the processor may send a control information to the reflector 120 such that the control information may move the reflector 120 to pre-stored value by controlling at least one of the installation position, the angle, the shape of the reflection surface of the reflector 120.

[0041] The spatial position and the direction of the reflector 120 and the changed spatial position and the direction of the reflector 120 may be stored in the memory 141 integrated in the processor 140.

[0042] The image forming unit 130 directly receives lights emitted from the markers 110, 111 and 112 and forms an image and, at the same time, receives lights reflected from the reflector 120 which are emitted from the markers 110, 111 and 112 and forms an image. For example, the image forming unit 130 may be a camera which receives lights from the reflector 120 that are directly emitted from the markers 110, 111 and 112, and forms images. In other words, the image forming unit 130 may include a lens 131 in which lights emitted from the markers 110, 111 and 112 and lights reflected from the reflector 120 pass through a focal, a body portion 132 arranged on a back portion of the lens 131 in which an image sensor 133 is integrated, the image sensor forms images by receiving lights emitted from the markers 110, 111 and 112 and lights reflected from the reflector 120.

[0043] The processor 140 calculates three-dimensional coordinates of the markers 110, 111 and 112 using the direct image and the reflection image formed on the image forming unit 130, and is capable of calculating a spatial position and a direction of the target 200 such as a lesion or a surgical instrument by comparing the three-dimensional coordinates of the markers 110, 111 and 112 with the pre-stored geometric information of the adjacent markers 110, 111 and 112.

[0044] Herein, the memory 141 is integrated in the processor 140. Meanwhile, geometric information between the markers which are adjacent to each other, in other words, length information of straight lines L1, L2 and L3 which connect the marker adjacent to each other and angle information A1, A2 and A3 which are formed by the pair of straight lines coupling the markers 110, 111 and 112 adjacent to each other may be pre-stored the memory 141 integrated in the processor 140.

[0045] Additionally, a spatial position and a direction of the reflector 120 may be pre-stored in the memory 141 integrated in the processor 140.

[0046] As described above, in the tracking system 100 according to an embodiment of the present invention, lights emitted from the markers 110, 111 and 112 flow to the image forming unit 130 and a direct image is formed on the image forming unit 130, as well as, lights reflected from the reflector 120 in which the lights emitted from the markers 110, 111 and 112 flow to the reflector 120 and flow to the image forming unit 130, and a reflection image is formed on the image forming units 130, and therefore, even though one image forming unit 130 is used, there is the same effect as using additional image forming unit as shown in a dotted line on the left side of the reflector 120 in **FIGS. 1 and 3**.

[0047] Referring to **FIGS. 1 to 7**, a tracking process of a spatial position and a direction of a target using a tracking system according to an embodiment of the present invention is described below.

[0048] **FIG. 4** is a block diagram explaining a tracking method according to an embodiment of the present invention, **FIG. 5** is a block diagram explaining a method of calculating three-dimensional coordinates, **FIG. 6** is an example diagram of an image sensor of the image forming unit in which a coordinate of a direct image and coordinate of a reflection image is virtually divided, and **FIG. 7** is a diagram explaining a relationship between two-dimensional coordinates and three-dimensional coordinates of a real marker.

[0049] Referring to **FIGS. 1 to 7**, in order to track a spatial position and a direction of a target 200 using a tracking system according to an embodiment of the present invention, first, at least three markers 110, 111 and 112 which are attached on the target 200 are activated making the markers 110, 111 and 112 to emit light, or, at least one light source is activated to irradiated light toward the markers 110, 111 and 112 which are attached on the target 200 such that the light is reflected and emitted by the markers 110, 111 and 112 (S110).

[0050] In more detail, when at least three self-luminous markers 110, 111 and 112 are attached on the target 200, the markers 110, 111 and 112 are activated to emit lights. Alternatively, when at least three passive (non-self-luminous) markers 110, 111 and 112 are attached on the target 200, at least one light source is activated to irradiate light toward the passive markers 110, 111 and 112 which are attached on the target 200 such that the light is reflected and emitted by the passive markers 110, 111 and 112.

[0051] Lights emitted from the at least three markers 110, 111 and 112 are directly transferred to the image forming unit 130 and a direct image of each of the markers 110, 111 and 112 are formed in the image forming unit 130, and at the same time, lights reflected from the reflector 120, in which the light emitted from the at least markers 110, 111 and 112 are transferred to the reflector 120, are transferred to the image forming unit 130 and a reflection image of each of the markers 110, 111 and 112 are formed in the image forming unit 130 (S120).

[0052] In other words, a direct image is formed on the image forming unit 130 by directly receiving lights emitted from

at least three markers 110, 111 and 112 which are attached on the target 200 and, at the same time, a reflection image is formed on the image forming unit 130 by receiving lights reflected from the reflector 120 in which the light emitted from the at least markers 110, 111 and 112 are transferred to the reflector 120.

[0053] In more detail, lights emitted from the at least three markers 110, 111 and 112 are directly transferred to the image forming unit 130 through a first optical path, pass a lens of the image forming unit 130, and make a direct image of the at least three markers 110, 111 and 112 on an image sensor 133 integrated in the body portion 132 and, at the same time, lights emitted from the at least three markers 110, 111 and 112 are reflected by the reflector 120 through a second optical path and transferred to the image forming unit 130, pass a lens of the image forming unit 130, and make a reflection image of the at least three markers 110, 111 and 112 on an image sensor 133 integrated in the body portion 132. In other words, lights emitted from the markers 110, 111 and 112 are transferred to the image forming unit 130 in two paths (first path: marker → image forming unit, second path: marker → reflector → image forming unit), and make two images (direct image and reflection image) of each of the markers 110, 111 and 112 of the two paths (first and second paths).

[0054] As described above, when a direct image and reflection image are formed in the image forming unit 130, three-dimensional coordinates of the markers 110, 111 and 112 are calculated (S130).

[0055] FIG. 5 shows a detailed process of calculating three-dimensional coordinates of each of the markers 110, 111 and 112.

[0056] In order to calculate three-dimensional coordinates of the markers 110, 111 and 112, first, two-dimensional coordinates of the direct image and reflection image of each of the markers 110, 111 and 112 which are formed on the image forming unit 130 are calculated through the processor 140 (S131).

[0057] Herein, after calculating two-dimensional coordinates of the direct image and reflection image of each of the markers 110, 111 and 112, a camera calibration is processed for each coordinates (S132).

[0058] As described above, after processing a camera calibration, three-dimensional coordinates of each of the markers 110, 111 and 112 are calculated by using two-dimensional coordinates of the direct and reflection images (S133).

[0059] Referring to FIGS. 6 and 7, a detailed process of calculating three-dimensional coordinates of each of the markers 110, 111 and 112 is described in below.

[0060] As shown in FIG. 6, one side of the image sensor 133 is virtually divided in a FOV (field of view) of a direct image and another side of the image sensor is virtually divided in a FOV (field of view) of a reflection image, two-dimensional coordinates of the direct image of the image sensor 133 is represented by a coordinate system (U,V), and two-dimensional coordinates of the reflection image of the image sensor 133 is represented by a coordinate system (U',V'). Referring to FIG. 7, a relationship between the two-dimensional coordinates of the markers 110, 111 and 112 in real space and the three-dimensional coordinates of the markers 110, 111 and 112 in real space may be represented in a formula below.

[Formula 1]

$$s \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \alpha & \gamma & u_0 \\ 0 & \beta & v_0 \\ 0 & 0 & 1 \end{bmatrix} \underbrace{\begin{bmatrix} r_1 & r_2 & r_3 & t \end{bmatrix}}_{[R \quad t]} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$\tilde{m} \qquad \qquad \qquad A \qquad \qquad \qquad \tilde{M}$

[0061] Herein, m is two dimensional coordinates of the markers in the image, M is three-dimensional coordinates of the markers in real space, and A(R, t) is a matrix of the camera.

[0062] In order to explain more briefly, when three-dimensional coordinates of real markers 110, 111 and 112 are represented in X, a relational formula between three-dimensional coordinates of real markers 110, 111 and 112 and coordinates of direct image (x_L), and a relational formula between three-dimensional coordinates of real markers 110, 111 and 112 and coordinates of reflection image (x_R) are represented in below.

[Formula 2]

$$x_L = P_1 X$$

$$x_R = P_2 X$$

[0063] Herein, P_1 is a camera matrix of the direct image, and P_2 is a camera matrix of the reflection image.

[0064] And, relation formulas of the direct image and reflection image of each of the markers 110, 111 and 112, $x_L = P_1 X$, $x_R = P_2 X$, may be represented in a linear equation $AX = 0$, and the equation may be represented in Formula 3.

[Formula 3]

$$x(P_1^{3T}X) - (P_1^{1T}X) = 0$$

$$y(P_1^{3T}X) - (P_1^{2T}X) = 0$$

$$x(P_2^{3T}X) - y(P_2^{1T}X) = 0$$

[0065] Herein, P_j^T is a row vector of the matrix P .

[0066] The formula 3 may be represented in Formula 4.

[Formula 4]

$$\begin{bmatrix} x_L P_1^{3T} - P_1^{1T} \\ y_L P_1^{3T} - P_1^{2T} \\ x_R P_2^{3T} - P_2^{1T} \\ y_R P_2^{3T} - P_2^{2T} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ W \end{bmatrix} = [0]$$

[0067] Herein, W may be a scale factor.

[0068] Three-dimensional coordinates of the markers 110, 111 and 112 are obtained by calculating X , Y , and Z through solving the linear equation represented in formula 4.

[0069] As described above, after calculating three-dimensional coordinates of each of the markers 110, 111 and 112 through the processor 140, three-dimensional coordinates of the markers 110, 111 and 112 in real space are compared to pre-stored geometric information of the markers which are adjacent to each other through the processor 140, and a spatial position and a direction of the markers 110, 111 and 112 attached on the target 200 is calculated (S140).

[0070] Herein, as described above, geometric information between the adjacent markers 110, 111 and 112 may be length information of straight lines $L1$, $L2$ and $L3$ which connect the marker adjacent to each other and angle information $A1$, $A2$ and $A3$ which are formed by the pair of straight lines coupling the markers 110, 111 and 112 adjacent to each other.

[0071] In other words, the spatial position and the direction of the markers 110, 111 and 112 are calculated by comparing the three-dimensional coordinates of the markers 110, 111 and 112 in real space to length information of straight lines $L1$, $L2$ and $L3$ which connect the marker adjacent to each other and angle information $A1$, $A2$ and $A3$ which are formed by the pair of straight lines coupling the markers 110, 111 and 112 adjacent to each other, in which the length information and the angle information are pre-stored in the processor 140.

[0072] As described above, a tracking system and method using the same according to an embodiment of the present invention, lights emitted from each of the markers 110, 111 and 112 are directly flowed to an image forming unit 130 and a direct image is formed on the image forming unit 130 and, at the same time, lights reflected from the reflector 120

are flowed to the image forming unit 130 and a reflection image is formed on it. In other words, lights emitted from the markers 110, 111 and 112 are transferred to the image forming unit 130 in two paths (first path: marker -> image forming unit, second path: marker -> reflector -> image forming unit), and make two images (direct image and reflection image) of each of the markers 110, 111 and 112 of the two paths (first and second paths).

[0073] Therefore, a tracking system and method using the same according to an embodiment of the present invention, one image forming unit 130 is used to calculate a spatial position and direction of the markers 110, 111 and 120 attached on the target 200.

[0074] Therefore, there is an effect of reducing a manufacturing cost of the tracking system with small and lightweight, and relatively low restriction of surgical space comparing with conventional tracking system.

[0075] It will be apparent to those skilled in the art that various modifications and variation can be made in the present invention without departing from the scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

Claims

1. A tracking system comprising at least three markers (110, 111, 112) attached on a target and adapted to emit lights or adapted to reflect lights emitted from at least one light source (150), **characterized in that** the tracking system (100) comprises:

a reflector (120) reflecting the lights which are emitted from the markers (110, 111, 112) or the lights reflected by the markers (110, 111, 112);

an image forming unit (130) which is adapted to form a direct image by directly receiving lights emitted from the markers (110, 111, 112) and, at the same time, is adapted to form a reflection image by receiving lights reflected from the reflector (120) after being emitted from the markers (110, 111, 112); and

a processor (140) which is adapted to calculate three-dimensional coordinates of the markers (110, 111, 112) using the direct image, the reflection image, and a spatial position and direction of the reflector (120) pre-stored in a memory (141) of the processor (140), and is adapted to calculate a spatial position and direction of the target by comparing the three-dimensional coordinates of the markers (110, 111, 112) with a pre-stored geometric information between the markers (110, 111, 112) adjacent to each other.

2. The tracking system (100) of claim 1, wherein the reflector (120) is a mirror which reflects lights emitted from the markers (110, 111, 112) towards the image forming unit (130) to form a reflection image.

3. The tracking system (100) of claim 1, wherein the reflector (120) changes an image forming position of the reflection image by changing at least one of an installation position, an angle, and a shape of a reflection surface under the control of the processor (140).

4. The tracking system (100) of claim 1, wherein the image forming unit (130) is a camera which forms an image by receiving the light emitted from the markers (110, 111, 112) and the lights reflected from the reflector (120).

5. The tracking system (100) of claim 1, wherein the geometric information between the markers (110, 111, 112) comprises length information of straight lines which connect the markers (110, 111, 112) adjacent to each other, and angle information which is formed by a pair of straight lines adjacent to each other.

6. A tracking method comprising forming a direct image on an image forming unit (130) by directly receiving lights emitted from at least three markers (110, 111, 112) attached on a target, **characterized in that** the tracking method comprises:

forming a reflection image by receiving lights reflected from a reflector (120) that is installed in a specific area to reflect lights emitted from the markers (110, 111, 112) when forming the direct image at the same time;

calculating three-dimensional coordinates of each of the markers (110, 111, 112) through a processor (140) by using the direct image, the reflection image, and a spatial position and direction of the reflector (120) pre-stored in a memory (141) of the processor (140); and

calculating a spatial position and a direction of the target by comparing the three-dimensional coordinates of each of the markers (110, 111, 112) and geometric information between the markers (110, 111, 112) adjacent to each other, wherein the geometric information is pre-stored in the processor (140).

7. The tracking method of claim 6, wherein the geometric information comprises length information of straight lines which couple the marker (110, 111, 112) adjacent to each other and angle information which is formed by the pair of straight lines adjacent to each other.

8. The tracking method of claim 6, wherein forming the reflection image on the image forming unit (130) comprises controlling at least one of an installation position, an angle, and a shape of a reflection portion of the reflector (120) through the processor (140) to change an image forming position of the reflection image.

9. The tracking method of claim 6, wherein calculating the three-dimensional coordinates of the markers comprises:

calculating two-dimensional coordinates of the direct and reflection images of the markers (110, 111, 112) through the processor (140); and

calculating the three-dimensional coordinates of the markers (110, 111, 112) through the processor (110, 111, 112) by using the two-dimensional coordinates of the direct and reflection images of the markers (110, 111, 112) and the spatial position and the direction of the reflector (120).

Patentansprüche

1. Trackingsystem umfassend wenigstens drei Marker (110, 111, 112), die an einem Ziel angebracht und daran angepasst sind, Lichter zu emittieren, oder daran angepasst sind, von wenigstens einer Lichtquelle (150) emittierte Lichter zu reflektieren,

dadurch gekennzeichnet, dass das Trackingsystem (100) umfasst:

einen Reflektor (120), der die von den Markern (110, 111, 112) emittierten Lichter oder die von dem Markern (110, 111, 112) reflektierten Lichter reflektiert;

eine Bilderzeugungseinheit (130), die daran angepasst ist, durch direktes Empfangen von von den Markern (110, 111, 112) emittierten Lichtern ein direktes Bild zu erzeugen, und gleichzeitig daran angepasst ist, durch Empfangen von Lichtern, die von dem Reflektor (120) reflektiert werden, nachdem sie von den Markern (110, 111, 112) emittiert worden sind, ein Reflexionsbild zu erzeugen; und

einen Prozessor (140), der daran angepasst ist, unter Verwendung des direkten Bilds, des Reflexionsbilds, und einer in einem Speicher (141) des Prozessors (140) zuvor gespeicherten räumlichen Position und Richtung des Reflektors (120) dreidimensionale Koordinaten der Marker (110, 111, 112) zu berechnen, und daran angepasst ist, durch Vergleichen der dreidimensionalen Koordinaten der Marker (110, 111, 112) mit einer zuvor gespeicherten geometrischen Information zwischen den aneinander angrenzenden Markern (110, 111, 112) eine räumliche Position und Richtung des Ziels zu berechnen.

2. Trackingsystem (100) nach Anspruch 1, wobei der Reflektor (120) ein Spiegel ist, der von den Markern (110, 111, 112) emittierte Lichter in Richtung der Bilderzeugungseinheit (130) reflektiert, um ein Reflexionsbild zu erzeugen.

3. Trackingsystem (100) nach Anspruch 1, wobei der Reflektor (120) durch Ändern einer Installationsposition, eines Winkels und/oder einer Form einer Reflexionsfläche unter der Steuerung des Prozessors (140) eine Bilderzeugungsposition des Reflexionsbilds ändert.

4. Trackingsystem (100) nach Anspruch 1, wobei die Bilderzeugungseinheit (130) eine Kamera ist, die durch Empfangen der von den Markern (110, 111, 112) emittierten Lichter und der von dem Reflektor (120) reflektierten Lichter ein Bild erzeugt.

5. Trackingsystem (100) nach Anspruch 1, wobei die geometrische Information zwischen den Markern (110, 111, 112) eine Längsinformation von geraden Linien, die die aneinander angrenzenden Marker (110, 111, 112) verbinden, und eine Winkelinformation umfasst, die durch ein Paar von aneinander angrenzenden geraden Linien gebildet ist.

6. Trackingverfahren umfassend Erzeugen eines direkten Bilds auf einer Bilderzeugungseinheit (130) durch direktes Empfangen von Lichtern, die von wenigstens drei an einem Ziel angebrachten Markern (110, 111, 112) emittiert werden,

dadurch gekennzeichnet, dass das Trackingverfahren umfasst:

Erzeugen eines Reflexionsbildes durch Empfangen von Lichtern, die von einem Reflektor (120) reflektiert wer-

den, der in einem spezifischen Bereich installiert ist, um von den Markern (110, 111, 112) emittierte Lichter zu reflektieren, während gleichzeitig das direkte Bild erzeugt wird;

Berechnen dreidimensionaler Koordinaten von jedem der Marker (110, 111, 112) durch einen Prozessor (140) unter Verwendung des direkten Bilds, des Reflexionsbilds, und einer in einem Speicher (141) des Prozessors (140) zuvor gespeicherten räumlichen Position und Richtung des Reflektors (120), und

Berechnen einer räumlichen Position und einer Richtung des Ziels durch Vergleichen der dreidimensionalen Koordinaten eines jeden der Marker (110, 111, 112) und einer geometrischen Information zwischen den aneinander angrenzenden Markern (110, 111, 112), wobei die geometrische Information zuvor in dem Prozessor (140) gespeichert wird.

7. Trackingverfahren nach Anspruch 6, wobei die geometrische Information eine Längeninformati von geraden Linien, die die aneinander angrenzenden Marker (110, 111, 112) verbinden, und eine Winkelinformation umfasst, die durch ein Paar von aneinander angrenzenden geraden Linien gebildet ist.

8. Trackingverfahren nach Anspruch 6, wobei das Erzeugen des Reflexionsbilds auf der Bilderzeugungseinheit (130) ein Steuern einer Installationsposition, eines Winkels und/oder einer Form eines Reflexionsabschnitts des Reflektors (120) durch den Prozessor (140) umfasst, um eine Bilderzeugungsposition des Reflexionsbilds zu ändern.

9. Trackingverfahren nach Anspruch 6, wobei das Berechnen der dreidimensionalen Koordinaten der Marker umfasst:

Berechnen zweidimensionaler Koordinaten des direkten Bilds und des Reflexionsbilds der Marker (110, 111, 112) durch den Prozessor (140); und

Berechnen der dreidimensionalen Koordinaten der Marker (110, 111, 112) durch den Prozessor (110, 111, 112) durch Verwenden der zweidimensionalen Koordinaten des direkten Bilds und des Reflexionsbilds der Marker (110, 111, 112) und der räumlichen Position und der Richtung des Reflektors (120).

Revendications

1. Système de suivi comprenant : au moins trois balises (110, 111, 112) fixées à une cible et capables d'émettre de la lumière ou capables de refléter de la lumière émise par au moins une source lumineuse (150),
caractérisé en ce que le système de suivi (100) comprend :

un réflecteur (120) réfléchissant la lumière émise par les balises (110, 111, 112) ou la lumière réfléchie par les balises (110, 111, 112),

une unité de formation d'image (130) qui est capable de former une image directe quand elle reçoit directement la lumière émise par les balises (110, 111, 112) et, en même temps, est capable de former une image par réflexion quand elle reçoit la lumière réfléchie par le réflecteur (120) après qu'elle ait été émise par les balises (110, 111, 112), et

un processeur (140) qui est capable de calculer les coordonnées tridimensionnelles des balises (110, 111, 112) en utilisant l'image directe, l'image par réflexion et une position spatiale et une direction du réflecteur (120) préenregistrées dans une mémoire (141) du processeur (140), et est capable de calculer une position spatiale et une direction de la cible en comparant les coordonnées tridimensionnelles des balises (110, 111, 112) avec une information géométrique préenregistrée entre des balises (110, 111, 112) adjacente l'une à l'autre.

2. Système de suivi (100) selon la revendication 1, **caractérisé en ce que** le réflecteur (120) est un miroir qui réfléchit la lumière émise par les balises (110, 111, 112) vers l'unité de formation d'image (130) afin de former une image par réflexion.

3. Système de suivi (100) selon la revendication 1, **caractérisé en ce que** le réflecteur (120) modifie une position de formation de l'image, de l'image par réflexion, en modifiant au moins un facteur parmi une position d'installation, un angle et une forme d'une surface de réflexion sous le contrôle du processeur (140).

4. Système de suivi (100) selon la revendication 1, **caractérisé en ce que** l'unité de formation d'image (130) est un appareil photo qui forme une image en recevant la lumière émise par les balises (110, 111, 112) et la lumière réfléchie par le réflecteur (120).

5. Système de suivi (100) selon la revendication 1, **caractérisé en ce que** l'information géométrique entre les balises

(110, 111, 112) comprend l'information sur la longueur des lignes droites qui connectent les balises (110, 111, 112) adjacentes les unes aux autres, et l'information sur l'angle qui est formé par une paire de lignes droites adjacentes l'une à l'autre.

- 5 6. Méthode de suivi comprenant : former une image directe sur une unité de formation d'image (130) à la réception directe de la lumière émise par au moins trois balises (110, 111, 112) fixées sur une cible, **caractérisée en ce que** la méthode de suivi comprend :

10 former une image par réflexion à la réception de la lumière réfléchie par un réflecteur (120) qui est installé dans une zone spécifique afin de réfléchir la lumière émise par les balises (110, 111, 112) quand l'image directe est formée en même temps,
calculer les coordonnées tridimensionnelles de chacune des balises (110, 111, 112) via un processeur (140) en utilisant l'image directe, l'image par réflexion et une position spatiale et une direction du réflecteur (120) préenregistrée dans la mémoire (141) du processeur (140), et
15 calculer une position spatiale et une direction de la cible en comparant les coordonnées tridimensionnelles de chacune des balises (110, 111, 112) et l'information géométrique entre les balises (110, 111, 112) adjacentes les unes aux autres, où l'information géométrique est préenregistrée dans le processeur (140).

- 20 7. Méthode de suivi selon la revendication 6, **caractérisée en ce que** l'information géométrique comprend l'information sur la longueur de lignes droites qui couplent les balises (110, 111, 112) adjacentes les uns aux autres et l'information sur l'angle qui est formé par une paire de lignes droites adjacentes l'une à l'autre.

- 25 8. Méthode de suivi selon la revendication 6, **caractérisée en ce que** former l'image par réflexion sur l'unité de formation d'image (130) comprend de contrôler au moins un facteur parmi une position d'installation, un angle et une forme d'une partie de la réflexion du réflecteur (120) via le processeur (140) afin de modifier une position de formation de l'image de l'image par réflexion.

- 30 9. Méthode de suivi selon la revendication 6, **caractérisée en ce que** le calcul des coordonnées tridimensionnelles des marqueurs comprend :

calculer les coordonnées bidimensionnelles des images directe et par réflexion des balises (110, 111, 112) via le processeur (140), et
calculer les coordonnées tridimensionnelles des balises (110, 111, 112) via le processeur (140) en utilisant les coordonnées bidimensionnelles des images directes et par réflexion des balises (110, 111, 112) et la position spatiale et la direction du réflecteur (120).
35

40

45

50

55

FIG. 1

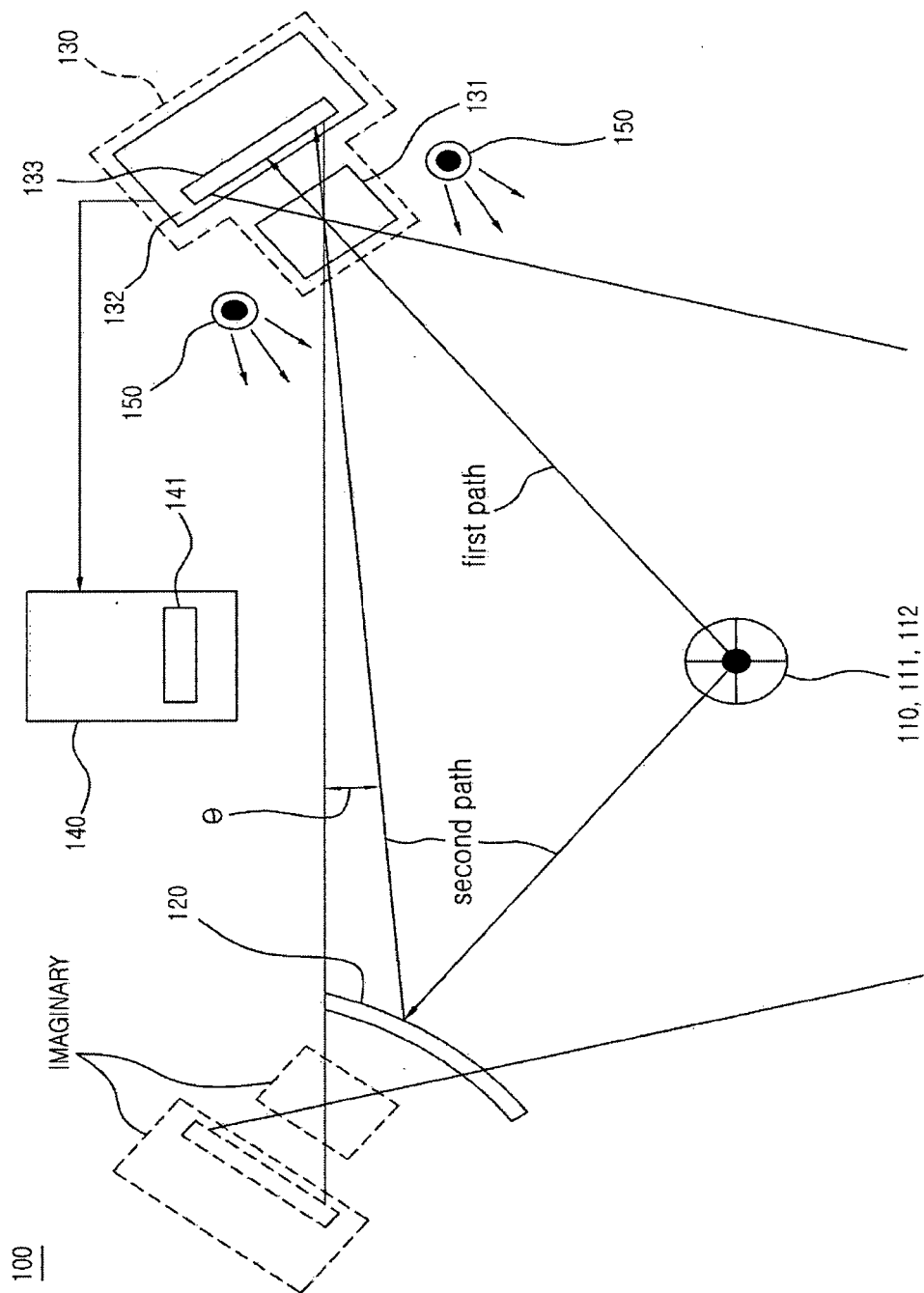


FIG. 2

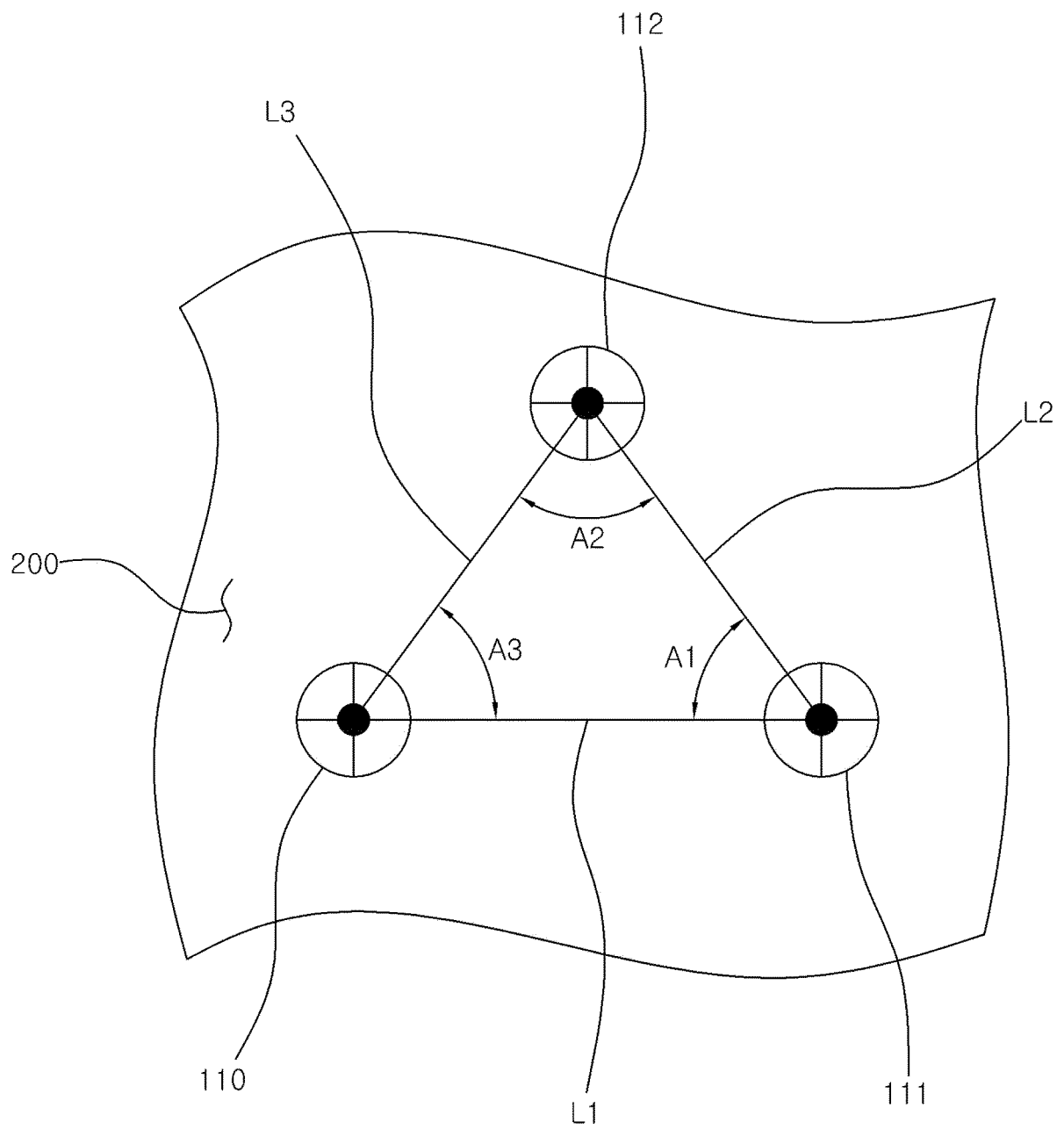


FIG. 3

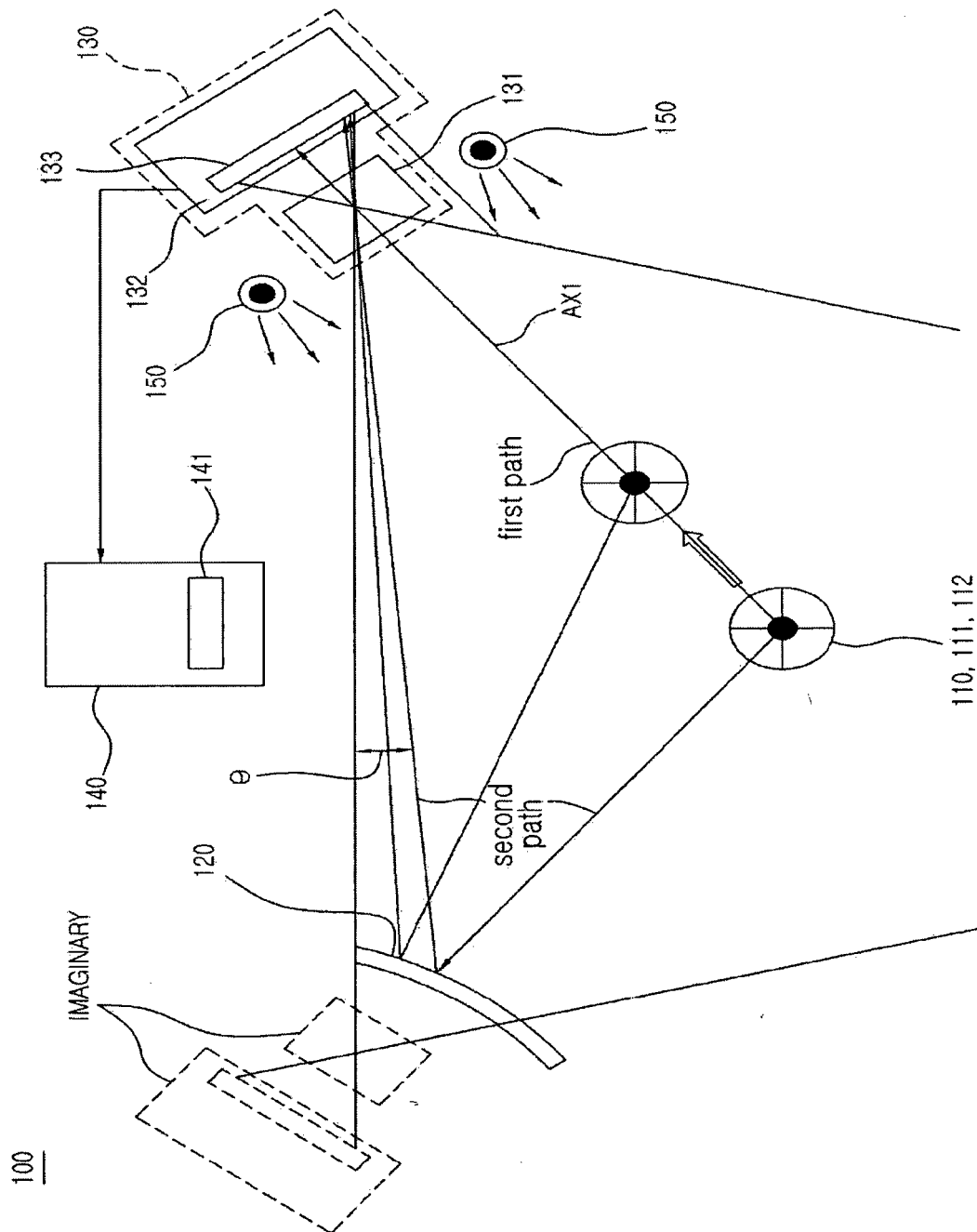


FIG. 4

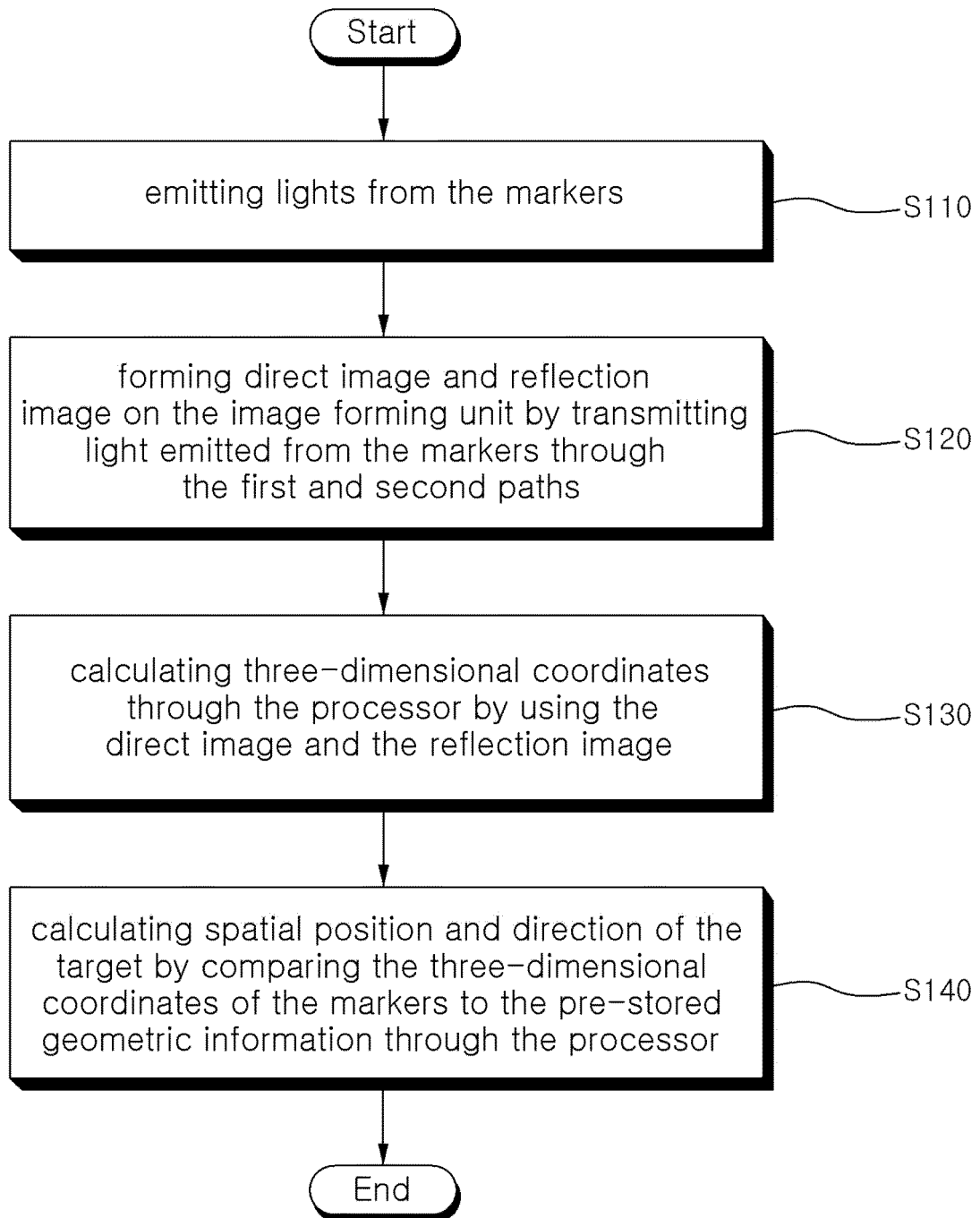


FIG. 5

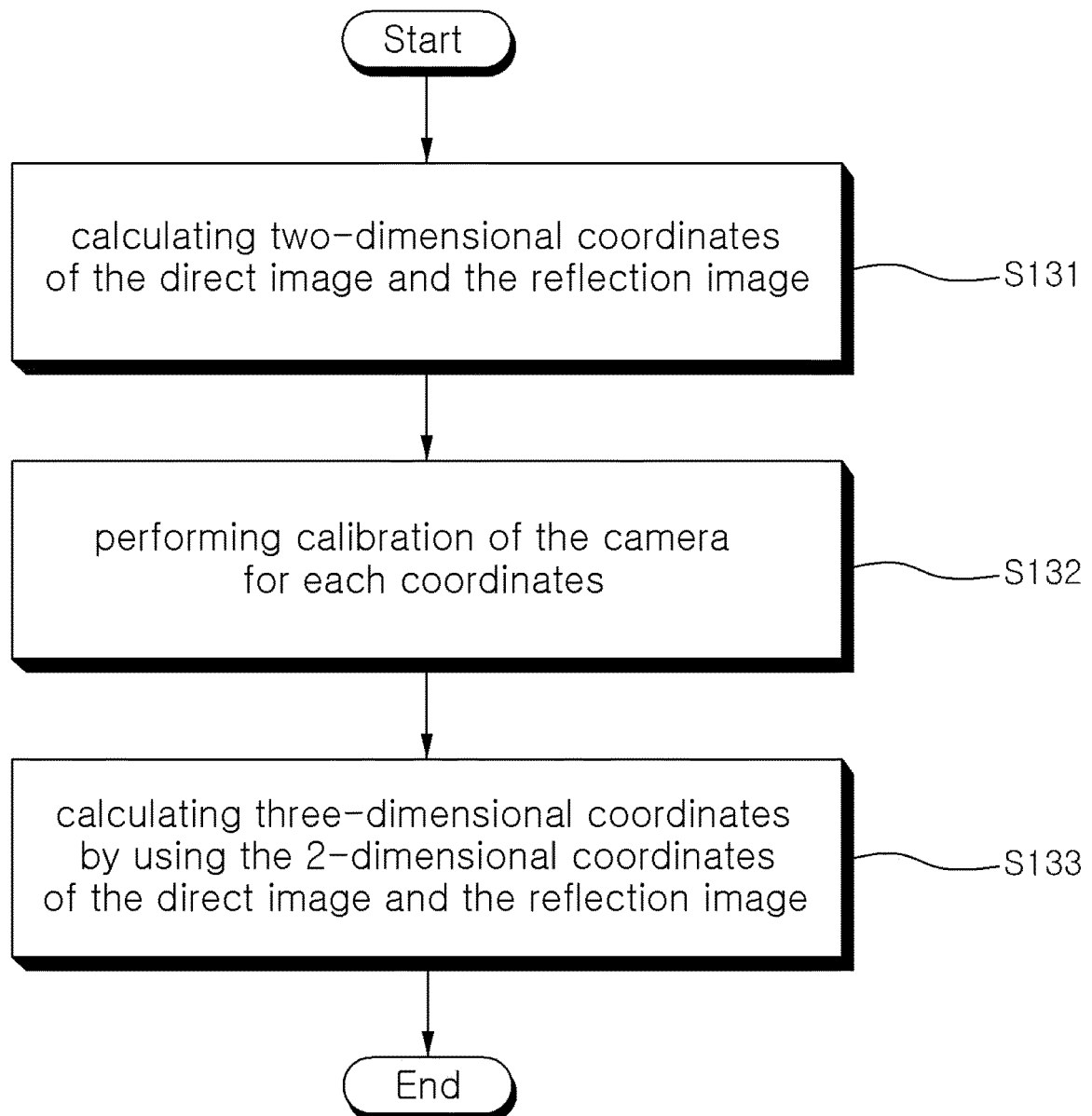
S130

FIG. 6

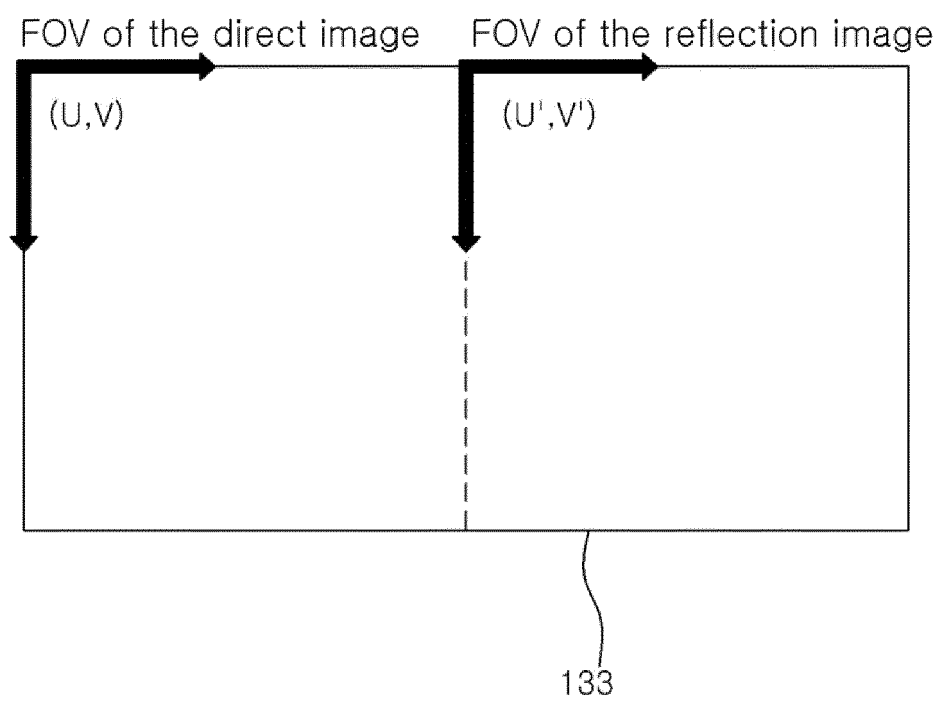
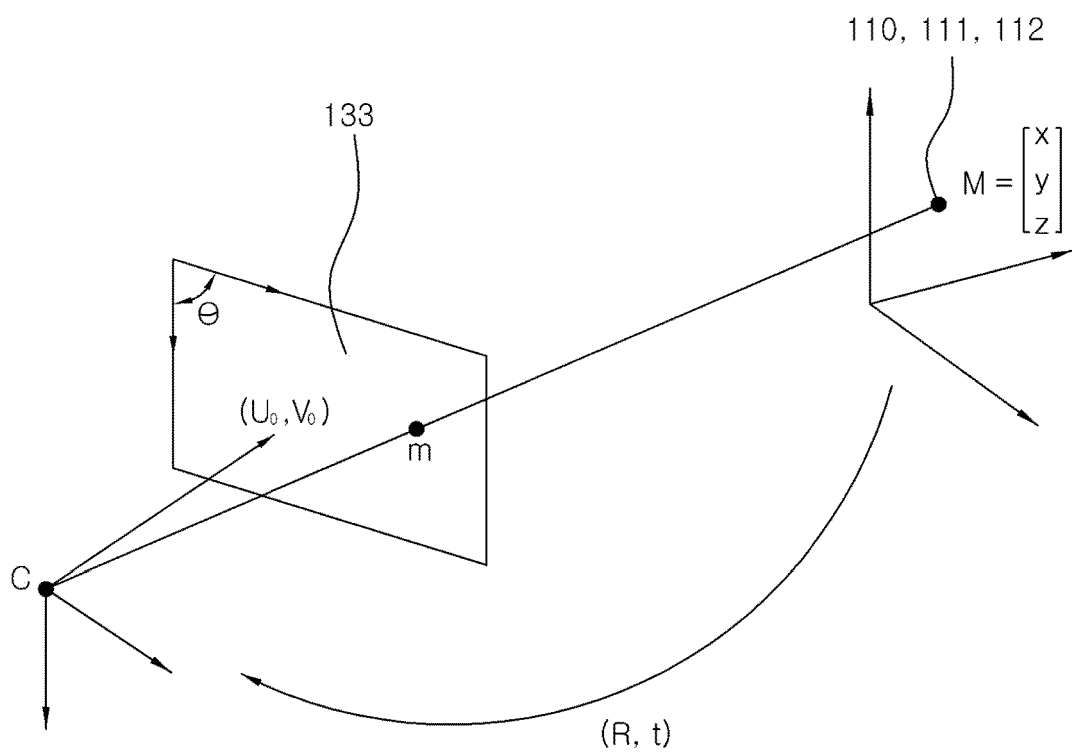


FIG. 7



REFERENCES CITED IN THE DESCRIPTION

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.

Patent documents cited in the description

- WO 0202028 A [0008]