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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 February 2009 (12.02.2009)

PCT

(10) International Publication Number
WO 2009/020381 A1

(51) International Patent Classification:
*G03B 35/00* (2006.01) *H04N 5/232* (2006.01)
*G03B 37/00* (2006.01)

(21) International Application Number: PCT/MY2008/000084

(22) International Filing Date: 7 August 2008 (07.08.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PI 20071300 7 August 2007 (07.08.2007) MY

(71) **Applicant** *(for all designated States except US)*: **MIMOS BERHAD** [MY/MY]; Technology Park Malaysia, 57000 Kuala Lumpur (MY).

(72) **Inventor; and**
(75) **Inventor/Applicant** *(for US only)*: **HON, Hock, Woon** [MY/MY]; C-14-1 Bayu Tasik 2 Condo, Bandar Sri Permaisuri, 56000 Kuala Lumpur (MY).

(74) **Agent: ABDULLAH, Mohd, Bustaman**; Lot C9-3. Jalan Selaman 1, Dataran Palma, 68000 Ampang, Selangor (MY).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

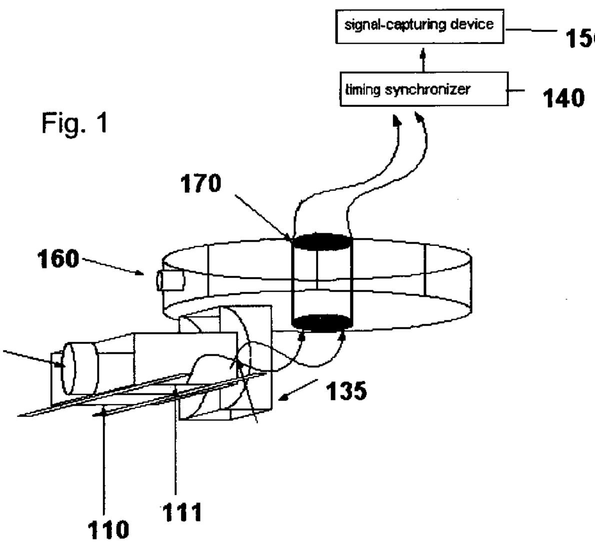
(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17:**
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *of inventorship (Rule 4.17(iv))*

**Published:**
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(54) **Title:** APPARATUS AND METHOD FOR THREE-DIMENSIONAL PANORAMIC IMAGE FORMATION

Fig. 1




(57) **Abstract:** The present invention relates to a method for generating a 3D panoramic image which includes the steps of: (a) capturing two video signals from each sensors (110, 111) that arrives in a line-by-line manner with the video synchronization pulse where the video signals are synchronized by the video synchronization pulse from each of the video signals; (b) spatial integration of a 2D image collection on a line by line basis over a certain period of time depending on the rotation speed of a rotary stage (120); (c) temporal determination of the video signal with reference to the first sensor (110) for a given convergent distant; (d) compensating the time difference in order to achieve viewable disparity by padding with plain image data. The amount of padding is dependent upon the convergent distant; (e) integrating both resultant perspective images (43, 44) to produce a single 3D panoramic image.

WO 2009/020381 A1

# APPARATUS AND METHOD FOR THREE-DIMENSIONAL PANORAMIC IMAGE FORMATION

The present invention relates to a method and apparatus for 3-dimensional (3D) panoramic image formation, more particularly to capturing and generating a 3D image using line-scan sensors with a single projection centre and without image stitching.

## BACKGROUND TO THE INVENTION

Panoramic imaging technology has been used for merging multiple photographs of digital images to produce a single seamless 360° panoramic view of a particular scene. A camera is usually employed in such a way that a sequence of image inputs is obtained as the camera is rotated around the focal point of the camera lens causing every two neighboring images to slightly overlap each other. The intensity values from the two neighboring images in the overlap region are weighted and then summed to form a smooth transition. The resultant panorama provides a 2 dimensional (2D) description of the environment.

Generally, multiple cameras are usually utilized in order to obtain both intensity and 3D panorama. There have been systems producing depth panoramic images. An example of such system is found in the U.S. Patent No. 6,023,588 which utilizes a side-by-side camera system in imitating a human viewer. However, this is impossible by using the side-by-side configuration. One solution displaces the camera vertically such that the line between the rear-nodal points of the cameras is aligned with the rotation axis.

In order to generate 3D images, a camera set swivels at the nodal point at a constant angular interval and produces intensity images. The 3D panorama is constructed by stitching neighboring 3D images like the conventional 2D panorama form by stitching two neighboring intensity images together. However, problems arise when two adjacent 3D images in a sequence are merged. Distortion appears when a sequence of 3D images is used to describe a shape of an object.

U.S Patent No. 7,010,158 describes a method of modeling and reconstructing 3D scene wherein each 3D panoramic image is derived from a plurality of range images captured from a distinct spatial position. The 3D panoramic images are generated by positioning a camera at a first distinct spatial location; acquiring the plurality of range images of the scene by rotating the camera about a vertical axis relative to the scene, wherein there is an inter-overlap region between adjacent images; and forming a 3D panoramic image about the vertical axis from the plurality of acquired range images. A plurality of 3D panoramic images is created by repeating these steps at additional spatial positions in the scene. This invention simplifies the merging process of the 3D panoramic images drastically compared to merging the entire set of individual range images. However, it still requires image stitching process for 3D panoramic image generation.

## SUMMARY OF THE INVENTION

The present invention is directed to overcoming one or more of the problems set forth above. Briefly summarized, the present invention relates to a method for generating a 3D panoramic image which comprises:

(a) capturing two video signals from each sensor that arrive in a line-by-line manner with synchronization pulses where the video signals are synchronized by the synchronization pulse from each of the video signals;

(b) spatial integrating a 2D image collection on a line-by-line basis over a certain period of time depending on the rotation speed of a rotary stage;

(c) assigning the first video signal as a starting mark of temporal registration with reference to the first sensor for a given convergent distant;

(d) compensating the time difference in order to achieve viewable disparity which does not exceed the human maximum allowable parallax by padding with plain image data; and

(e) integrating both the video signals to produce a single 3D panoramic image.

More specifically, the video signals are obtained by placing two rotating sensors side-by-side that share the same projection center and centre of rotation. The image data are then extracted from the video signals and synchronized and build up in the system memory in order to form perspective two-dimensional images which are generated after a full cycle of 360° rotation.

The amount of padding with plain data is dependent upon the convergent distant.

An advantage of the present invention is that image stitching is not required to generate 3D panoramic image and it requires only a single lens or one projection centre to acquire the images. A selectable coverage of the field of the view is another advantage achieved by using the tilt-able holder.

Another significant advantage with the setup that uses two line-scan sensors with a single lens is that the calibration of the sensor in terms of their spatial position, raw, pitch and yaw with respect to each other is much easier as only a single lens is used. The lens is used as a reference point for calibration for both the line-scan sensors.

These and other aspects, objects, features and advantages of the present invention will be more clearly understood and appreciated from a review of the following detailed description of the preferred embodiment and appended claims, and by reference to the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

The specific features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

Fig. 1 illustrates the image formation apparatus and its peripheral controllers;

Fig. 2 illustrates a field of view control of dual-sensor line-scan in action;

Fig. 3a, 3b and 3c illustrate perspectives view of tilting sensors with goniometer;

Fig. 4 shows the simplified data processing flow and potential resultant images; and

Fig. 5 shows the time integration volume covered by sensor 1 and sensor 2.

## DETAILED DESCRIPTION OF THE INVENTION

In the following description of the preferred embodiments of the present invention, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. It is understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

Referring to Fig. 1, there is illustrated an embodiment of the present invention to capture a 3D panoramic image of interest. A single standard C-mount, CS-mount or F-mount lens **100** is used as a common projection centre for two high-speed line-scan sensors **110, 111** that are arranged side-by-side on the same plane, where scene in object space is backed projected to the sensors **110, 111** respectively. Both sensors **110, 111** are packaged into a single unit and mounted on a motorized control goniometer **135** and a rotary stage **120** (see fig. 5) with a centre of rotation (center of the package unit).

The rotary stage **120** has two parts; the upper part is stationary and the lower part is movable stage. A slip ring **170** is placed in between the 2 stages from the camera and to the synchronizer which are connected through the slip ring **170** to avoid entanglement of the cables.

A timing synchronizer **140** is used to synchronize the raw video signals from each sensor **110, 111** start time before they are captured by a signal-capturing device **150**. The signal-capturing device **150** may be a frame grabber or a digital signal processor (DSP). The synchronization plays a vital role in determining the integrity of the image quality as the video signal might not arrive to the image capture device as the exact same time.

A laser point source **160** is used as a reference point. The laser point will be used to indicate the starting point of the scanning. This can ease the process of image registration.

Fig. 2 shows that the separation of the two sensors **110, 111** can be changed by a motorized control **113** at the back of the sensors **110, 111**. The motorized control **113** controls the overlapping field of view by opening up or closing the apertures of the two cameras to achieve an equal angle. With this capability convergent distant can be adjusted by the said apparatus.

Fig. 3a shows that the camera is in the center point of the goniometer **135**. Fig. 3b and Fig 3c further show the camera is positioned at the upper and lower position of the goniometer **135**. The vertical field of view for both sensors **110, 111** can be controlled by the goniometer **135**. The fields of view of the sensors **110, 111** can be changed by a tilt-able controller **130** (shown in fig. 5) to capture different areas in the scene when and if necessary. The goniometer **135** is used to position the camera set in order to face at a certain direction for field of view.

Referring to Fig. 4, two perspective images **40, 41** are produced at the end of a full rotation of each of the sensors **110, 111**. The full resolution of the image in the x axis (the moving axis) represents the panoramic field of view of the surrounding scene. The content of the resultant images **43, 44** shows the view from 0° to 359° in object space.

Each of the resultant images **43, 44** is captured by the individual sensors **110, 111** on a line-by-line-basis. The image data are stored temporarily on the signal capturing device's **150** (frame grabber) memory before transferring to the system memory.

The integration of the 3D panoramic images **40, 41** is carried out by interleaving the two image data, either vertically or horizontally, depending on the 3D viewing device used. In the course of integrating the 3D information from the two perspective images **40, 41**, calibration to limit the maximum allowable parallax for human eyes must be carried out in order to reduce the eyestrain caused by the maximum allowable parallax for the human eyes.

Fig. 5 shows time integration volume produced by both sensors **110, 111**. The first sensor **110** creates a different time integration volume **200** from the second sensor **111** as both sensors cover different perspective.

Constant speed rotation is achieved by a rotary stage **120** which is dependent upon the readout rate of the sensors **110, 111** and resolution required. The relationship between the speed of the rotary stage **120** and the camera read out rate also determines the field of view covers and the detail, the shape and the aspect ratio of the panoramic images.

Tilt-able controller **130** serves as the main tool to tilt the sensors **110, 111** to produce different time integration volume **200** to generate the 3D view of interest. The images are captured digitally by high speed scan CMOS or CCD (solid state) sensors **110, 111**.

## CLAIMS

1. A method to generate three-dimensional panoramic images comprising the steps of:

capturing a first video signal of an object of interest by a first sensor (110) that arrives in a line-by-line manner with video synchronization pulses to differentiate two consecutive video lines;

capturing a second video signal of an object of interest by a second sensor (111) that arrives in a line-by-line manner with video synchronization pulses to differentiate two consecutive video lines which has a different perspective from the first sensor (110);

spatial integrating a two-dimensional image on a line-by-line basis over a certain period of time;

assigning the first video signal as a starting mark of temporal registration;

detecting the offset disparity of the second sensor (111) in terms of time difference;

compensating the time difference with padding image data to reduce the image disparity or parallax; and

integrating both resultant perspective images (43, 44) to produce a single three dimensional image of the scene of interest.

2. A method to generate three-dimensional panoramic images according to claim 1, wherein the first image (40) and second image (41) are visible light images if a standard visible light line-scan sensor is used as the capturing device.

3. A method to generate three-dimensional panoramic images according to claim 1, wherein the first image (40) and second image (41) are thermal images if a thermal sensor is used as the capturing device.

4. A method to generate three dimensional panoramic images according to claim 1, wherein two perspective 360° images would be produced at the end of a full rotation of each sensors (110, 111).

5. An apparatus setup to generate three-dimensional panoramic images comprising:

two line-scan sensors (110, 111) arranged side-by-side on the same plane to capture video signals of object of interest;

a motorized tilt-able controller (130) to alter the field of view of the sensors (110, 111) depending on the object of interest;

a timing synchronizer (140) to synchronize the raw video signals from each sensor;

a signal-capturing device (150); and

a slip ring (170) to avoid cable entanglement during high speed rotation.

6. An apparatus setup to generate three-dimensional panoramic images according to claim 5, further comprising a rotary stage (120) for the sensors (110, 111) to capture images of the object of interest (40, 41).

7. An apparatus setup to generate three-dimensional panoramic images according to claim 5, wherein the tile-able holder (130) can change the coverage of the field of view of the sensors (110, 111) concurrently as they are mounted on the same base plate.

8. An apparatus setup to generate three-dimensional panoramic images according to claim 5, wherein the tilt-able controller (130) is rotated by goniometer (135) to change the angle of the sensors (110, 111) to cover different field of view of the object of interest (40, 41).

9. An apparatus setup to generate three-dimensional panoramic images according to claim 5, wherein the motorized control (113) controls the overlapping field of view by altering the distance between the two sensors (110, 111) to adjust the convergent distant.

10. An apparatus setup to generate three-dimensional panoramic images according to claim 5, further comprising a single standard C-mount, CS-mount or F-mount lens (100) as common projection center for both the sensors (110, 111)

11. An apparatus setup to generate three-dimensional panoramic images according to claim 5, wherein the signal capturing device (150) is a digital signal processor or frame grabber.

12. An apparatus setup to generate three-dimensional panoramic images according to claim 5, further comprising a laser pointer (160) to set images of interest (40, 41) as reference starting point on the resultant images (43, 44) to ease the image registration process.

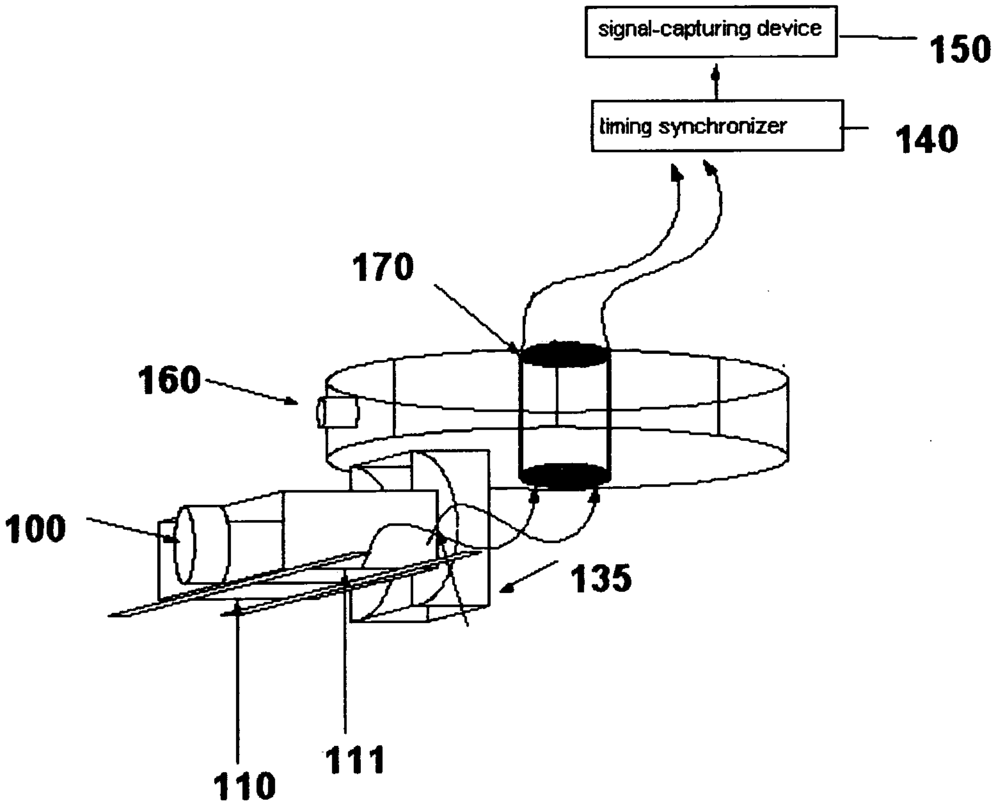

signal-capturing device
150
timing synchronizer
140
170
160
100
135
110
111

Fig. 1

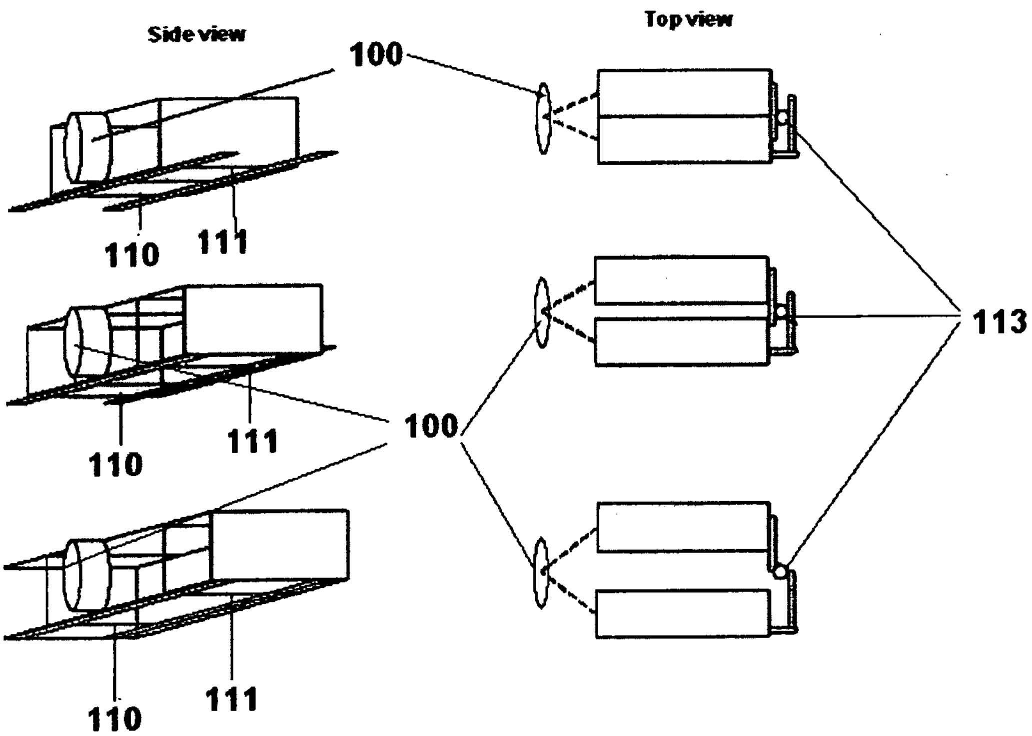



Fig. 2

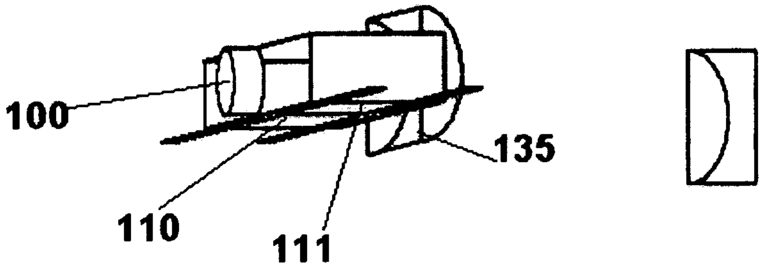



Fig. 3a

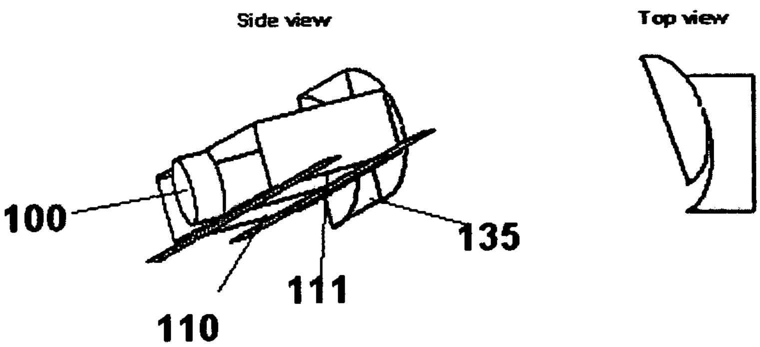



Fig. 3b

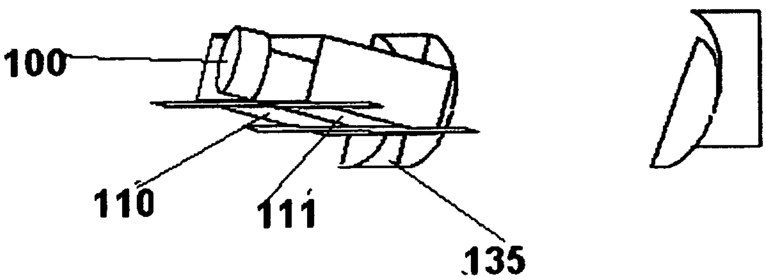



Fig. 3c

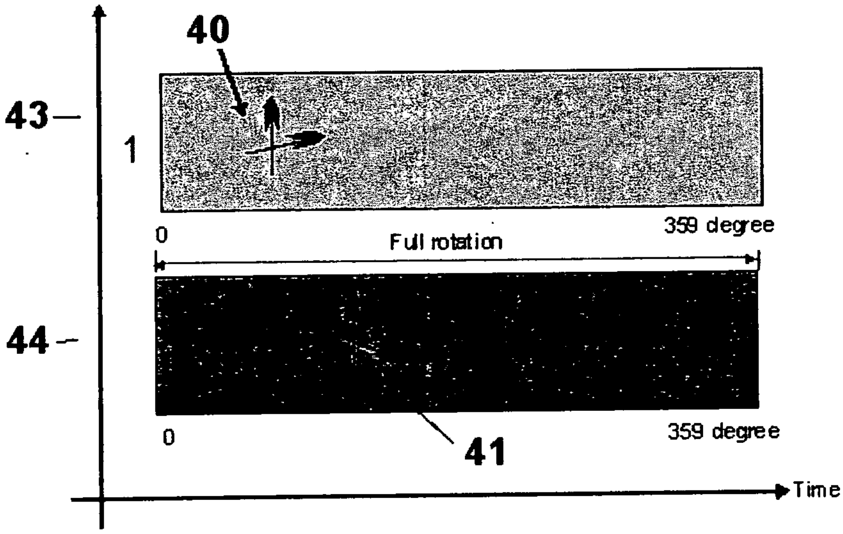



Fig. 4

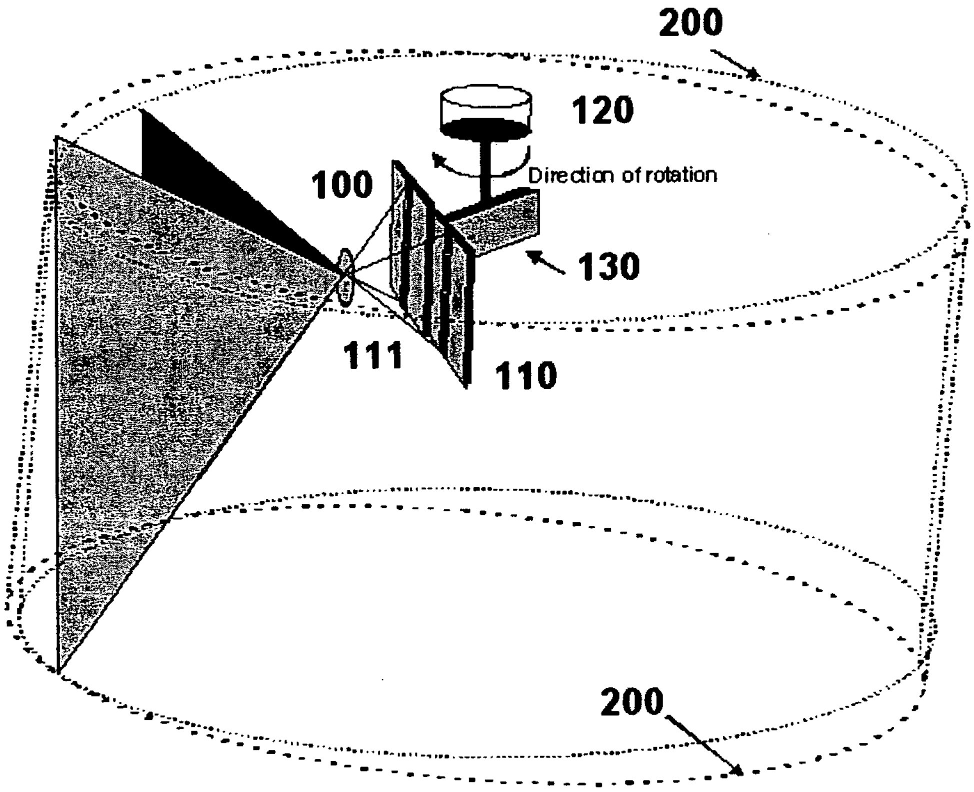



Fig. 5

# INTERNATIONAL SEARCH REPORT

International application No.
**PCT/MY2008/000084**

**A. CLASSIFICATION OF SUBJECT MATTER**

***G03B 35/00(2006.01)i, G03B 37/00(2006.01)i, H04N 5/232(2006.01)i***

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 8 : G03B, H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korea Utility Mpdels and applications for Utility Models since 1975
Japanese Utility Models and applications for Utility Models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS (KIPO internal) & keywords: "camera", "panora*", "three", and "dimension*"

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 2007/0115351 A1(MCCORMACK) 24 May 2007<br>See abstract, page 1, paragraph [0011] - page 3, paragraph [0029], and Figures 1-3 | 1-12 |
| X | US 2006/0215031 A1(KRAHNSTOEVER et al.) 28 September 2006<br>See abstract, page 1, paragraph [0013] - page 7, paragraph [0059], and Figures 1-4 | 1-12 |
| A | KR 10-2003-0062727 A(KO) 28 July 2003<br>See abstract, page 3, line 10 - page 5, line 12, and Figures 1-4 | 1-12 |
| A | US 2005/0029458 A1(GENG et al.) 10 February 2005<br>See abstract, page 2, paragraph [0029] - page 11, paragraph [0111], and Figures 1-13 | 1-12 |

☐ 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
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"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
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 23 DECEMBER 2008 (23.12.2008) | **23 DECEMBER 2008 (23.12.2008)** |


Name and mailing address of the ISA/KR
Korean Intellectual Property Office
Government Complex-Daejeon, 139 Seonsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea
Facsimile No. 82-42-472-7140

Authorized officer
LEE, Se Gyoung
Telephone No. 82-42-481-5518

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
**PCT/MY2008/000084**

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 2007-0115351 A1 | 24.05.2007 | None | |
| US 2006-0215031 A1 | 28.09.2006 | WO 2006-099172 A1 | 21.09.2006 |
| KR 10-2003-0062727 | 28.07.2003 | KR 2003062727 A | 28.07.2003 |
| US 2005-0029458 A1 | 10.02.2005 | None | |