PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04N 7/00, 5/76

A1

(11) International Publication Number: WO 99/51027

(43) International Publication Date: 7 October 1999 (07.10.99)

(21) International Application Number: PCT/US99/05869

(22) International Filing Date: 17 March 1999 (17.03.99)

(30) Priority Data:
09/052,458 31 March 1998 (31.03.98) US

(71) Applicant *(for all designated States except US)*: INTEL CORPORATION [US/US]; 2200 Mission College Boulevard, Santa Clara, CA 95052 (US).

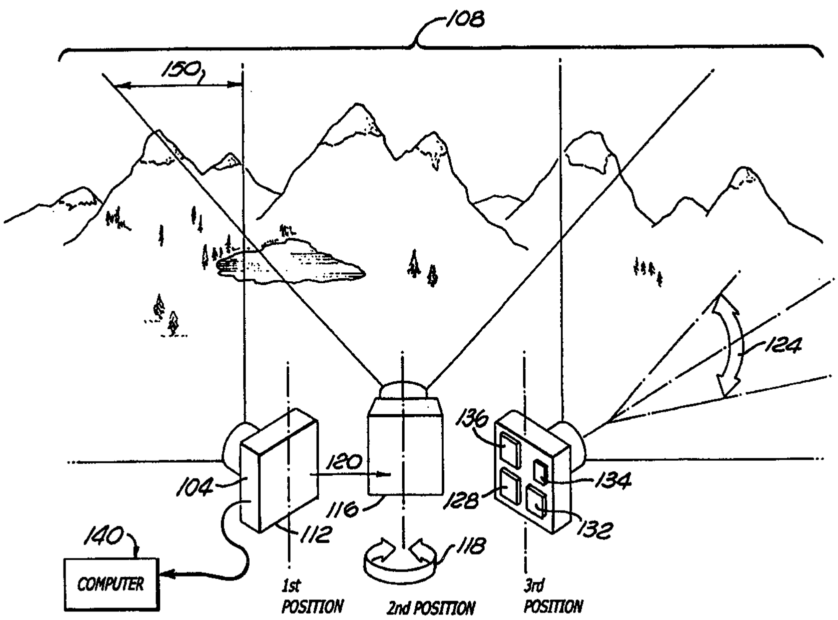
(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: DUNTON, Randy, R. [US/US]; 16026 S. 14th Drive, Phoenix, AZ 85045 (US). CHARLESWORTH, Thomas, Mark [GB/US]; 25805 North Chisum Trail, Scottsdale, AZ 85225 (US).

(74) Agents: CORTES, Roland, B. et al.; Blakely, Sokoloff, Taylor & Zafman LLP, 7th floor, 12400 Wilshire Boulevard, Los Angeles, CA 90025 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, 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, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, 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), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD OF AND APPARATUS FOR CREATING PANORAMIC OR SURROUND IMAGES USING A MOTION SENSOR EQUIPPED CAMERA



(57) Abstract

A camera system for generating panoramic images is described. The camera uses sensors (128) to determine the orientation of the camera as each processor (140) reconstructs a single panoramic image from the recorded images using the recorded orientation information.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

METHOD OF AND APPARATUS FOR CREATING PANORAMIC OR SURROUND IMAGES USING A MOTION SENSOR EQUIPPED CAMERA

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates generally to generating composite images. More particularly, the present invention relates to using motion sensors to determine movement and orientation of a camera. The data from the motion sensor is combined with multiple images taken by the camera to stitch together a large composite image.

(2) Related Art

Photographic and imaging systems today are primarily designed for use in recreating localized images. Typically, a wide angle lens is used when a panoramic photo is desired. A wide angle lens has the disadvantage that the lens typically produces distortion at the edges of the image. A second disadvantage of the wide angle lenses is that more subject matter is recorded per square millimeter of film resulting in a less detailed image being recorded. One method of solving the problem is to use multiple cameras or electronic sensors to record multiple images. The multiple images are subsequently recombined to produce a composite image.

In order to record scenes outside the field of view of wide angle lenses, traditional panoramic imaging systems utilized two or more cameras. Preferably, the relationship between the two cameras was fixed. Thus, when two images were recombined, the information relating the two images was known because of the fixed relationship between the two cameras. The problem with using two cameras is that two camera systems are more expensive than a single camera arrangement. Two cameras typically require two lenses, two camera bodies, and two sets of film.

In still, a third prior art method of generating a series of images to be recombined, a lens system is moved to record a sequence of images. However, such movement often results in excessive overlap between recorded images. The excessive overlap represents excess data which consumes large amounts of memory. Excessive overlap also requires the recording of extra images. These extra images must also be stored and processed.

Attempts to reduce overlap may result in a failure to record information. A failure to record sufficient information may produce gaps between images making it difficult to reconstruct a composite image. Thus, it is desirable to design a system which can quickly and easily generate multiple images with optimum overlap regions for combination into a single composite image. Such a system will be described in the following application.

BRIEF SUMMARY OF THE INVENTION

A system for generating a composite image is described. The system includes an imaging apparatus configured to record a first image at a first orientation and a second image at a second orientation. A sensor detects movement of the imaging apparatus. A processor is configured to generate a panoramic image by stitching together the first image and the second image using an output of the sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates one embodiment of an image apparatus for generating composite images.

Figure 2 is a flow diagram describing the process of generating two images using the imaging apparatus of Figure 1.

Figure 3 illustrates a second embodiment of the invention for generating a surround image.

Figure 4 is a flow diagram describing the process of combining two images to form a single composite image.

Figure 5 is a flow chart describing a method for controlling movement of the imaging apparatus to optimize overlap regions.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, a system for using a single camera with a single lens system to generate composite images including both surround images and panoramic images will be described. Panoramic images are images covering large areas., typically beyond the field of view of a wide angle lens. Panoramic images include surround images which are images projected in an arc around a viewer, typically an arc of 360° completely surrounding the user.

In one embodiment, a camera includes a set of motion sensors, preferably a micro-machined silicon ("MEMS") sensor, which detects linear and rotational acceleration or movements of the camera, and thereby can compute displacement of the camera to determine positions at which a camera is located. Alternately a global positioning ("GPS") system may be used to determine location. Another type of motion sensor which may also be used are vibrating MEM sensors or commercially available laser gyros. Using the position information including camera orientation information and the at least two images taken by the camera, a processor can recreate a composite or panoramic image of a subject.

In the accompanying description, certain details will be provided to facilitate understanding of the invention. For example, the specification will describe the invention using particular MEMS sensor types such as micro-machined accelerometers. However, it is recognized that other position sensors or motion detectors may be used. In particular, GPS systems and other types of MEMS may be appropriate. The actual sensor used will depend on the cost of the sensor, whether a sensor can provide data with sufficient accuracy, the power consumption of the sensor, and the size of the sensor. Thus, the included details are provided to facilitate understanding of the invention, and should not be interpreted to limit the scope of the invention.

A camera for generating a panoramic image is illustrated in Figure 1. In Figure 1, a camera 104 is used to generate a composite image of a subject 108. The subject is typically a scene or image across a wide area. The camera is in an initial position 112 when the first image is taken. After the first image is taken, the camera is moved to a second position 116. The movement may include both a lateral translation illustrated by arrow 120 and may include a rotation motion illustrated by arrow 124. In one embodiment, a motion sensor 128 within the camera detects the lateral translation and the rotation of the camera. In order to detect lateral and rotational movements, two MEMS sensors are preferably used, one MEMS sensor detects lateral acceleration 120 and a second MEMS sensor detects rotation. In one embodiment, preventing lateral movements allows a single MEMS sensor to be used.

In a preferred embodiment, MEMS sensor 128 is an inertial sensor. Such sensors are based on comb drive actuator technology developed by Howe and described in an article entitled "Laterally Driven Polysilicate Resident Micro structures", by W.C. Tang, T.C. Nguyen and R.T. Howe, proceedings IEEE Microelectromechanical Systems Workshop, Salt Lake City, Utah, U.S.A., February, 1989, pages 53-59. An example of an appropriate accelerometer is a 50N1G accelerometer from Analog Devices. Analog Devices also produces integrated BiCMOS devices merged with a micro machine sensor for determining device rotation. These sensors are being used in advanced automotive braking systems. These sensors are being commercialized by General Motors and are described in the article "Overview Of MEMS Activities In The U.S." by C.H. Mastrangelo who is with the Center for Integrated Sensors and Circuits, Department of Electrical Engineering, University of Michigan, Ann Arbor, Michigan, 48109. The article from Mastrangelo also describes alternative embodiments of motion sensors, including optical actuators which may be used to determine the motion of a camera. By integrating the acceleration of the camera, a velocity can be developed. A second integration of the velocity generates a displacement of the camera. This displacement information may be used to determine a second position 116 of a camera 104 when the second image is taken with respect to the first position 112 and orientation of the camera 104.

The relative orientations and positions of the camera, including both the first position 112 and the second position 116, are recorded either in a memory device 132 in the camera, or in an alternative embodiment, the data may be stored in an external memory coupled to the camera. Some motions sensors, such as sensors which measure acceleration may not produce position data. In these embodiments, data describing the motion of the camera, such as acceleration data, may be recorded in memory. At a later time, a processor uses the motion data to compute position data. The respective motion or position and orientation data are organized to allow correlation of each image recorded with a corresponding position, such as first position 112 or second position 116.

Each image recorded may be recorded on photographic film, or more preferably, using electronic sensors 134. In one embodiment, the electronic sensors are Complementary Metal Oxide Semiconductor (CMOS) sensors. In alternate embodiments, photo sensing charge couple device arrays ("CCD") or photo-diodes may be used. The electronic image output by the electronic sensors are stored in a second memory device 136. If the image was recorded on photographic film, the image is converted to an electronic form for further processing. The conversion may be accomplished using a scanner or other methods of converting chemical or light data to electronic data. Such scanners are commercially available from several vendors, including Hewlett Packard of Palo Alto, California. The digital image is stored in memory device 136.

In order to create a single panoramic image from the two or more images of one subject, a processing unit 140 retrieves the images and the corresponding position and orientation information and recombines them into a single, panoramic image. The processing unit 140 may be implemented in a graphics processor card. In another embodiment, the processor is a general microprocessor executing a program to handle graphics processing functions. Various methods of processing two images to generate one composite image are described in

------------------------.

Figure 2 illustrates a flow chart describing the steps used to create a panoramic image from the camera of Figure 1. In step 204, before the first image is taken, the user resets a camera position indicator. The resetting of the camera position indicator preferably clears the memory 132 storing output of the motion sensor, such that the first image recorded in a sequence is preferably at a zero point reference frame. The camera records an image of a subject at the zero point reference frame in step 208. At approximately the same time as the recording of the first image occurs, a corresponding position and orientation of the camera is recorded in memory 132. In the camera of Figure 1, a CCD array generates the image stored in the second memory 136 of Figure 1.

After the camera has recorded the first image and corresponding position and orientation information, the camera is repositioned or reoriented in step 212. The relocation may involve both a lateral translation 120 and orientation (rotational) movement 124. Either a person or a motor driven apparatus may move the camera. In one embodiment, the camera rotates around a tripod, minimizing lateral movements and allowing embodiments of the camera which do not measure lateral translation. During the repositioning, a sensor, preferably a MEMS sensor, records the motion and rotation of the device in step 216. In one embodiment of the invention, the MEMS sensor records acceleration and integrates the acceleration to generate a displacement. The recorded acceleration, rotation or displacement information is stored in a memory device.

When the camera is oriented at a second position, the camera records a second image of the subject. As the second image is recorded, the camera uses information from the motion sensor and records a camera position and orientation corresponding to the second image. The position and orientation information is stored in a position and orientation memory device 132. The second image and the first image must have a sufficient amount of subject matter overlap so that the processor will be able to reconstruct the overlapping regions and generate a stitched panoramic image.

The prior sequence of steps 204 through 220 described a system as used in a still camera. It is contemplated that a MEMS or motion sensor may be installed in a video camera and many images taken as the camera moves. Each image corresponds to a set of position and orientation data generated from information recorded by the motion sensors. These images may then be reconstructed with neighboring images to generate a comprehensive panoramic image. The techniques described in the reconstruction of such a moving image are accomplished by repeated iterations of steps 204 through 220 and a series of reconstruction steps executed by the processor. In step 224, the position and orientation information generated by the motion sensor, along with the corresponding recorded images, are transferred to a processor.

Figure 3 illustrates one embodiment of a camera system 300 for recording a surround or hemispherical image. Light from a subject passes through a lens system 304 which generates an image of the subject on mirror 308. Mirror 308 directs the image to a sensor 312. Sensor 312 may be a photographic film or preferably, sensor 312 is an array of charge coupled device sensors or a CMOS device. The output of sensor 312 is stored in a memory device (not shown).

In the illustrated embodiment, an assembly including lens system 304, mirror 308 and sensor 312 are mounted together in fixed relation to each other such that mirror tilt actuator 316 can tilt the assembly along a first degree of freedom to record portions of the subject above and below (along the y-axis) a particular point. The degree of tilt is recorded in one type of sensor, an encoder 320, which records the amount of tilt when an image is recorded.

In the illustrated embodiment, the assembly including lens system 304, mirror 308 and sensor 312 are also mounted on a free rotating ring 324 which rotates the assembly along a second degree of freedom to record portions of the subject to either side (along the x axis) of a point. Movement or rotation may be executed by a motor 328 coupled to the free rotating ring 324. A shaft encoder 332 serves as a motion sensor to determine and record the position, including orientation, of free rotating ring 324 at each point in which an image is recorded.

The camera system 300 of Figure 3 can be used to record images used in generating composite images with minimal overlap regions. In a first application, the system may be used to record a surround image in a cylindrical format. When the camera system 300 is used to record a cylindrical format surround image, mirror tilt actuator 316 maintains the lens 304 and mirror 308 at a constant tilt while a motor 328 rotates the camera system 300 in a circle along a "x" axis direction. The images recorded by the camera system 300 represents a cross section of a cylinder at a preset tilt. At preset angular positions, along the circle, images are recorded allowing a processor (not shown) to recombine the recorded images to generate a cylindrical image. The sections to be combined are similar to assembling sections 350 of a pie 352 of Figure 3B. The preset angular positions take into account the field of view of the camera system 300 and the overlap region desired between adjacent images. The motion sensor or motor encoder can be used to determine when camera system 300 has reached the preset positions and indicate that an image is to be recorded.

Camera system 300 can also be used to record a hemispherical format. One method of recording a surround image in a hemispherical format utilizes sequentially recording several surround images 360, 362, 364, 366 as shown in Figure 3C. After a surround image at a given tilt is recorded, the mirror tilt actuator 316 is changed to an adjacent preset tilt position so that the camera system 300 records a different surround image with each revolution of camera system 300. The preset tilt positions take into account the field of view of the camera system 300 in the y direction and the overlap region desired between adjacent "surround images." The motion sensor or tilt encoder 320 determines when camera system 300 has reached the preset tilt position.

Figure 4 is a flow diagram describing the steps taken by the processor or processing device 140 to reconstruct a composite image from two or more images using corresponding position and orientation data. In step 404, the processor receives camera position and orientation information and the corresponding image data from the camera. The processor then selects corresponding points in a first and second image in step 408. Corresponding points are points in different images or perspectives which correspond to the same point in a subject. Thus, a corresponding point is a point or pixel in the first image which corresponds to a point on the subject, and a second point or pixel in the second image which corresponds to the same point on the subject. The point in the first image and the point in the second image are defined to be corresponding points. For example, the tip of a person's nose is a point on the subject which may have a corresponding point in both a first and a second image. In one embodiment of the invention, pattern recognition software is used to determine corresponding points. A second, simpler method of determining corresponding points involves an end user, which selects a point in the first image, selects or "clicks" on the first point using a mouse or other pointing device, and selects or "clicks" on the corresponding point in the second image. In a preferred embodiment, three corresponding points are chosen for each overlap region. An overlap region is the redundant date region where two image are being combined. In step 412, the selected corresponding points and their x,y coordinates are recorded in a record stored in a memory device. The record is typically a two dimensional record, because an x and y coordinate must be recorded for each point.

In step 416, a processor identifies operations which can be used to manipulate the two images such that the corresponding points in the two images match. In particular, step 416 involves identifying rotation, translation and scaling operations to be performed on at least one of the two images. In order to determine the operations for matching the corresponding points, data from the motion sensors may be used. If the motion sensors are accurate and sensitive enough, the identification of corresponding points may be unnecessary because the movement of the camera in relation to a fixed subject may be mathematically computed to determine alignment of the images. Typically, the computer performs operations, including rotation, translation and scaling of at least one of the two images to achieve an overlap region that is properly aligned between the two images.

When data is electronically stored, the overlap region between the two images typically has twice the data necessary to generate an image of the overlap region. In order to reduce data redundancy, the extraneous data in one data image may be removed. In an alternate method of combining data, an interpolation or averaging of the data from two images in the overlapping region may occur between the two data sets to generate a single data set representing the overlap region. The decision on whether to average or interpolate data or to delete data from one image depends on the computational power of the processor and the accuracy of the rendition desired. Increased accuracy requires increased processing power which allows for averaging or interpolation of data in the overlap region.

In step 424, the parameters defining a resulting panoramic image are recomputed. In particular, if the image being recombined is a three dimensional image, a recalculation of texture surfaces, color surfaces and triangle vertices, in a 3-D point set is executed to generate a new database containing the redefined building blocks or elements. These elements are typically triangles in a 3-D database. A typical algorithm used for such kind of recomposition of a triangle mesh is the Delauni algorithm as described in ________________. If the images being recombined are two dimensional images, such a reconstruction of a mesh is unnecessary and the program is complete when a composite image combining the two images is generated.

When the images being recombined are three-dimensional images, the texture vertices of the 3-D point set, including new texture surfaces and new color surfaces must be computed in step 328. These newly computed texture and color surfaces are reapplied to the new texture vertices which were computed in step 424.

In summary, the process described in the flowchart in Figure 4 allows a more comprehensive panoramic image to be generated from two images. The first image is generated by a camera which takes a first image at a first position. Motion sensors detect the movement and rotation or position of the camera as the camera is moved to a second position, where a second image is taken. By using position information, a processor can combine the first image and the second image to generate a comprehensive panoramic image.

The described system reduces costs because less equipment is needed. Specifically, only one lens system is needed. A single lens system makes the system less bulky than prior art panoramic imaging systems. Finally, the system described is suitable for video cameras, in which multiple images are taken. These multiple images may be combined to generate a moving panoramic or surround image database.

The described system may be further refined to improve the ease of use and the data gathering capacity of the camera 104 or camera system 300. Figure 5 is a flow chart describing a method to assist a user improve the data gathering capacity of camera 104 or camera system 300. In step 504, the camera takes a first image of a subject from a first position. The camera may then proceed to compute optimum camera positions from which to take subsequent images in step 508. In the camera system 300 of Figure 2, the optimum positions are typically those with the minimum required overlap. Thus, the camera may rotate a predetermined number of degrees after each recording of an image. The number of degrees depends on the field of view which in turn depends on the focal length of the lens 304. A wide angle lens allows more degrees of rotation in the x direction between images thus requiring few images to be recorded in a circle. A telescopic lens having a narrow field of view allows fewer degrees of rotation after recording an image.

In step 512, the camera begins an image capture sequence. Orientation measurements are taken to determine the orientation of the camera.

In camera systems based on manual movement of the camera, the camera prompts the user to move in step 516. In one embodiment, the prompts may be given in the form of arrows displayed in the camera viewfinder. The arrows prompt a user to move the camera in a particular direction, or rotate the camera to a particular orientation. The arrows may be displayed using a liquid crystal display (LCD). An auto-ranging device may be used to provide signals to a processor. The processor controls the display to output signals prompting the user to maintain the proper amount of overlap between sequential images. One method of measuring overlap may be accomplished by causing the processor to select a point on the subject at one edge of the field of view. The processor tracks the movement the point across the field of view as the camera moves. The camera signals the user when the selected point reaches an area on the opposite edge of the field of view allowing the user to record a second image. In an alternate embodiment, a MEMS sensor may determine where camera has been reoriented sufficiently to optimize the overlap region and justify the recording of a second image. The amount of reorientation depends on the field of view of the lens. In manually moved cameras, a visual, sound or voice signal may be used to tell the user to move the camera in a particular direction or rotate the camera to a particular orientation to adjust the overlap region.

In step 420, the camera determines whether the camera is within a tolerance distance or orientation from an optimum position. If the camera is not within the tolerance, the camera returns to step 516 prompting the user to further adjust the camera position in a feedback arrangement. If in step 520 it is determined that the camera is within the tolerance distance, the camera records a second, subsequent image of the subject in step 524.

In step 528, the camera determines whether all images necessary for a database have been recorded. The number of images needed is determined by the field of view of the lens, the amount of overlap desired, and whether a surround, a hemispherical or a panoramic image is desired. If additional images are needed, the camera returns to step 516 prompting the user to move the camera to a subsequent position for the recording of a subsequent image. When it is determined in step 528 that a sufficient number of images have been recorded, the recording of images is complete and a stitched comprehensive image may be reconstructed.

While certain exemplary embodiments have been described in detail and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention is not to be limited to the specific arrangements and construction shown and described, since various other modifications may occur to those with ordinary skill in the art.

CLAIMS

What is claimed:

1. A system for generating a three-dimensional image comprising:

an imaging apparatus configured to record a first image at a first orientation and a second image at a second orientation;

a sensor for detecting reorientation of the imaging apparatus from the first location to the second orientation; and

a processor configured to generate a panoramic image by stitching together the first image, the second image and an output of the motion sensor.

2. The system of claim 1 wherein the motion sensor is a MEMS sensor.

3. The system of claim 1 wherein the change in orientation includes a relocation of the imaging apparatus.

4. The system of claim 1 wherein the motion sensor is a laser gyro.

5. The system of claim 1 wherein the imaging apparatus further comprises:

a lens system;

an array of electronic sensors for generating an electronic image.

6. The system of claim 5 wherein the electronic sensors are part of a charge coupled device array.

7. The system of claim 5 wherein the electronic sensors are part of a Complementary Metal Oxide Semiconductor sensor.

8. The system of claim 1 wherein the imaging apparatus is a video camera.

9. A method of generating a panoramic image comprising the steps of:

recording a first image using an imaging apparatus oriented in a first orientation; reorienting the imaging apparatus to a second orientation;

recording data sufficient to define the reorientation of the imaging apparatus between the first location and the second orientation;

recording a second image using the imaging apparatus at the second orientation; and

combining the first image and the second image to form a panoramic image.

10. The method of claim 9 wherein the step of combining the first image and the second image further comprises the steps of:

selecting corresponding points on the first and second images; and

identifying rotation, translation and scaling operations to meter the first image and the second image.

11. The method of claim 9 wherein the step of recording data sufficient to define the first location and a second location after the move further comprises the steps of:

detecting an acceleration; and

recording the acceleration and time duration of the acceleration to enable a processor to compute displacement of the imaging apparatus.

12. The method of claim 10 further comprising the steps of:

generating a mesh of triangles to simulate a three-dimensional surface.

13. A method of prompting a user recording a panoramic image of a subject comprising the steps of:

determining field of view of a lens in a camera;

recording a first image from a first position;

prompting a user to move to a second position and orientation, said second position and orientation suitable for taking a second image for use in reconstructing a panoramic image of the subject; and

recording the second image.

14. The method of claim 13 wherein the first position is the same as the second position and changing only the orientation of the camera changes.

15. The method of claim 13 further comprising the step of:

reconstructing a panoramic image using the first image and the second image.

16. The method of claim 13 wherein the recording of the first image and the recording of the second image occurs at two different points in time.

17. The method of claim 13 wherein the panoramic image is a surround image.

18. An apparatus for generating panoramic images comprising;

a lens assembly;

a light-sensitive detector to record images generated by the lens assembly;

a motor to rotate the lens assembly; and

a decoder to determine the orientation of the lens assembly when an image is recorded.

19. The apparatus of claim 18 further comprising a tilt actuator to tilt the lens assembly to a desired angle.

20. The apparatus of claim 19 further comprising an encoder to determine the amount of tilt of the lens assembly when the image is recorded

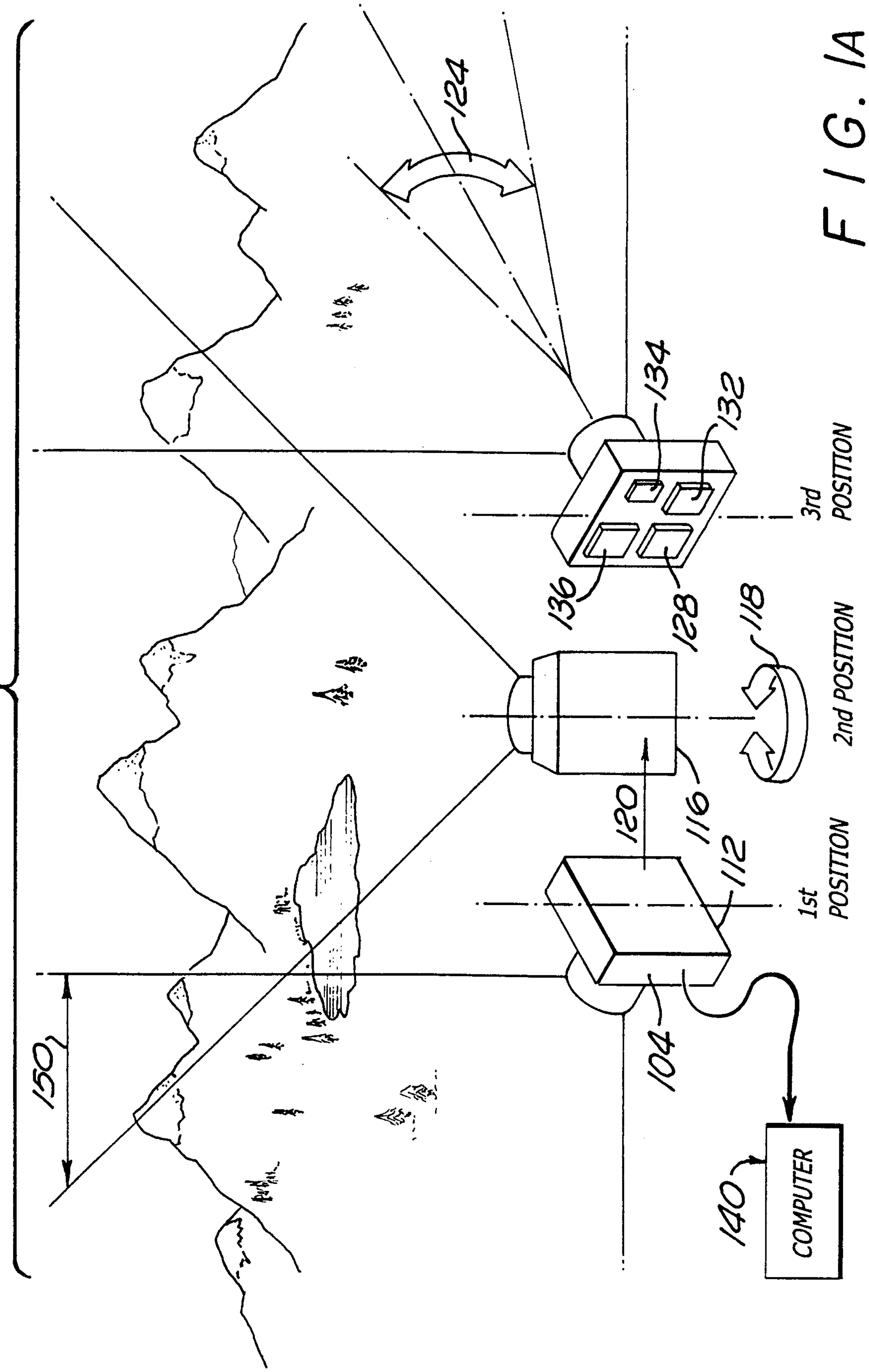

108
124
134
132
3rd POSITION
136
128
118
2nd POSITION
120
116
112
1st POSITION
150
104
140
COMPUTER

FIG. 1A

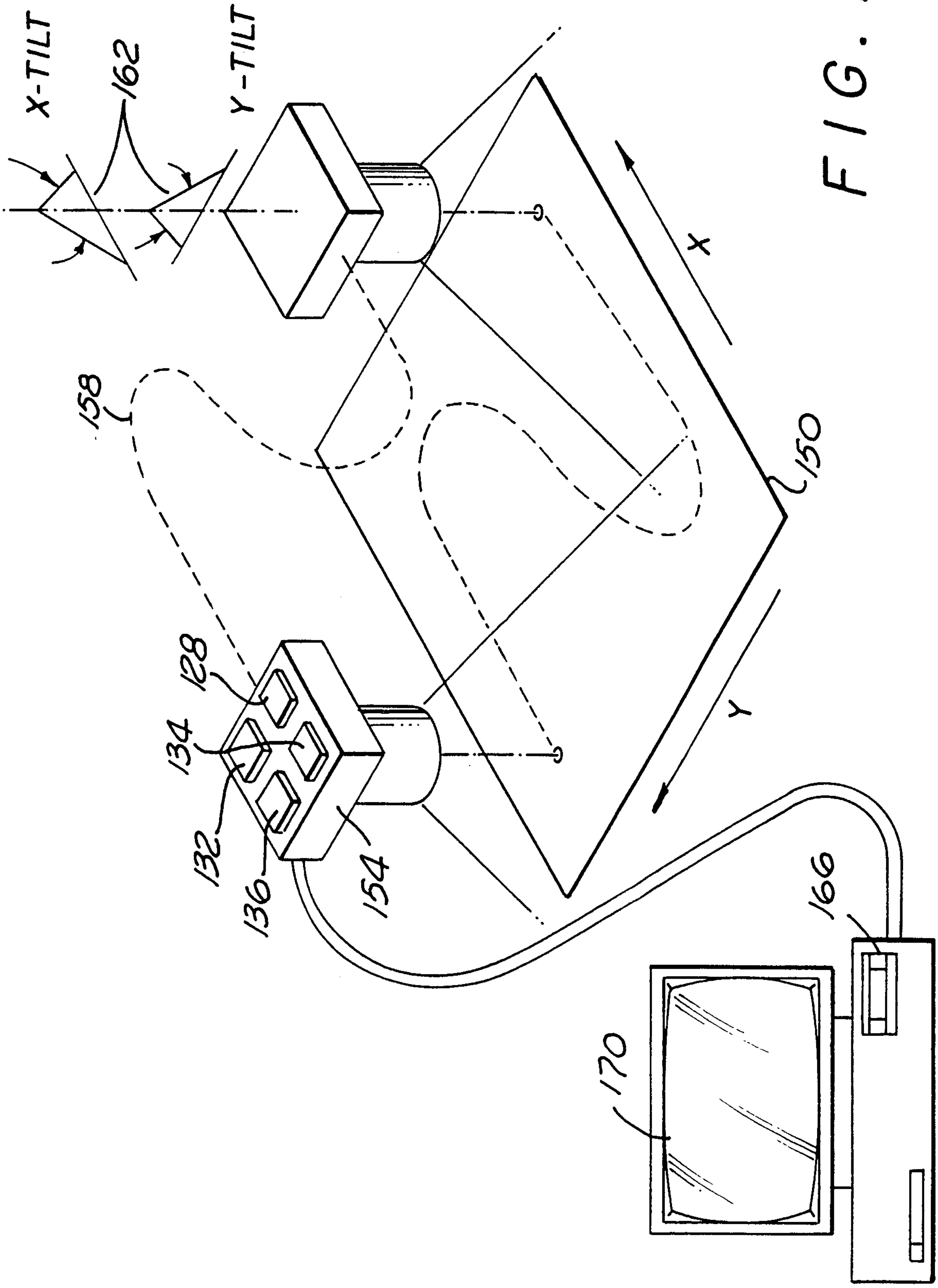


FIG. 1B

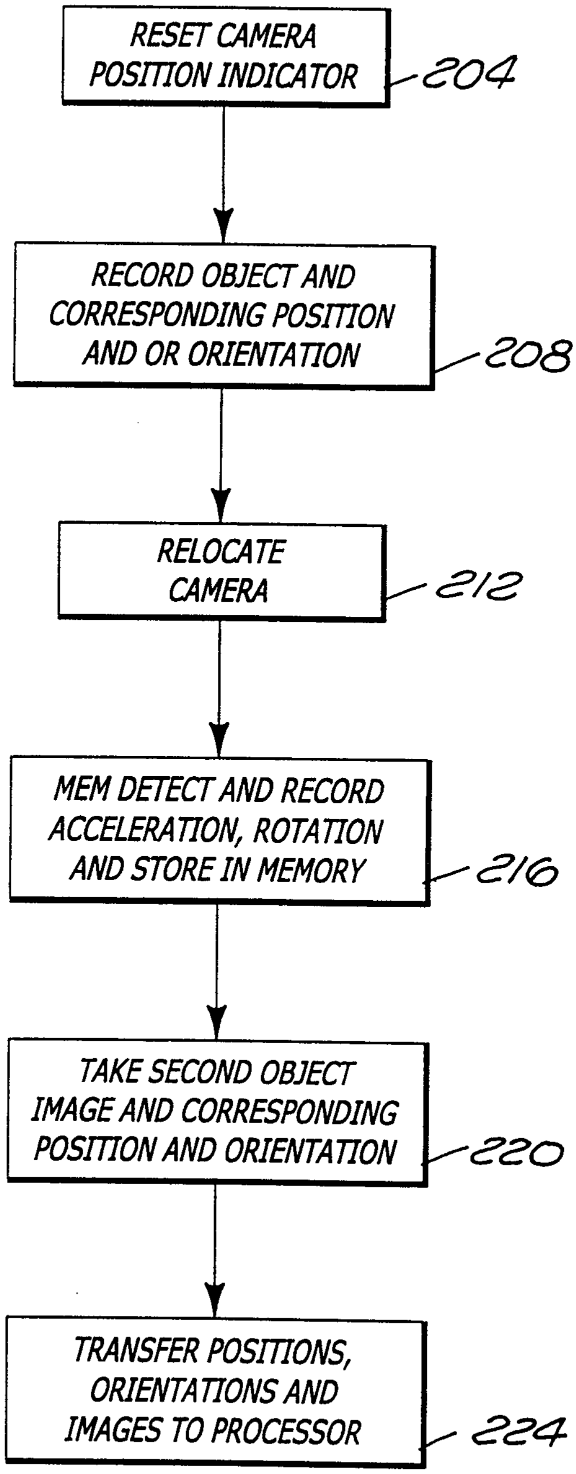

RESET CAMERA POSITION INDICATOR
204
RECORD OBJECT AND CORRESPONDING POSITION AND OR ORIENTATION
208
RELOCATE CAMERA
212
MEM DETECT AND RECORD ACCELERATION, ROTATION AND STORE IN MEMORY
216
TAKE SECOND OBJECT IMAGE AND CORRESPONDING POSITION AND ORIENTATION
220
TRANSFER POSITIONS, ORIENTATIONS AND IMAGES TO PROCESSOR
224

FIG. 2

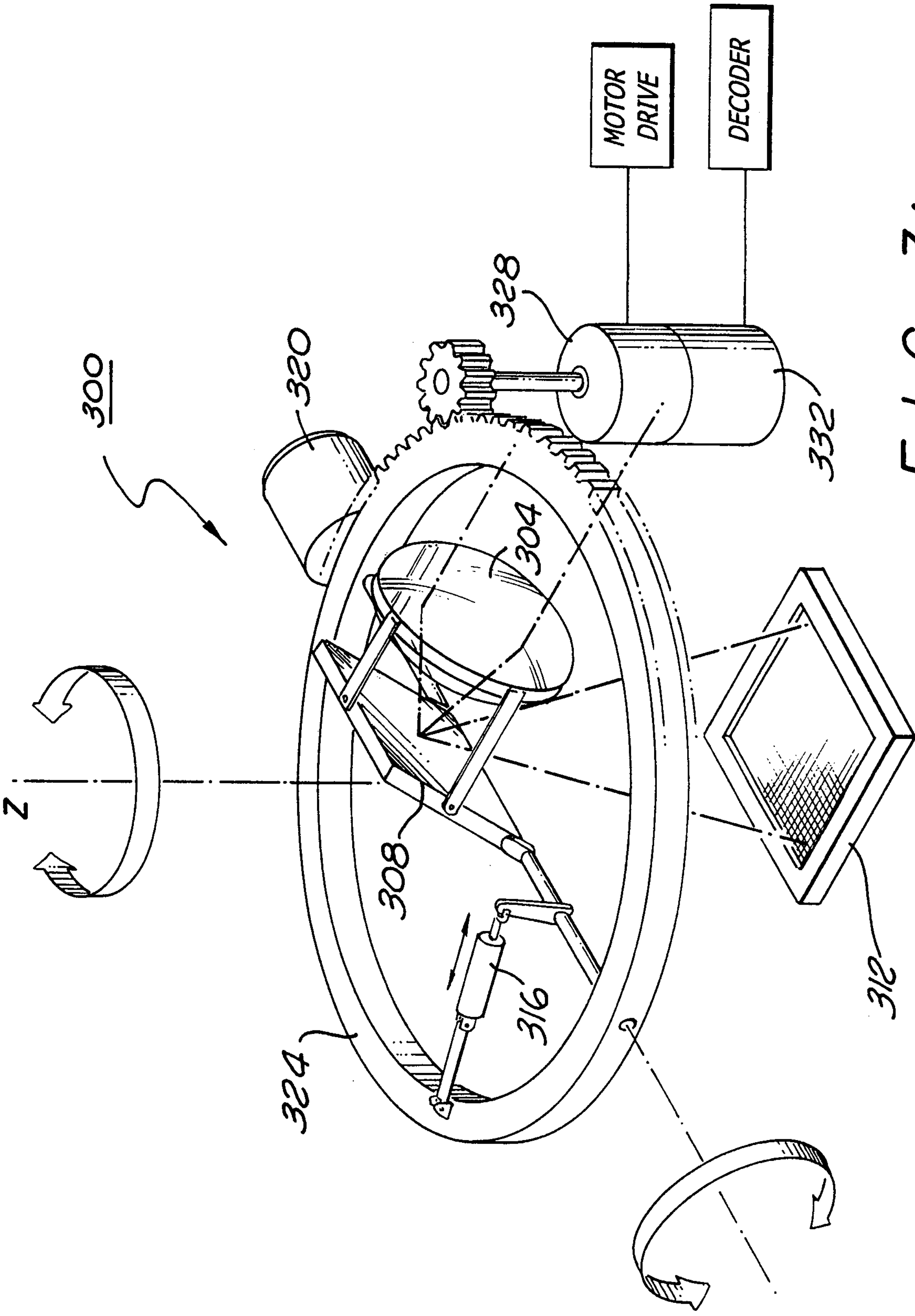


FIG. 3A

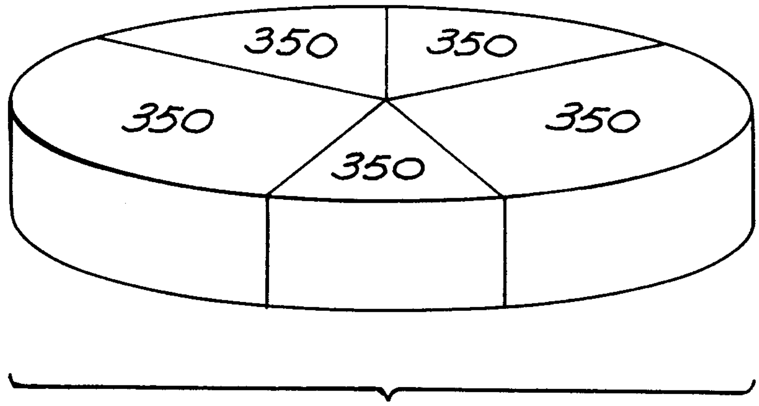


FIG. 3B

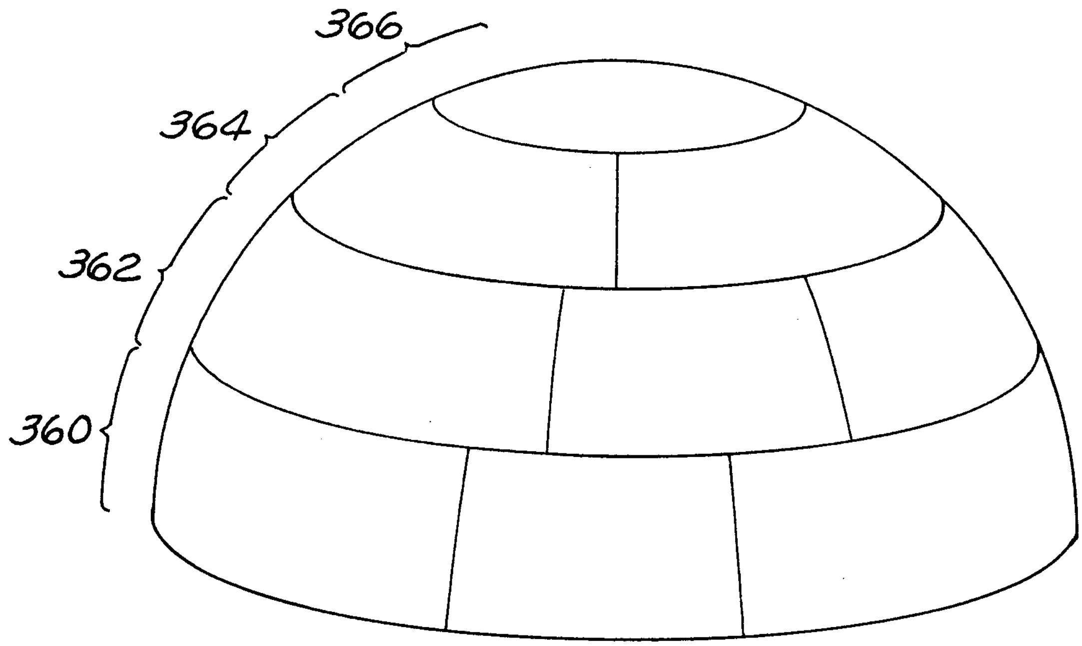


FIG. 3C

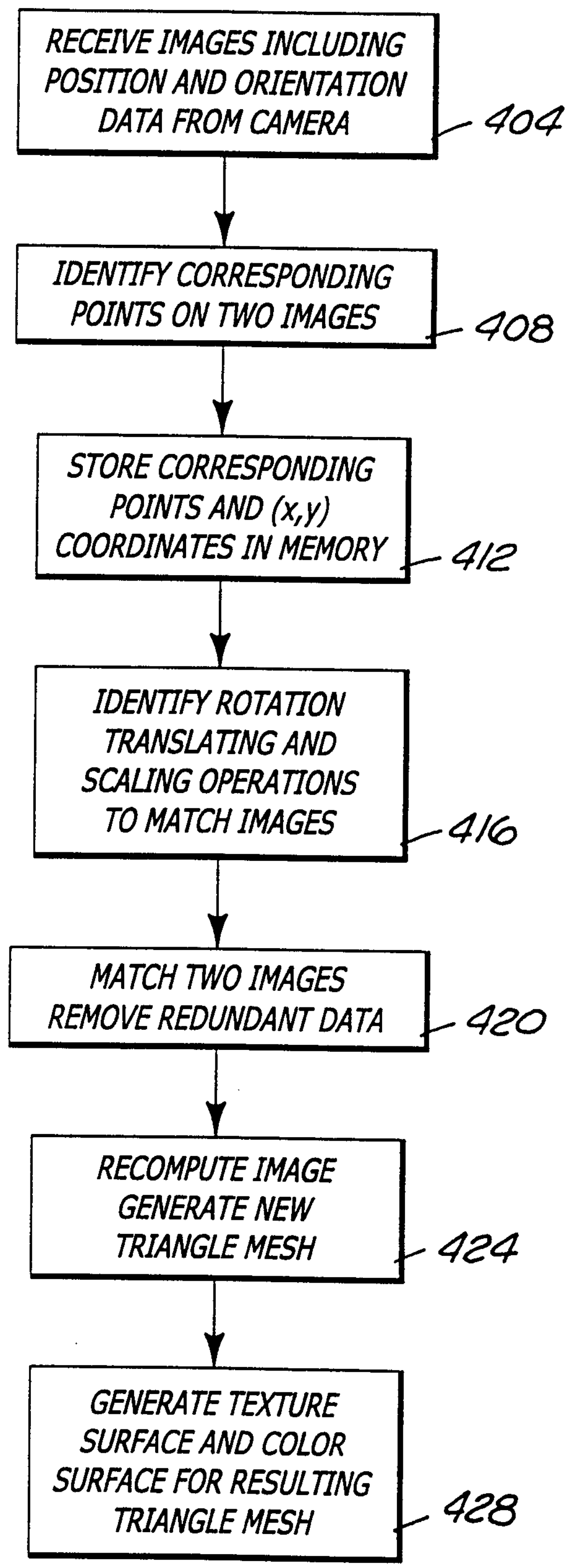

RECEIVE IMAGES INCLUDING POSITION AND ORIENTATION DATA FROM CAMERA
404
IDENTIFY CORRESPONDING POINTS ON TWO IMAGES
408
STORE CORRESPONDING POINTS AND (x,y) COORDINATES IN MEMORY
412
IDENTIFY ROTATION TRANSLATING AND SCALING OPERATIONS TO MATCH IMAGES
416
MATCH TWO IMAGES REMOVE REDUNDANT DATA
420
RECOMPUTE IMAGE GENERATE NEW TRIANGLE MESH
424
GENERATE TEXTURE SURFACE AND COLOR SURFACE FOR RESULTING TRIANGLE MESH
428

FIG. 4

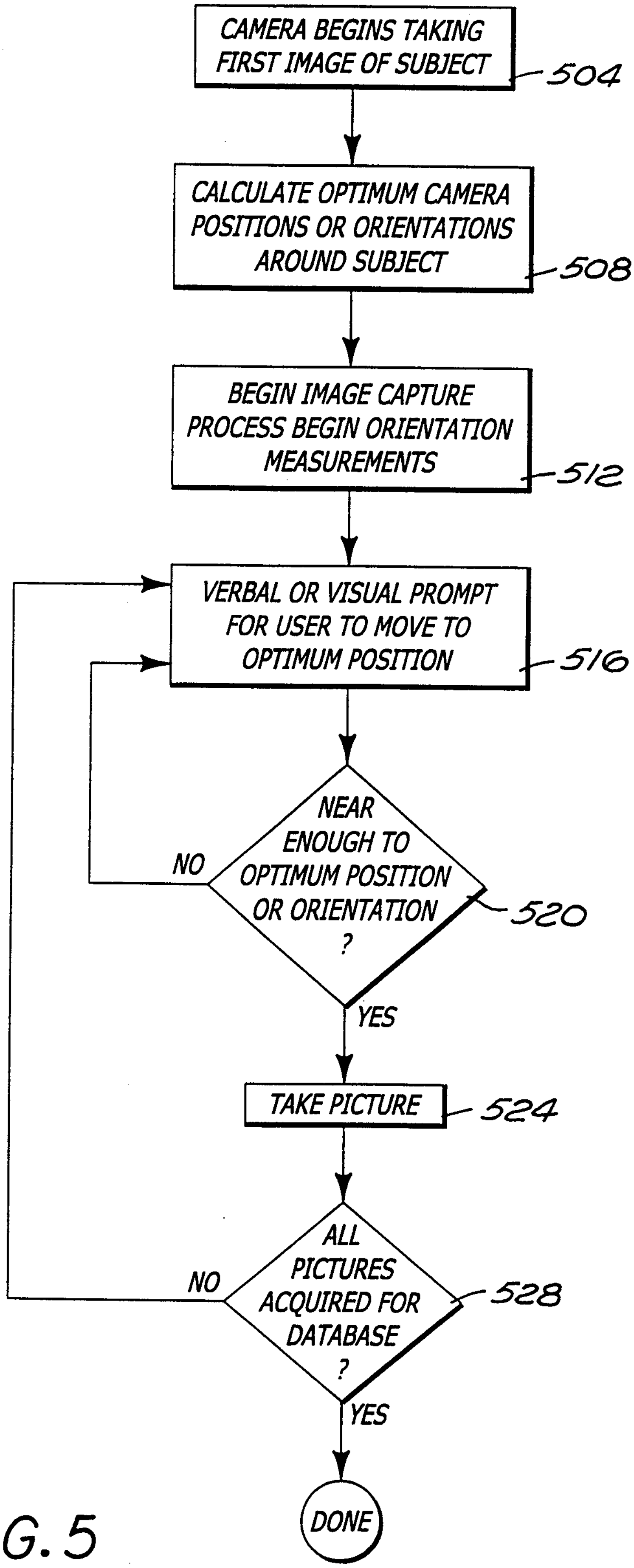

CAMERA BEGINS TAKING FIRST IMAGE OF SUBJECT
504
CALCULATE OPTIMUM CAMERA POSITIONS OR ORIENTATIONS AROUND SUBJECT
508
BEGIN IMAGE CAPTURE PROCESS BEGIN ORIENTATION MEASUREMENTS
512
VERBAL OR VISUAL PROMPT FOR USER TO MOVE TO OPTIMUM POSITION
516
NEAR ENOUGH TO OPTIMUM POSITION OR ORIENTATION ?
520
NO
YES
TAKE PICTURE
524
ALL PICTURES ACQUIRED FOR DATABASE ?
528
NO
YES
DONE

FIG.5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/05869

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04N 7/00, 5/76
US CL :348/39, 232
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)

U.S. : 348/36-39, 232

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

None.

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

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 4,895,431 A (TSUJIUCHI et al) 23 January 1990, Figs 1-2.	18-20 -------- 1-17
Y	US 5,262,867 A (KOJIMA) 16 November 1993, Fig. 6.	1-17
Y	US 5,659,195 A (KAISER et al) 19 August 1997, col. 1, lines 12-19.	2
Y	US 4,138,196 A (REDMAN) 06 February 1979, col. 2, lines 40-58.	4
Y	US 4,754,327 A (LIPPERT) 28 June 1988, col. 2, lines 6-18.	11

☐ 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 document 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 another 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
27 JULY 1999	20 AUG 1999

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	TOMMY P. CHIN
Facsimile No. (703) 305-3230	Telephone No. (703) 305-4715

Form PCT/ISA/210 (second sheet)(July 1992) ★