Abstract: A photogrammetric imaging system and method that includes a camera array of two or more cameras directed coplanarily at different angles for angular separation. A forward motion correction tiltable support to which the camera array is coupled is provided, adapted to be tilted at a predetermined time and angular velocity for compensating for blur caused by forward motion of a platform on which the system is mounted. A roll mechanism for rolling the camera array is provided, allowing sweeping-motion, and a lateral motion correction optical mechanism is also provided for lateral motion correction for each of the cameras compensating for the lateral roll.
AIRBORNE PHOTOGRAMMETRIC IMAGING SYSTEM AND METHOD

FIELD OF THE INVENTION

[0001] The present invention relates to an airborne photogrammetric imaging system and method and more particularly, to a photogrammetric imaging system and method for airborne imaging with panoramic sweep motion and having forward motion compensation and lateral sweeping motion compensation.

BACKGROUND OF THE INVENTION

[0002] To achieve a photogrammetric solution based on aerial images, at least two images from different view angles have to be recorded of the same object or terrain. Superimposing recorded images of an object or terrain requires precise knowledge of the flight motions of the camera platform. In addition to the change in position of the photography platform in the course of the flight, the yaw, roll and pitch motions of the aircraft lead to image-data that does not adjoin and fit accurately together. A solution for the problem of the positioning of the aircraft was found to be sensing the three spatial coordinates and three direction data of the camera at each point in time as precisely as possible by means of a combination of GPS (geographical positioning system) and INS (inertial navigation system). The spatial coordinates and direction data sensed at the instant of recording are associated with each terrain line, and the actual positions of the terrain lines are deduced from this data. Computerized image-processing enables the fitting of the images.

[0003] Solution for neutralizing the yaw, roll and pitch effects have also been developed, as is clarified later in the text.

[0004] Both planimetric and altimetric precision of the photogrammetric solution depend on angular resolution of a camera as well as on image scale and optical distortion correction accuracy. In addition, the altimetric precision improves with increase of the angular separation between the view angles.
[0005] The aforementioned factors suggest the optimal photogrammetric camera should use a large image format and a lens achieving the optimal balance between the field-of-view width and angular resolution.

[0006] The common standard in airborne film imaging was the use of large format photographic film. The film's large photosensitive area enables photographing a relatively wide-angle image at high angular resolution. The photography can be made from considerable altitudes by the use of a long focal length lens. Large stereo angle associated with the wide field-of-view facilitates accurate photogrammetry solution for terrain elevation map. Wide area coverage obtained at each photography flight leg minimizes the number of over flights required to collect data of an area of interest. Digital imaging arrays have CCD or CMOS photosensitive receptor areas that are substantially smaller than the standard film frame format. Thus, to achieve the comparable resolution and field-of-view, the photography altitude must be much lower and the focal length of the lens used much shorter. These considerations typically made impractical an application of a single fixed digital camera for photogrammetry purposes and a solution was found by the use of a cluster of fixed digital cameras mounted in a rigid case and aligned to provide a continuity of the integral field-of-view. An example of the use of a cluster of cameras is given in the presentation of Helmut Heier and Alexander Hinz from Z/hnaging GmbH in: A digital air borne camera system for photogrammetry and thematical applications, presented in 1999 at the Hanover meeting of the International Society for Photogrammetry and Remote Sensing (ISPRS). See also: Hinz, A., C. Dröstel, H. Heier (2000) Digital Modular Camera: System Concept and Data Processing Workflow. Archives of the Intl. Soc. For Photogrammetry and Remote Sensing, Vol. 33, Amsterdam, The Netherlands, 2000, and Franz Leberl and Michael Gruber Economical Large Format Aerial Digital Camera GIM International, The worldwide Magazine for Geomatics, June 2003.

[0007] The cluster camera systems are designed to provide integral field-of-view similar to one of a film-based mapping camera. However, because of the CCD format limitation this field-of-view is achieved by means of a shorter focal length lens, featuring coarser angular resolution. For this reason the common digital mapping camera systems should be applied at considerably lower flight altitudes to enable
photogrammetry precision comparable with the film cameras. The lower flight altitudes result in narrow width of the covered terrain strip in a single flight run. Therefore, more over flights are necessary over a given area of interest. As a result, much more aircraft flight hours are required, and the cost of the aerial mapping becomes substantially higher.

[0008] To partially overcome the inherent limitation of the small format Teuchert and Mayr in WO2000/066976A2 and Teuchert in US 6473119 describe photogrammetric camera cluster systems for airborne terrain photography that include several fixed-mounted cameras arranged at considerable angular separation from each other in the flight direction (each system tilted forward or rearward at a different and fixed angle from the horizontal of the aircraft), with no continuity of the fields-of-view. The electro-optical sensors scan the over flown terrain and record each scanned terrain-region at least twice from respectively different angles along the flight path. Such a configuration can achieve the desirable angular resolution. However, in the combination with the longer focal length optics the described systems give very limited across-track coverage (because of the small CCD format) in a direction that is perpendicular to the direction of flight.

[0009] There are known prior art solutions enabling wide across-track coverage to be achieved by a single, relatively small-format digital camera combined with a relatively long focal length lens. These solutions relate to a field of aerial reconnaissance cameras where information content of the imagery is a primary objective rather than precise photogrammetry. Particularly, US 5668593 (Lareau et al.) describes a digital airborne camera with the ability to broaden the photographed boundaries relatively to the aircraft's flight path by the use of a stepping mirror and a de-rotating prism mechanism for a panoramic coverage of the terrain. The camera applies step-framing combined with electronic on-detector forward motion compensation.

[0010] US 6658207 (Partynski et al.) describe an airborne camera that combines continuous rotation about roll axis with electronic motion compensation of the said roll rotation at a special electro-optical detector array. The electronic motion compensation is applied during a short time span of the detector's exposure (integration time). Successive overlapping frames of scene imagery are generated, by means of
synchronization of the detector exposure events with roll rotation angle of the camera. In addition, the camera applies a complex combination of a Cassegrain objective rotation and an azimuth mirror rotation (at a half of the objective rotation rate), to compensate for the aircraft forward motion.

[0011] In Teuchert in US 6473119 a photogrammetric system comprising an array of nine cameras, arranged in three groups of three coplanar cameras, was disclosed. One group of coplanar cameras is directed perpendicular (nadir) to the ground, whereas the other two groups of cameras are aimed sideways in a fixed angular position. In this setup each group of coplanar cameras is assigned a specific fixed strip along the flight path (see also Teuchert and Mayr in WO2000/066976A2, where a set-up of six cameras is disclosed).

[0012] It is a purpose of the present invention to provide a novel photogrammetric system that uses a set-up of a single coplanar group of cameras that covers a wide region across the terrain below the flight path of the aircraft carrying it.

SUMMARY OF THE INVENTION

[0013] There is thus provided, in accordance with some preferred embodiments of the present invention, a photogrammetric imaging system comprising:

[0014] a camera array comprising two or more cameras directed coplanarly at different angles for angular separation;

[0015] a forward motion correction tiltable support to which the camera array is coupled adapted to be tilted at a predetermined time and angular velocity for compensating for blur caused by forward motion of a platform on which the system is mounted;

[0016] a roll mechanism for rolling the camera array, allowing sweeping motion;

[0017] a lateral motion correction optical mechanism for lateral motion correction for each of the cameras compensating for the lateral roll.

[0018] Furthermore, in accordance with some preferred embodiments of the present invention, the lateral motion correction optical mechanism comprises a back scan mirror mechanism provided for each camera.
Furthermore, in accordance with some preferred embodiments of the present invention, the camera array comprises three cameras.

Furthermore, in accordance with some preferred embodiments of the present invention, the forward motion correction tiltable support comprises a platform mounted on a gimbal.

Furthermore, in accordance with some preferred embodiments of the present invention, the gimbal is inertially controlled by means of a closed-loop servo control with a gyroscope feedback sensor.

Furthermore, in accordance with some preferred embodiments of the present invention, the gimbal is adapted to be rotatable at a rate of \( V/R \) where \( V \) is ground speed of an aircraft the system is mounted on and \( R \) is slant range to an imaged target.

Furthermore, in accordance with some preferred embodiments of the present invention, the roll mechanism comprises roll gimbal.

Furthermore, in accordance with some preferred embodiments of the present invention, the system is further provided with an inertial orientation and navigation unit for precise measurement of geo-location, altitude and attitude of the camera array.

Furthermore, in accordance with some preferred embodiments of the present invention, the cameras comprise digital cameras.

Furthermore, in accordance with some preferred embodiments of the present invention, there is provided a photogrammetric imaging method comprising:

- providing a photogrammetric system comprising:
- an camera array comprising two or more cameras directed coplanarly at different angles for angular separation;
- a forward motion correction tiltable support to which the camera array is coupled;
- a roll mechanism for rolling the camera array, allowing sweeping motion;
- a lateral motion correction optical mechanism;
- mounting the photogrammetric imaging system on an airborne platform flying in a flight path over a terrain;
[0033] acquiring images by the cameras while simultaneously providing forward motion correction using the forward motion correction tiltable support at a predetermined time and angular velocity for compensating for blur caused by forward motion of a platform on which the system is mounted and corresponding to the altitude of the airborne platform with respect to the terrain, and simultaneously providing lateral motion correction using the a lateral motion correction optical mechanism compensating for the lateral roll.

[0034] Furthermore, in accordance with some preferred embodiments of the present invention, the lateral motion correction optical mechanism comprises a back scan mirror mechanism.

[0035] Furthermore, in accordance with some preferred embodiments of the present invention, the camera array comprises three cameras.

[0036] Furthermore, in accordance with some preferred embodiments of the present invention, the forward motion correction tiltable support is adapted to be rotatable at a rate of V/R where V is ground speed of the airborne platform the system is mounted on and R is a slant range to an imaged target.

[0037] Furthermore, in accordance with some preferred embodiments of the present invention, the method further comprises acquiring precise measurement of geo-location, altitude and attitude of the camera array for matching images acquired by different cameras of the same target object using an orientation and navigation unit for.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] In order to better understand the present invention, and appreciate its practical applications, the following Figures are provided and referenced hereafter. It should be noted that the Figures are given as examples only and in no way limit the scope of the invention. Like components are denoted by like reference numerals.

[0039] Fig. 1 illustrates a schematic view of a photogrammetric camera system, according to a preferred embodiment of the present invention.
Fig. 2A shows a three-dimensional view of a single scan taken by a photogrammetric camera system, according to a preferred embodiment of the present invention.

Fig. 2B depicts plane view of two adjacent scans taken by a photogrammetric camera system, according to a preferred embodiment of the present invention.

Fig. 3 shows the product of terrain coverage by three consecutive scans taken by a photogrammetric camera system, according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A main aspect of the present invention is the introduction of a novel airborne photogrammetric imaging system, which facilitates acquiring two or more images of the same object along a flight path and in across wide region of area perpendicular to the direction of flight path using a camera array of only three coplanar cameras.

In the present invention of an airborne photogrammetric imaging system and method, a panoramic sweep motion of a camera array is introduced having both a forward motion compensation system and lateral motion compensation system. The rolling sweeping motion of a cluster of fixed digital cameras mounted in a rigid case and aligned in the direction of advancement of an aircraft provide a novel and improved method and device for the efficient generation of a wide cross-track clear photogrammetric imaging while flying small number of flight runs.

The present invention is aimed at providing a photogrammetric camera system that is carried on an aircraft. A novel aspect of the present invention is camera array, comprising of three aligned cameras, each camera directed at a different direction of view along a fly path. The entire camera array is capable of rolling laterally in a pattern of bi-directional panoramic scan, so as to allow photographs to be taken not only vertically but also of a wide area on both sides of the aircraft's ground track. The system is also provided with mechanisms for forward motion compensation and lateral motion (roll) compensation, for enabling smear-less imaging.

In the present invention the cameras are mounted on an FMC gimbal (axis) mechanism, which in turn is installed inside a roll gimbal. The cameras are operated
simultaneously while continuously sweeping in a bi-directional panoramic scan rotation of the roll gimbal about the roll axis of the aircraft. As the cameras rotate about the roll axis in a continuous fashion, the potential smear related to the rotation is compensated for by a back-scan mirror system in each camera. The potential smear related to forward motion of the aircraft is compensated for by controlled rotation of the FMC gimbal mechanism at V/R rate (where V is ground speed of the aircraft and R is slant range to the target). The simultaneous compensation of the forward and roll motions enables high-resolution imagery to be generated without loss of resolution or blur of the photographed image. The camera system can be equipped with INS/GPS (Inertial Navigating System/Geographical Positioning System) device for precise measurement of the camera system's geo-location, altitude and attitude.

[0047] The system takes multiple frames during the panoramic scan, not only underneath the aircraft but also leftward and rightward of the aircraft's ground track. The substantial angular separation of the cameras in the vertical plane allows imaging of ground objects at frontward and rearward angles. The combination of the panoramic scan with the angular separation of the cameras enables multiple (at least twice) imaging of any object inside a wide ground strip at substantially different angles, facilitating an accurate photogrammetric solution based on the images. The INS/GPS geo-location, altitude and attitude readings associated with each frame further improve the accuracy and convergence speed of the photogrammetric solution. Thus, the present invention makes possible use of relatively long focal length digital cameras for mapping purposes, despite the CCD format being relatively small. As a result, the digital aerial survey can be performed at higher resolution. Alternatively, the mapping mission can be carried on from higher flight altitude, facilitating wider ground coverage on each imaging leg, decreasing the required flight time and the cost of the entire survey.

[0048] To correct for the image motion on the recording media caused by forward motion of the aircraft during the exposure interval in framing cameras several Forward Motion Compensation (FMC) techniques exist that are well known. In addition, the lateral-to-the-flight-direction scan rotation of cameras adds another smear factor that is addressed by various lateral scan compensation techniques. Compensation can be introduced by moving the film or the lens to keep the image stationary while the
exposure is taking place. In a film framing camera, the compensation is usually accomplished by moving the film to match the rate of image motion. Lareau et al. describe an electro-optical step frame camera system in which the forward motion compensation is achieved electronically in the focal plane of the electro-optical detector. The use of rotatable mirrors for FMC function, as described by Teuchert in US 6473119, is also known and used. The use of an electronic lateral scan compensation mechanism and a mechanical FMC by adjusted simultaneous rotation of the Cassegrain objective and azimuth mirror is specified in US 6658207 by Partynski et al.

[0049] Reference is now made to the figures in order to explain the present invention.

[0050] Fig. 1 illustrates a schematic view of a photogrammetric camera system, according to a preferred embodiment of the present invention.

[0051] A photogrammetric camera system according to a preferred system of the present invention, denoted by general numeral 10, comprises a casing 12 in which three imaging sensors 18, 20 and 22, such as, but not limited to, CCD cameras, are arranged in an aligned arrangement, along the anticipated flight path, directed at different angles of view. The cameras are fixed to support 34, such that their relative orientation is kept fixed. The casing 12 is pivotally connected by roll gimbal 15 so as to allow axial rotation about axis 14. Casing 12 is provided with an opening 36, to allow the cameras viewing outside the casing. The roll gimbal performs bi-directional panoramic scan. During each scan swath, the gimbal rotation is continuous one; no step-and-stare is required. The support 34 is pivotally connected by FMC gimbal 16 to the casing 12. The FMC gimbal 16 rotates backwards during the roll scan, and performs a return forward rotation in a dead time span when the roll gimbal changes its scan direction. Both the roll and FMC gimbals are inertially controlled by means of a closed-loop servo control with a gyroscope feedback sensor, and thus isolate the cameras from the roll and pitch angular perturbations of the aircraft platform. The preferred configuration includes 3 cameras, but in general it could be 2 or more. An Inertial Navigation System (INS) 38, is preferably integrated into the imaging system. The camera type selected for incorporation with the system of the present invention has preferably an area imaging sensor which provides images of high geometric fidelity in a format which is easily compatible with the existing photogrammetric analysis techniques.
Casing 12 can roll laterally, perpendicular to the direction of flight, allowing the camera array to cover areas on either side of the path just beneath the aircraft.

Casing 12 sweeps across predetermined angles on either side of the perpendicular to the ground over which the aircraft flies. The sweeping motion is made possible by a roll gimbal 15, and is activated by an electrical motor. It is desirable to allow sweeping motion that covers imaging of at least 20 to 40 degrees in both sides of the perpendicular to the ground beneath the aircraft and roll gimbal should therefore be made to allow such sweeping angles.

As acquisition of image data by the camera array is subjected to lateral scan motion, lateral motion compensation is required. For that aim the cameras 18, 20, 22 are each provided with a back scan mirror 24, 26 and 28, for lateral correction. Other alternative lateral correction mechanisms may also be employed, for example a prism mechanism. The lateral correction is achieved by tilting the back-scan mirrors in a direction opposite to the direction of roll, and in an angular velocity that compensates for the angular velocity of the roll.

As the casing 12 sweeps laterally, the mirrors tilt in the opposite direction of the sweeping motion during integration time span of the detectors. When the integration time span is completed the mirrors resume their initial position ready for the next integration. The tilt axis of each back scan mirror is parallel to the roll gimbal axis, for the optimal motion compensation in the whole field-of-view of each camera.

An Inertial Navigation System (INS) is preferably augmented by embedded Geographical Positioning System (GPS) or Differential GPS (DGPS) receiver. This EMS/(D)GPS provides accurate measurements of longitude, latitude, altitude and angular attitude of the camera system during image acquisition. The measurements enable precise geo-referencing of each image, and facilitate effective solution of large photogrammetric model based on a large number of individual image frames.

A replaceable filter 32 can be placed in each of the cameras so as to adjust spectral band recorded by the cameras.

Fig. 2A, 2B and 3 illustrate a schematic demonstration of the operation of a photogrammetric camera system 10, according to a preferred embodiment of the present
invention. The following simplifications were made to the figures for facilitating of the illustration clearness:

[0059] 1) A cross-track coverage is shown as containing three frames.

[0060] 2) Footprint of the scans and frames is shown as straight and rectangular frames taken by the forward and backward-oriented cameras (18 and 22) are shown as of the same ground width as one taken by the central camera 20.

[0061] 3) Angular separation between the adjacent cameras is shown as equal to two fields-of-view of an individual camera.

[0062] 4) Overlap between the adjacent frames (both in forward and lateral directions) is not shown.

[0063] Real photogrammetric system accordingly to the present invention may have different angular separation between the adjacent cameras, may scan larger or smaller across-track angle compared with the three frames and typically applies some overlap between the adjacent frames. Because of the perspective geometry, frames taken by the forward and backward-oriented cameras have somewhat enlarged footprint and some curvature. The simplifications at the figures are not principal and were made only for facilitation of the illustration clearness.

[0064] Fig 2A shows a three-dimensional view of a single scan taken by a photogrammetric camera system 10 according to a preferred embodiment of the present invention. Three cameras, 18, 20 and 22 photograph simultaneously the terrain below in a wide path along both sides of an advancing aircraft. A set of three separate strips of images, 42, 44 and 46 are obtained in a single panoramic scan sweep. The number of images acquired per single sweep may vary and is not limited to three images, as demonstrated in the example in Fig 2B. As the aircraft ground track advances 40, the consecutive scan creates another set of three strips, adjacent to the previous set with a forward overlap.

[0065] As shown in Fig 2A in each scan several image frames are taken. A detailed explanation of the scanning paths is given in Fig. 2B in which an example of the footprint of a single frame is designated 67 and the center point of the frame is marked by an enlarged point designated as 66. The center points of all the rest of the frame in Fig. 2B are designated by an enlarged point not numbered.
Fig. 2B depicts plane view of two adjacent scans taken by a photogrammetric camera system, according to a preferred embodiment of the present invention. The photogrammetric cameras 18, 20 and 22, scan stripes 46, 44 and 48 simultaneously, respectively, in a single sweep. As the aircraft advances the photogrammetric camera system sweeps in the opposite direction and cameras 18, 20 and 22 scan consecutive strips, designated 52, 50 and 48, respectively.

Designated in Fig. 2 lines 72, 76 and 80 indicate the direction of number n scan of the three cameras 18, 20 and 22 respectively. Lines 74, 78 and 82 indicate the direction of the consecutive scan, the n+1 scan, of each of the three cameras 18, 20 and 22 respectively. On reaching the end of each scan and prior to proceeding with the consecutive scan the FMC gimbal returns simultaneously with the reversal of the scan gimbal in each of the cameras.

Illustrated in Fig. 2 for only camera 20 but occurs simultaneously in cameras 18 and 22 as well, at the location designated 60 the aircraft is at the start of photographing the n-th scan. By the time the scan of the camera is complete, indicated by scan line 76, the aircraft is at location designated 62. To prepare for the consecutive scan, n+1, the FMC gimbal returns to the starting position and the scan gimbal reverses, as indicated by path 64 in the figure. The camera is now ready to scan along line 78. On reaching the end of the scan the FMC gimbal return and scan gimbal reversal procedures are repeated. The change in location of the aircraft during the scanning of the n+1 image along scan line 78 is given by locations indicated 63 and 69.

In this manner, a wide strip centered about the aircraft's ground path is completely covered by the images. Each object at the terrain is photographed three times, by the forward-oriented, downward-oriented and backward-oriented cameras. The controlled rotation of the FMC gimbal enables alignment of the ground path of the images taken by the central camera in a straight line. The angular separation between the cameras creates the required stereo angle facilitating the accurate photogrammetry. The typical angular separation between the adjacent cameras can be about 15°; combined with the typical 5° of each camera's field-of-view this gives the total 40° along-track angle which is comparable with the 43° along-track coverage angle of a classical wide-format film camera equipped with a 12-inch lens.
By the means of forward motion compensation and lateral scan compensation, the present invention generates sharp, un-blurred images without the requirement of the expensive and complex on-detector electronic image motion compensation.

Fig. 3 illustrates the product of terrain coverage by consecutive scans after some forerun, triple coverage for each point of the mapped area is achieved by forward-oriented, downward-oriented and backward-oriented cameras.

Seen in Fig. 3 is an illustration of the overlap of the photographed terrain (mapped area) as manifested by the photography of a certain a strip of land by the three cameras of the present invention, as seen in Fig. 1. An area-strip receiving a single coverage 84, taken by a single camera (camera 18) is designated by the arrowed boundaries marked as: a. A strip with double coverage 86, taken by two cameras (cameras 18 and 20) designated by the arrowed boundaries marked as: b, and a strip with triple coverage 88, taken by three cameras (cameras 18, 20 and 22) designated by the arrowed boundaries marked as: c.

The system can be fitted with relatively long focal length lenses, allowing the mapping mission to be flown at a considerable flight altitude. Particularly, a typical focal length can be about 400 mm, providing 7,500 photo scale when flying at 3.0 km altitude above the terrain. Note that the photogrammetric camera system of the present invention is not limited to use in this altitude only and can be used at other altitudes as well. A 3.0 km-wide strip can be covered in this scenario when flying at ground speed of 200 knots and operating 36x24 mm - format detectors at 4.5 frames-per-sec. The classic wide-format film-based mapping camera with 12-inch focal length lens enables the same photo scale from a comparable 2.3 km altitude and covers 1,900 m — wide strip. For comparison, at the same photo scale a typical quad-cluster fix-mounted digital mapping camera with 80 mm lens forces flying as low as 600 m and covers only 560 m strip. Therefore, the present invention requires only one-sixth of the flight legs to be flown in order to map the same terrain area, resulting in substantial time saving and cost decrease of the mapping mission. Moreover, the higher flight altitude improves the flight safety and lessens the noise disturbance sensed at the ground.

The present invention provides an improved electro-optical wide angle sweeping photogrammetric camera system which is capable of generating sharp scene imagery
without blur due to two motion compensation systems working simultaneously: a mechanical gimbal axis system for the forward motion compensation and opto-mechanical back scan mirror compensation for the smear caused by the perpendicular sweeping motion of the cameras.

[0075] The image data obtained using the photogrammetric camera system of the present invention can be processed using known processing techniques to obtain the desired photogrammetric solution for orthophoto and elevation map.

[0076] It should be clear that the description of the embodiments and attached Figures set forth in this specification serves only for a better understanding of the invention, without limiting its scope.

[0077] It should also be clear that a person skilled in the art, after reading the present specification could make adjustments or amendments to the attached Figures and above described embodiments that would still be covered by the present invention.
CLAIMS

1. A photogrammetric imaging system comprising:
   a camera array comprising two or more cameras directed coplanarly at different angles
   for angular separation;
   a forward motion correction tiltable support to which the camera array is coupled
   adapted to be tilted at a predetermined time and angular velocity for compensating for
   blur caused by forward motion of a platform on which the system is mounted;
   a roll mechanism for rolling the camera array, allowing sweeping motion;
   a lateral motion correction optical mechanism for lateral motion correction for each of
   the cameras compensating for the lateral roll.

2. The system of claim 1, wherein the lateral motion correction optical mechanism
   comprises a back scan mirror mechanism provided for each camera.

3. The system of claim 1, wherein the camera array comprises three cameras.

4. The system of claim 1, wherein the forward motion correction tiltable support
   comprises a platform mounted on a gimbal.

5. The system of claim 4, wherein the gimbal is inertially controlled by means of a
   closed-loop servo control with a gyroscope feedback sensor.

6. The system of claim 4, wherein the gimbal is adapted to be rotatable at a rate of
   V/R where V is ground speed of an aircraft the system is mounted on and R is slant
   range to an imaged target.

7. The system of claim 1 wherein the roll mechanism comprises roll gimbal.
8. The system of claim 1, further provided with an inertial orientation and navigation unit for precise measurement of geo-location, altitude and attitude of the camera array.

9. The system of claim 1, wherein the cameras comprise digital cameras.

10. A photogrammetric imaging method comprising:
    providing a photogrammetric system comprising:
        a camera array comprising two or more cameras directed coplanarly at different angles for angular separation;
        a forward motion correction tiltable support to which the camera array is coupled;
        a roll mechanism for rolling the camera array, allowing sweeping motion;
        a lateral motion correction optical mechanism;
    mounting the photogrammetric imaging system on an airborne platform flying in a flight path over a terrain;
    acquiring images by the cameras while simultaneously providing forward motion correction using the forward motion correction tiltable support at a predetermined time and angular velocity for compensating for blur caused by forward motion of a platform on which the system is mounted and corresponding to the altitude of the airborne platform with respect to the terrain, and simultaneously providing lateral motion correction using the a lateral motion correction optical mechanism compensating for the lateral roll.

11. The method of claim 10, wherein the lateral motion correction optical mechanism comprises a back scan mirror mechanism.
12. The method of claim 10, wherein the camera array comprises three cameras.

13. The method of claim 10, wherein the forward motion correction tiltable support is adapted to be rotatable at a rate of V/R where V is ground speed of the airborne platform the system is mounted on and R is a slant range to an imaged target.

14. The method of claim 10, wherein the roll mechanism comprises roll gimbal.

15. The method of claim 10, further comprising acquiring precise measurement of geo-location, altitude and attitude of the camera array for matching images acquired by different cameras of the same target object using an orientation and navigation unit for.

16. The method of claim 10, wherein the cameras comprise digital cameras.
Fig. 2B
**INTERNATIONAL SEARCH REPORT**

A. CLASSIFICATION OF SUBJECT MATTER

INV. GOIC11/02 GOIC11/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. RELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

GOIC

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>WO 03/102505 A (RAFAEL ARMAMENT DEV AUTHORITY [IL]; GREENFELD ISRAEL [IL]; YAVIN ZVI [IL] 11 December 2003 (2003-12-11) paragraph 1; page 19, paragraph 1 - page 60, last paragraph; figures 1-5</td>
<td>1-16</td>
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<td>Y</td>
<td>WO 00/66976 A (TEUCHERT WOLF D [DE]; MAYR WERNER [DE]) 9 November 2000 (2000-11-09) cited in the application the whole document</td>
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<td>A</td>
<td>US 6 658 207 B1 (PARTYNSKI ANDREW J [US] ET AL) 2 December 2003 (2003-12-02) cited in the application column 3, line 40 - column 28, line 14; figures 1-4</td>
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**X** Further documents are listed in the continuation of Box C. **X** See patent family annex.

Date of the actual completion of the international search

21 April 2008

Date of mailing of the international search report

29/04/2008

Name and mailing address of the ISA/

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Fax: (+31-70) 340-3016

Authorized officer

Springer, O liver
### DOCUMENTS CONSIDERED TO BE RELEVANT

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