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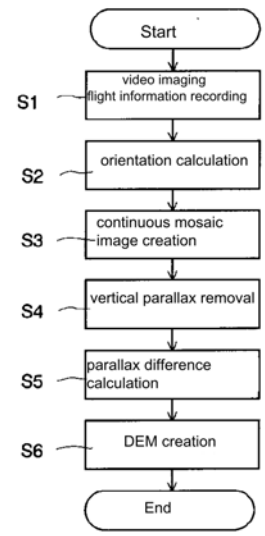
(54) **[Title of invention]** Three-Dimensional Data Extraction Method and Device, and Stereo Image Forming Device

(57) **[Abstract]**

**[Object]** To create DEM data from video images.

**[Constitution]** Video images are taken of a target region from the air (S1). At this time, the camera position is measured by way of differential GPS. The camera is mounted on an anti-vibration device, and the orientation of the camera is measured precisely by way of gyroscope output and magnetic bearing sensor output thereof. Exterior orientation elements are determined accurately by matching fields in video images that overlap 60% (S2). The leading line, middle line, and final line of each field are extracted, and are separately combined to create continuous mosaic images consisting of a forward view image, a nadir view image and a rearward view image (S3). The vertical parallax is removed from the continuous mosaic images (S4). The parallax difference is calculated from the forward view image and the rearward view image (or the nadir view image) (S5), and the height is calculated from the parallax difference (S6).



**[Claims]**

**[Claim 1]** A three-dimensional data extraction method comprising: a basic information collection step of imaging a three-dimensional data extraction target while moving, recording that image signal, and recording imaging information including the position and orientation of the imaging camera; and a three-dimensional data generation step of generating three-dimensional data for said extracted object from the images and imaging information collected in said basic information collection step,

the three-dimensional data extraction method being characterized in that said three-dimensional data generation step comprises:

a continuous mosaic image generation step of extracting image data of prescribed lines in prescribed screens in consecutive screens of captured images, and generating at least two continuous mosaic images from among a forward view image, a nadir view image, and a rearward view image;

a vertical parallax removal step of removing vertical parallax from the continuous mosaic images generated in said continuous mosaic image generation step,

a parallax difference calculation step of calculating the parallax difference for a prescribed position in the continuous mosaic images from which vertical parallax was removed in said vertical parallax removal step; and

a height calculation step of calculating the height of said prescribed position from the parallax difference calculated in said parallax difference calculation step.

**[Claim 2]** The three-dimensional data extraction method recited in claim 1, further comprising an orientation calculation step of establishing, by way of relative orientation and successive orientation, exterior orientation elements from consecutive screens of captured images.

**[Claim 3]** The three-dimensional data extraction method recited in claim 2, wherein said orientation calculation step comprises: a relative orientation step of extracting, from consecutive screens of captured images, two screens that overlap in a prescribed proportion and performing relative orientation; and a successive orientation step of associating models that have been relatively oriented by said relative orientation step.

**[Claim 4]** The three-dimensional data extraction method recited in claim 3, wherein said prescribed proportion is 60%.

**[Claim 5]** The three-dimensional data extraction method recited in any one of claims 2 to 4, wherein said vertical parallax removal step comprises: an exterior orientation element interpolation step of interpolating exterior orientation elements for each line of the continuous mosaic images generated in said continuous mosaic image generation step, in accordance with the exterior orientation elements determined in said orientation calculation step; and a projection step of transforming the lines of the continuous mosaic images generated in said continuous mosaic image generation step into images projected to a prescribed altitude in accordance with the exterior orientation elements of said lines.

**[Claim 6]** The three-dimensional data extraction method recited in any one of claims 1 to 5, wherein said parallax difference calculation step comprises: an intermediate image formation step of forming one or more intermediate images between said continuous mosaic images; a corresponding point detection step of going through said one or more intermediate images and detecting corresponding points in said continuous mosaic images; and a computation step of calculating the parallax difference of said corresponding points in accordance with the detection results of said corresponding point detection step.

**[Claim 7]** The three-dimensional data extraction method recited in claim 6, wherein said intermediate image formation step extracts image data of intermediate lines in prescribed screens in consecutive screens of captured images, and forms said intermediate image.

**[Claim 8]** The three-dimensional data extraction method recited in any one of claims 1 to 7, wherein a GPS reception means is provided as a means for detecting the position of said camera.

**[Claim 9]** The three-dimensional data extraction method recited claim 8, wherein a correction means that differentially corrects the output of the GPS reception means is further provided.

**[Claim 10]** The three-dimensional data extraction method recited in any one of claims 1 to 9, wherein said camera is prevented from vibrating by an anti-vibration means.

**[Claim 11]** A three-dimensional data extraction device characterized by comprising: a video camera that images a three-dimensional data extraction target; a position measurement means that measures the position of said video camera; a recording means that records images captured by said video camera and measurement values of said position measurement means; a conveyance means that conveys said video camera and said position measurement system [*sic*]; a reproduction means that reproduces the image information and position information recorded by said recording means; a continuous mosaic image generation means that extracts image data of prescribed lines in prescribed screens in consecutive screens of captured images, and generates at least two continuous mosaic images from among a forward view image, a nadir view image, and a rearward view image; a vertical parallax removal means that removes vertical parallax from the continuous mosaic images generated by said continuous mosaic image generation means; a parallax difference calculation means that calculates parallax difference in continuous mosaic images from which vertical parallax has been removed by said vertical parallax removal means; and a height calculation means that calculates the height of said [*sic*] prescribed position from the parallax difference calculated by said parallax difference calculation means.

**[Claim 12]** The three-dimensional data extraction device recited in claim 11, further comprising an orientation calculation means that establishes, by way of relative orientation and successive orientation, exterior orientation elements from consecutive screens of captured images.

**[Claim 13]** The three-dimensional data extraction device recited in claim 12, wherein said orientation calculation means provides: a relative orientation step of extracting, from consecutive screens of captured images, two screens that overlap in a prescribed proportion and performing relative orientation; and a successive orientation step of associating models that have been relatively oriented by said relative orientation step.

**[Claim 14]** The three-dimensional data extraction device recited in claim 13, wherein said prescribed proportion is 60%.

**[Claim 15]** The three-dimensional data extraction device recited in any one of claims 12 to 14, wherein said vertical parallax removal means comprises an exterior orientation element interpolation means that interpolates exterior orientation elements in each line of the continuous mosaic images generated by said continuous mosaic image generation means, in accordance with the exterior orientation elements determined by said orientation calculation means; and a projection means that transforms the lines of the continuous mosaic images generated by said continuous mosaic image generation means into images projected to a prescribed altitude in accordance with the exterior orientation elements of said lines.

**[Claim 16]** The three-dimensional data extraction device recited in any one of claims 11 to 15, wherein said parallax difference calculation means comprises: an intermediate image formation means that forms one or more intermediate images between said continuous mosaic images; a corresponding point detection means that goes through said one or more intermediate images and detects corresponding points in said continuous mosaic images; and a computation means that calculates the parallax difference of said corresponding points in accordance with the detection results of said corresponding point detection means.

**[Claim 17]** The three-dimensional data extraction device recited in claim 16, wherein said intermediate image formation means extracts image data of intermediate lines in prescribed screens in consecutive screens of captured images, and forms said intermediate image.

**[Claim 18]** The three-dimensional data extraction device recited in any one of claims 11 to 17, wherein said position measurement means is a GPS reception means.

**[Claim 19]** The three-dimensional data extraction device recited in claim 18, further comprising a correction means that differentially corrects the output of the GPS reception means.

**[Claim 20]** The three-dimensional data extraction device recited in any one of claims 11 to 19, wherein said camera is mounted on said conveyance means via an anti-vibration means.

**[Claim 21]** The three-dimensional data extraction device recited in any one of claims 11 to 20, wherein said conveyance means is an aircraft.

**[Claim 22]** The three-dimensional data extraction device recited in any one of claims 11 to 21, further comprising a bearing detection means that detects the bearing of said camera, wherein the output of said bearing detection means is also recorded in said recording means.

**[Claim 23]** The three-dimensional data extraction device recited in any one of claims 11 to 22, wherein said camera is disposed so that the direction of travel of said conveyance means is a direction that is perpendicular to the direction of the scan lines of the camera.

**[Claim 24]** A stereo image formation device characterized by comprising: an extraction means that extracts line image data, at two or more different prescribed line positions in screens, in a video captured image; and a combining means that combines line image data from the same line positions.

**[Claim 25]** The stereo image formation device recited in claim 24, further comprising a vertical parallax removal means that removes vertical parallax from the images combined by said combining means, based on exterior orientation elements of each of the line image data on which [the images] are based.

**[Detailed Description of the Invention]**

**[0001]**

**[Field of Industrial Application]** The present invention relates to a method and a device for three-dimensional data extraction, and to a stereo image formation device; more specifically, it relates to a method and device for extracting three-dimensional data from video images, and to a stereo image formation device that forms stereo images from video images.

**[0002]**

**[Prior Art]** Conventionally, aerial survey technology based on aerial photographs has been used in creating three-dimensional topographical maps. But aerial survey technology involves having a helicopter or light airplane fly above a locality while taking stereoscopic photographs of the ground, and analyzing the resulting stereo photographs; obtaining stereographic photographs alone requires a great deal of time and expense, and analysis of the same likewise entails enormous effort and expense. If three-dimensional measurement is done by stereo matching using aerial photographs taken from a low altitude, matching errors will occur due to the influence of occlusion. This is because the two images that form a stereo image are seen from different viewing directions, and differences in the image due to differences in the observation direction make perfect matching impossible. In conventional cases, attempts have been made to eliminate such influence by using multiple orientation points on the ground, but with this, automation is impossible.

**[0003]**

**[Problems to Be Solved by the Invention]** In contrast, it is easy to automate the technology using video images to create topographical maps. But in the prior art, in extracting photographic three-dimensional data, in the same way as in an aerial survey, it is considered necessary to have several air-photo signal points in the image (signals for which clear three-dimensional coordinates are known), and even if the necessary number of air-photo signals are assured, the errors will be of poor precision, which is in meter units, making this impractical.

**[0004]** Three-dimensional topographical maps are useful for the management of roads, rivers, railroads, and the like, and for planning new routes for the same and surveying the state of development of cities and the like; there is a demand for a system that makes it possible to acquire three-dimensional topographical data quickly, cheaply, and simply. If three-dimensional topographical data is available, bird's-eye views can also be created easily (shown on a display or output on a printer), and various simulations can be run. And if three-dimensional data can be obtained by processing video images, it will also be easy to extract just the parts that have changed, thus also making it easy to survey the state of development of cities and the like.

**[0005]** An object of the present invention is to propose a three-dimensional data extraction method and device, which extract three-dimensional data automatically.

**[0006]** Another object of the present invention is to propose a three-dimensional data extraction method and device, which extract three-dimensional data from video images.

**[0007]** Another object of the present invention is to propose a stereo image formation device that forms stereo images (two images suitable for stereo matching) from video images.

**[0008]**

**[Means for Solving the Problems]** In the present invention, image data of prescribed lines of video images are extracted, and continuous mosaic images having different parallax are formed. After vertical parallax is removed from these continuous mosaic images, the parallax difference is calculated by stereo matching. Heights are calculated from the resulting parallax differences.

**[0009]** Preferably, at least three images that overlap in a prescribed proportion are extracted from consecutive screens of captured images, the screens are matched by way of the overlapping parts thereof, and exterior orientation elements are established. Then, in accordance with the exterior orientation elements determined by this orientation calculation, the exterior orientation elements are interpolated for each line of the continuous mosaic images, and the lines of the continuous mosaic images are transformed into images projected to a prescribed altitude, in accordance with the exterior orientation elements of said lines.

**[0010]**

**[Operation]** The above processing can be automated on a computer, thus making it possible to automatically execute on a computer all the processes by which the stereo images needed for stereo matching are obtained from images resulting from video imaging, and by which heights are calculated, making to possible to quickly obtain three-dimensional data for a desired region or the like.

**[0011]** Being video images, a great deal of information is available that is needed for establishing exterior orientation elements, and the precision of the exterior orientation elements is increased. Consequently, the height data that is ultimately obtained is also of good precision. Furthermore, in the stereo image matching computation as well, by temporarily creating intermediate images for said stereo images, and searching for corresponding points chainwise, the corresponding points between stereo images can be established with greater precision than in the case of stereo photographs, and the occlusion problem can be completely solved.

**[0012]**

**[Working Example]** Hereafter, referring to the drawings, a working example of the present invention is described in detail.

**[0013]** FIG. 1 shows a schematic block diagram of an airborne measurement system in a working example of the present invention; FIG. 2 shows a schematic block diagram of an on-the-ground measurement system; and FIG. 3 shows schematic block diagram of an on-the-ground analysis system.

**[0014]** The airborne measurement system shown in FIG. 1 will be described. In this working example, the airborne measurement system shown in FIG. 1 is aboard a helicopter. In this working example, a high-quality camera 10 is mounted on a high-precision anti-vibration stabilizing device (anti-vibration device) 12, and the high-quality image signal output thereof is recorded on videotape by a high-quality video tape recorder 14. Note that, the camera 10 is generally facing downward, and is set so that the image directly below moves in a direction that is perpendicular to the scan lines. The output image signal of the camera 10 is also applied to a high-quality monitor 16. This allows visual confirmation of what the camera 10 is capturing and the state of imaging.

**[0015]** The high-precision anti-vibration stabilizing device 12 is made so that vibration from the aircraft does not affect the camera 10. This makes it possible to record images without blurring. That is to say, by combining a gyroscope and gimbal servo, the high-precision anti-vibration stabilizing device 12 has a spatial stabilization function that keeps the optical axis of the camera 10 pointed in a fixed direction in inertial space against any fluctuations in the angles about the roll, pitch, and yaw axes that arise in the airframe.

**[0016]** [Reference numeral] 18 is a personal computer that, along with collecting and recording measurement data, controls the high-precision anti-vibration stabilizing device 12 via a three-axis control device 20, controls the camera 10 via a camera control device 22, and controls the VTR 14 via a VTR control device 24. With the three-axis control device 20, the target bearing of the anti-vibration stabilizing device 12 can be set arbitrarily; the camera control device 22 controls the focus, zoom, diaphragm value, color balance and the like of the camera 10, and the VTR control device 24 controls the recording start, stop, and pause on the VTR 14, and also acquires and transfers to the computer 18 a time code that is recorded together with the output image signal of the camera 10. This time code is used for synchronization when analyzing the image information and other measurement data that is recorded on the VTR 14, in the on-the-ground analysis system.

**[0017]** A height above ground sensor 26 detects the height above ground, and the magnetic bearing sensor 28 detects the magnetic bearing. Because, even with the high-precision anti-vibration stabilizing device 12, there is slow directional movement caused by gyroscopic drift, it is necessary to correct the orientation of the camera by way of the magnetic bearing sensor 28. The outputs of the sensors 26 and 28 are applied to the computer 18 as digital data. Also input to the computer 18 is tri-axial gyroscopic data from the anti-vibration stabilizing device 12 indicating the tri-axial orientation of the camera 10 (roll angle, pitch angle, and yaw angle), and zoom data indicating the zoom value from the camera 10.

**[0018]** [Reference numeral] 30 is a GPS (global positioning system) receiving antenna, and 32 is a GPS reception device that collects the current ground coordinates (longitude, latitude, and altitude) from the GPS antenna 30. The GPS position measurement data output from the GPS reception device 32 is applied to the computer 18 for recording, and is also applied to a navigation system 34 for navigation. The navigation system 34 performs three-dimensional graphic display of the current position on a screen of a monitor 38, with respect to set survey lines in accordance with navigational (survey line data) that has been previously recorded on a floppy disk 36. This makes it possible to capture images following along desired survey lines in regions where there are no target objects on the ground, or in regions where they cannot be ascertained (for example, mountainous regions or sea regions or the like).

**[0019]** Note that, the differential GPS (D-GPS) method in which, even at reference points where the coordinates are known, measurements are taken by GPS, and the GPS position measurement data is corrected by the measurement error, is known as a way to improve GPS measurement precision. In this working example, this differential GPS method is adopted; the coordinates of a reference station of known coordinates are measured at the same time by GPS, and the measurement error data is radioed to the helicopter as GPS correction data. The communication device 40 receives the GPS correction data from the reference station and transfers it to the computer 18.

**[0020]** The computer 18 records the flight data that is input (height above ground data, magnetic bearing data, zoom data, tri-axial gyroscopic data), together with GPS correction data and

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