Abstract:

A camera includes a lens configured to admit light rays from a scene where the lens has a left portion and a right portion, wherein left and right portions have the same correspondence as a viewer's left eye and right eye. A pair of orthogonal polarizing filters corresponding to the left and right lens portions arranged with the lens bifurcate the light rays into a left group and a right group of two orthogonally polarized groups of rays. One or more focal plane image detectors are configured to distinguishably receive two orthogonally polarized images in a single frame on the basis of the pair of orthogonal polarizing filters. A 3-D image processor decodes the two orthogonally polarized images in the single frame received from the one or more focal-plane image detectors into signals corresponding to a "left eye" view image and a "right eye" view image.
SINGLE LENS 3-D CAMERA

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This Application claims priority from U.S. Patent Application Serial No. 13/150,988, entitled "SINGLE LENS 3-D CAMERA", filed June 1, 2011, and assigned to the assignee hereof and the contents of which are expressly incorporated by reference herein in their entirety.

FIELD

[0002] This disclosure relates generally to video cameras, and more particularly to 3-D cameras.

BACKGROUND

[0003] A number of approaches have been developed for 3-D image capture. These technologies typically seek to achieve stereoscopic images or a 2-D image plus a depth-map. Approaches may include a single camera or more than one camera. The use of two cameras or the use of two sets of lens systems to achieve 3-D parallax may impact the cost, complexity and bulkiness of such imaging systems. In addition, where two or more camera or optical beam systems are used, spatial tracking and alignment must be taken into account.

SUMMARY

[0004] In an embodiment, a method of 3-D imaging includes admitting light rays from a scene to a lens aperture having a left portion and a right portion, wherein left and right portion has the same correspondence as a viewer's left eye and right eye. The rays are bifurcated into a left group and a right group having two orthogonal polarizations utilizing two orthogonal polarizing filters corresponding to the left and right lens portions. The scene is imaged on a focal-plane image detector. The image detector includes a light sensor array configured to distinguishably detect two orthogonally polarized images in a single frame on the basis of the
pair of orthogonal polarizing filters. The two orthogonally polarized images of the scene are processed to provide signals corresponding to a "left eye view" image and a "right-eye view" image.

[0005] In an embodiment, a camera includes a lens configured to admit light rays from a scene where the lens has a left portion and a right portion, wherein left and right portion has the same correspondence as a viewer's left eye and right eye. A pair of orthogonal polarizing filters corresponding to the left and right lens portions arranged with the lens bifurcate the light rays into a left group and a right group of two orthogonally polarized groups of rays. One or more focal plane image detectors are configured to distinguishably receive two orthogonally polarized images in a single frame on the basis of the pair of orthogonal polarizing filters. A 3-D image processor decodes the two orthogonally polarized images in the single frame received from the one or more focal-plane image detectors into signals corresponding to a "left eye" view image and a "right eye" view image.

[0006] A camera includes a means for receiving light rays from an scene from two viewing angles through a single lens, a means for polarizing the light rays from the two viewing angles into two orthogonally polarized portions, means for distinguishably imaging the two orthogonally polarized portions of the light rays in a single frame on the basis of the orthogonal polarization of the two portions, and means for decoding the two images from the single frame into signals corresponding to images from the two viewing angles.

BRIEF DESCRIPTION OF THE FIGURES

[0007] Embodiments of this disclosure are illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements, and in which:

[0008] FIG. 1 is a schematic representation of a 3-D digital imaging camera, in accordance with an aspect of the disclosure.
FIG. 2 is a schematic representation of a portion of a dual polarization imaging detector, in accordance with an aspect of the disclosure.

DETAILED DESCRIPTION

In an aspect of the disclosure, an apparatus and method of using is described for 3-D image capture to obtain in a single image frame, utilizing filtering, a left and right image each having different views of an object scene. Signal processing, either in the image detector or a subsequent image processing component decodes the frame to provide the left and right images separately.

In 3-D imaging ("stereo imaging"), light rays entering the left eye and right eye of a viewer coming from a different view of a scene. This parallax is mimicked by using a single camera lens system. Advantage may be taken of a lens system having a specified aperture by dividing the aperture into left and right portions, or sub-apertures. The scene corresponding to each portion may be filtered with a corresponding polarizer, where the two polarizers are orthogonal to each other. An imaging detector, such as a CMOS array, CCD array, phototransistor array, or equivalents, maybe modified to receive both orthogonally polarized images in a single frame, as described below, where the two images may be decoded and separated.

For the sake of ease of description, a lens may be described as having a left portion and a right portion which may be equal halves, and which are therefore defined by a virtual boundary down a vertical the center of the lens as viewed looking toward a scene being imaged. Other bifurcations of the lens than equal portions may be considered to be within the scope of this disclosure. The lens may be a single lens, or a compound lens, which is common in the art of camera optics. Two polarizers may be referred to as orthogonally polarized, whether the polarization is linear for each polarizer, in which case the polarizations are arranged at 90° to each other, or circular, in which case the polarizations are "left" and "right" circular polarizations.
Referring to FIG. 1, a camera 100 includes a lens 105. The lens 105 may be a single lens or a compound lens, as shown in FIG. 1. A filter 109, comprising a left polarizer 110 and a right polarizer 115 may be placed at any of several locations within the camera. For example, the filter 110 may be placed directly adjacent to the lens 105, or directly adjacent to an iris diaphragm 120a, as shown in FIG. 1. However, there may be other locations for the filter that are acceptable, however, image reversal may occur in the optical system, depending on details of design, and the nomenclature defined herein may be revised accordingly.

Additionally, there may be other locations for the iris diaphragm, such as iris diaphragm 120b, as shown in FIG. 1, where the lens 105 is a compound lens, and the iris diaphragm 120b is located within the compound lens. The lens 105 produces a focused image at an image focal-plane, where an image detector 130 may be placed in a path of light rays emerging from the lens 105. The image detector 130 may be, for example, a CMOS, CCD, phototransistor, or other type of imaging device comprising an array of pixel sensors. The image detector 130 may be a color image detector, in which case a single image 130 detector may be sufficient. The image detector 130 includes additional filtering for selective polarization, as described below.

Optionally, a color beam splitter 140 may be placed in a path following the lens 105 configured to split light rays emerging from the lens 105 into a plurality of complementary colors. Conventionally, for example, light may be split into red, blue and green, and three monochrome images may be detected by three separate image detectors 130 placed at three image focal-planes defined and arranged according to the lens 105 and the design of the color beam splitter 140. Thus, each image detector 130 receives a monochrome image of a specified color. In the embodiment of multiple detectors, such as described above, maintaining spatial registration of the multiple images when combined (or superimposed) may yield a single full color image.
The one or more image detectors 130 may provide input signals to a general image processor 150, which is conventionally concerned with processing chroma, luminance, etc., related to standard image processing that ultimately results in a stream of image output signals that constitute frames of a video stream. For the convenience of further discussion, it will be assumed that the camera 100 comprises a single image detector 130, and therefore, without further loss of generality, no color beam splitter 140 is used or further discussed.

In an aspect of the disclosure, the output signals from the general image processor 150 may be further processed in accordance with properties of the image detector 130 to be described below to enable generation of signals incorporating 3-D properties.

The image detector 130, which may include a conventional pixel array sensor 240 (either color or monochrome), further includes a combination polarizing filters, and the image detector will now be referred to as a 3-D image detector 130. FIG. 2 is a schematic representation of a portion of a 3-D imaging detector 130. In one embodiment, the combination polarizing filter includes alternating segments (e.g., as columns, rows or a "checkerboard") of orthogonally polarizing filter elements 210, 215 placed in front of an imaging sensor array on a face of the 3-D image detector 130; that is, alternating segments of linear polarizers arranged at 90° to each other, or alternating segments of left and right circular polarizers, corresponding to the type of polarization employed in the left and right polarizers 110 and 115 are formed and aligned on the face of the 3-D image detector 130. In an embodiment, each polarizing filter element 210, 215 may extend over an entire vertical column of sensor elements, for example, where the width of the column may extend over one or more pixel elements, where the one or more pixel elements form a pixel cell 250. For example, in a full color imaged detector, the column polarizing filter elements 210, 215 may have a width equal to one or more of a Bayer cell, which is a configuration of red, green and blue filtered pixel elements well known in the art. Other cell configurations of color filtered pixels are also well known in the art and may be used accordingly. For highest resolution, the segment width may be only one cell wide. In a monochrome detector, as described
above, the cell may be only one pixel wide, and each segment of polarizing filter elements 210, 215 may be one or more pixels wide. Alternatively, the segments of polarizing filter elements 210, 215 may be arranged as horizontal rows. Alternatively the segments of polarizing filter elements 210, 215 may be arranged as alternating checkerboard "squares" or "patches."

[0019] Each set of same-polarized segments of polarizing filter elements 210 or 215 defines a sub-array of the 3-D image detector 130 that will only pass light of polarization corresponding to the polarization of polarizers 110 or 115. The two sub-arrays are spatially interleaved (in vertical columns, horizontal rows, or checkerboard). Therefore, each sub-array will pass light arriving from either the left half or right portion of the lens, according to the same corresponding polarization of the polarizers 110 and 115. The 3-D image detector 130 therefore receives two images, i.e., one from each of the left and right portions of the lens, providing parallax image information from two (left and right) viewing angles. The degree of parallax is at least in part determined by the diameter of the lens and an aperture of the iris diaphragm.

[0020] The signals output from the general image processor 150 may then be further processed by a 3-D processor 160, which may be a separate physical unit, or a subsystem within the general image processor 150, providing the additional ability to process the images from the 3-D image detector 130. The functionality of the dedicated 3-D processor 160 depends on knowledge of the relationship between the two orthogonally polarized sub-arrays and the elements 210, 215 of the imaging sensor array on the 3-D image detector 130 to distinguishably receive two orthogonally polarized images in a single frame. That relationship includes knowing the number of segments of each alternating type of polarizer across the span of the imaging sensor array, and how many pixel cells 250 are spanned by each polarizing segment. The 3-D processor 160 may then decode two interleaved images having orthogonal polarization into two signals corresponding to two frames of a scene.
viewed simultaneously from two separate viewing angles, providing a "left eye view" image and a "right eye view" image.

[0021] A configuration of alternating polarization segments, formed on a phototransistor array is described in "Integrated High Resolution Focal-Plane Polarization Imager," Z. K. Kalayjian and G. Andreou, ISA Expo 1998, ISBN/ID TP98ISA1107". Conventional photolithographic methods may be used to form the two sub-arrays of alternating polarization segments. The two sub-arrays may be formed directly on the pixel array, or they may be formed separately and aligned to the pixel array afterwards. As shown in FIG. 2, the sub-array of polarized elements 210 is arranged in one layer, and the sub-array of orthogonally polarized elements 215 is arranged in a second layer, spatially alternating to enable interleaved detection of two orthogonally polarized images with an optical efficiency of up to 50% as a result of the spatial duty cycle. Other configurations, including forming the two sub-arrays of polarizing element 210, 215 in a single layer, or altering the spatial duty cycle of each polarizing element sub-array, may also be contemplated within the scope of the disclosure.

[0022] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. A phrase referring to "at least one of a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover: a; b; c; a and b; a and c; b and c; and a, b and c. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed.
by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or, in the case of a method claim, the element is recited using the phrase "step for."
WHAT IS CLAIMED IS:

1. A method of 3-D imaging comprising;
admitting light rays from a scene to a lens aperture having a left portion and a right portion, wherein left and right portion has the same correspondence as a viewer's left eye and right eye;
bifurcating the light rays into a left group and a right group having two orthogonal polarizations utilizing two orthogonal polarizing filters corresponding to the left and right lens portions;
imaging both groups of rays from the scene on a focal-plane image detector, wherein the image detector comprises:
   a light sensor array configured to distinguishably detect two orthogonally polarized images in a single frame on the basis of the pair of orthogonal polarizing filters; and
   processing the two orthogonally polarized images of the scene to provide signals corresponding to a "left eye view" image and a "right-eye view" image.

2. The method of claim 1, further comprising:
   intercepting light rays passing through the left portion of the lens with the left segment;
   and
   intercepting light rays passing through the right portion of the lens with the right segment.

3. The method of claim 1, further comprising arranging the pair of orthogonal polarizing filters in front of the lens, facing a scene to be imaged.

4. The method of claim 1, further comprising arranging the pair of orthogonal polarizing filters with an iris aperture.
5. The method of claim 1, wherein the one or more image detectors comprise at least one of a CMOS array, CCD array and phototransistor array image detector.

6. The method of claim 5, where the one or more image detectors are color image detectors.

7. The method of claim 5, further comprising:
   separating colors of the light rays with a color beam splitter into a plurality of complementary colors; and
   directing the light rays of separated complementary colors to corresponding separate image detectors.

8. The method of claim 1, further comprising the image detector light sensor:
   distinguishably detecting the two orthogonally polarized images through an image detector array comprised of segments of a polarization filter having spatially alternating orthogonal polarizations.

9. The method of claim 8, further comprising:
   decoding signals provided from the image detector on the basis of the two orthogonally polarized images to provide a signal corresponding to "left eye-view" image and a "right-eye view" image.

10. A camera comprising:
    a lens configured to admit light rays from a scene, the lens having a left portion and a right portion, wherein left and right portion has the same correspondence as a viewer's left eye and right eye;
    a pair of orthogonal polarizing filters corresponding to the left and right lens portions arranged with the lens to bifurcate the light rays into a left group and a right group of two orthogonally polarized groups of rays;
a one or more focal-plane image detectors, wherein each image detector is configured to
distinguishably receive two orthogonally polarized images in a single frame on the basis of the
pair of orthogonal polarizing filters; and

a 3-D image processor to decode the two orthogonally polarized images in the single
frame received by the one or more focal plane image detectors into a "left eye" viewed image and
a "right eye" viewed image.

11. The camera of claim 10, wherein the left segment intercepts light rays passing through the
left portion of the lens and the right segment intercepts light rays passing through the right
portion of the lens.

12. The camera of claim 10, further comprising the pair of orthogonal polarizing filters
arranged in front of the lens facing a scene to be imaged.

13. The camera of claim 10, further comprising the pair of orthogonal polarizing filters
arranged with an iris aperture.

14. The camera of claim 10, wherein the one or more image detectors comprise at least one of
a CMOS array, CCD array and phototransistor array image detector.

15. The camera of claim 14, wherein the one or more image detectors are color image
detectors.

16. The camera of claim 14, further comprising a color separating beam splitter to direct light
rays of separated complementary color images to corresponding separate image detectors.
17. The camera of claim 10, wherein the image processor is configured to output signals corresponding to two images from the single frame received through the left portion of the lens and the right portion of the lens on the basis of the polarization of the.

18. The camera of claim 10, the focal-plane image detectors each comprising:
   an image sensor array; and
   segments of an image detector array of polarizing filter arranged with the image sensor array, wherein adjacent segments have alternating orthogonal polarization, whereby two interleaved images of having orthogonal polarization are detected by the image sensor array.

19. A camera comprising:
   means for receiving light rays from a scene from two viewing angles through a single lens;
   means for polarizing the light rays from the two viewing angles into two orthogonally polarized portions;
   means for distinguishably imaging the two orthogonally polarized portions of the light rays in a single frame on the basis of the orthogonal polarization of the two portions; and
   means for decoding the two images from the single frame into signals corresponding to images from the two viewing angles.
Receive frame of image data as pixel data stream |a|b|a|b|a|b|... from general processor

Refer to lookup table identifying pixel data with pixel location and pixel polarization a or b

De-interleave data stream of pixels from |a|b|a|b|a|b|... to |a|a|a|a|... + |b|b|b|b|...

Construct two image frames of polarization a and b

Output two synchronized image frames, polarization a and b.

FIG. 3

350

350

360

360

Frame |a|a|a|a|...

Frame |b|b|b|b|...
INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/001152

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04N9/04, H04N13/02

ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04N

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X Further documents are listed in the continuation of Box C.   X See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of 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

Date of the actual completion of the international search

3 September 2012

Date of mailing of the international search report

14/09/2012

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk

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<td>EP 0 501 718 A1 (SONY CORP [JP]) 2 September 1992 (1992-09-02) paragraph [0013]; figure 1</td>
<td>6,7,15, 16</td>
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Form PCT/ISA210 (patent family annex) (April 2005)