ABSTRACT

Electronic imaging apparatus includes a main mirror that rotates about two transverse axes to reflect light for an array of subimages through a lens to a correcting mirror that reflects the light to an image detector. The correcting mirror moves in translation and tilts to correct for loss of focus of the subimages. A method of generating high resolution images includes acquiring an array of subimages by moving the main mirror and correcting each subimage with the correcting mirror. A method of surveillance includes acquiring and storing an array of initial subimages, then acquiring new subimages, comparing the new subimages with the stored subimages, and storing changed subimages.
ELECTRONIC IMAGING APPARATUS WITH HIGH RESOLUTION AND WIDE FIELD OF VIEW AND METHOD

[0001] This application is a division of Ser. No. 11/162, 247 filed Sep. 2, 2005, and claims the benefit under 35 U.S.C. § 120 of the U.S. non-provisional patent application.

TECHNICAL FIELD

[0002] The present invention relates to electronic imaging and more particularly to an electronic imaging apparatus with a wide field of view that captures a plurality of subimages to generate high resolution images.

BACKGROUND ART

[0003] The resolution of a single image captured or acquired by an image capture device, such as a film or digital camera, is finite and therefore limited. Generally the resolution of an electronic imaging device is a tradeoff between the number of picture elements (pixels) and cost. Prior known devices scan an object, by acquiring a plurality of subimages of the object, to generate a high resolution image.

[0004] One known type of electronic imaging device, known as a document scanner, is suitable for acquiring images of flat, two dimensional objects of a limited size. In a document scanner, the object and the image detector are positioned a very small, fixed distance relative to each other, and the object or the image detector moves. Examples of document scanners are flatbed scanners, sheet fed scanners, handheld scanners, fax machines and copiers. Each of these scanners is limited to scanning two dimensional objects such as sheets of paper. Handheld scanners are difficult to use. Flatbed and sheet fed scanners can only scan up to a selected maximum size, generally the size of legal or letter size paper.

[0005] Other scanners, sometimes known as “over the desk” scanners, are spaced relative to the object, and can acquire images of three dimensional objects and images of larger objects than most document scanners. Although some scanners of this type move the image detector or the object, preferably the image detector and object remain stationary during image acquisition. U.S. Pat. No. 5,686,960 to Sussman et al. discloses a scanner having a stationary image detector spaced above the object and a rotating disk with a preselected number of deflectors that deflect tiles or subimages of the object through a lens onto the image detector. Sussman et al. also discloses a scanner having a stationary image detector spaced above the object and a pair of selectively rotatable mirrors that reflect tiles or subimages of the object through a lens onto the image detector. The image path from the object to the reflector or mirror in Sussman et al. is oblique rather than perpendicular to the object for all but at most one tile or subimage.

[0006] Generally for “over the desk” scanners with a stationary object and image detector, the image path from the object to the image detector is oblique or slanted. Such an oblique image path can distort and defocus the subimage acquired. U.S. Pat. No. 6,512,539 to Dance et al. discloses a scanner having a stationary image detector spaced above the object and an inner rotating mirror that receives light from four outer mirrors. Each outer mirror is centered over a quadrant of the object so that the image paths are perpendicular to the object. The scanner disclosed by Dance et al. requires an outer mirror for each subimage.

[0007] Prior known security or surveillance systems generally have stationary cameras or motor driven cameras that tilt, pan and zoom. Stationary cameras have a limited field of view and generally have limited resolution. Motor driven cameras generally sweep the area of interest over a period of multiple seconds, such that portions of the area of interest are missed by the camera for multiple seconds.

[0008] Some prior known systems for taking panoramic pictures use convex mirror systems with a camera to acquire the entire panorama in a single shot. These systems provide relatively low resolution pictures. Other systems for taking panoramic pictures rotate the camera about a center point.

DISCLOSURE OF THE INVENTION

[0009] Electronic imaging apparatus includes a main mirror assembly, a lens, a correcting mirror and an image detector. Light reflected by a region of an object is reflected by the main mirror assembly through the lens to the correcting mirror, and therefrom onto the image detector to acquire a subimage of the object. The main mirror assembly has a mirror that rotates about relatively orthogonal first and second axes to acquire an overlapping array of subimages. The correcting mirror is movable in translation and tilt, and corrects for focal variations for the overlapping array of subimages such that a high resolution image of the object is captured and generated without moving the object or the image detector. Electronic imaging apparatus for surveillance and panoramic photography includes a main mirror assembly, a lens and an image detector. The main mirror assembly rotates a mirror about a vertical axis and about a horizontal axis to reflect light for an array of subimages through the lens onto the image detector to acquire the array of subimages.

[0010] A method of generating high resolution images includes the steps of providing the electronic imaging apparatus, acquiring an array of subimages, and electronically merging or stitching the subimages together. The steps of acquiring includes, for each subimage, the substeps of moving the first mirror to reflect light for the subimage through the lens to the correcting mirror, and moving the correcting mirror to reflect light for the subimage to the image detector in focus. A method of generating a panoramic image comprises the steps of providing the electronic imaging apparatus, acquiring an array of subimages by successively acquiring a subimage, then moving the main mirror by rotating the mirror about at least one of the first or second axes, and then acquiring a next subimage, stitching the subimages together, and rotating all the subimages to an upright orientation to form a panoramic image. A method of high resolution surveillance comprises the steps of providing the electronic imaging apparatus, acquiring an array of initial subimages by successively acquiring a said subimage, then moving the main mirror, and then acquiring a next subimage, storing the initial subimages, after acquiring the array of initial subimages, acquiring an array of new subimages, then comparing each new subimage with the respective stored subimage, and if a new subimage is changed relative to the respective stored subimage, storing that new subimage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Details of this invention are described in connection with the accompanying drawings that bear similar reference numerals in which:
FIG. 1 is a top plan view of an electronic imaging apparatus embodying features of the present invention.

FIG. 2 is a side elevation view of the apparatus of FIG. 1.

FIG. 3 is a side elevation view of the apparatus of FIG. 1 with portions removed.

FIG. 4 is a perspective view of a main mirror assembly for the apparatus of FIG. 1.

FIG. 5 is a side elevation view of a main mirror assembly for the apparatus of FIG. 1.

FIG. 6 is a perspective view of a correcting mirror assembly for the apparatus of FIG. 1.

FIG. 7 is a bottom plan view of the correcting mirror assembly of FIG. 6.

FIG. 8 is a partial elevation side view of the correcting mirror assembly of FIG. 6.

FIG. 9 is a partial elevation side view of the correcting mirror assembly of FIG. 6 with an alternative actuator.

FIG. 10 is a side schematic view of image paths to an apparatus similar to the apparatus of FIG. 1, without a correcting mirror.

FIG. 11 is a side schematic view of image paths to the apparatus of FIG. 1, with a correcting mirror.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. 1, 2 and 3, an electronic imaging apparatus 11 embodying features of the present invention includes a main mirror assembly 14, a lens assembly 15, a correcting mirror assembly 16 and an image detector 17. The main mirror assembly 14 includes a main mirror 18. The lens assembly 15 includes a lens 19. The correcting mirror assembly 16 includes a correcting mirror 20. The main mirror 18, lens 19, correcting mirror 20 and image detector 17 are spaced from each other and aligned with each other to define an image path 21. Light from an object or scene of interest is received at the main mirror 18. The light is reflected by the main mirror 18 through the lens 19 to the correcting mirror 20. The correcting mirror 20 reflects the light to the image detector 17.

As shown in FIGS. 4 and 5, the main mirror assembly 14 includes an electrical first motor 23 having a first shaft 24 that rotates about a first axis 25. The first motor 23 is a stepper motor or other precisely controllable motor. The term motor as used herein includes any device, electrical or non-electrical, for imparting rotary motion, including, by way of example, and not as a limitation, rotary actuators and galvanometer type drive units. A substantially flat base 27 mounts on the shaft 24 perpendicular to the first axis 25. Two spaced, parallel side plates 28 attach to the base 27 and extend therefrom away from the first motor 23. Aligned motor shaft apertures 29 extend through the side plates 28.

An electrical second motor 31 mounts between the side plates 28 near the base 27. The second motor 31 is a stepper motor or other precisely controllable motor. The second motor 31 has a second shaft 32 perpendicular to the first axis 25 that extends through the motor shaft apertures 29 on opposite sides of the second motor 31. A transversely extending arm 33 attaches to each end of the second shaft 32, outside the side plates 28. The main mirror 18 rotatably attaches to the side plates 28 along a second axis 35 that is perpendicular to the first axis 25 and parallel to the second shaft 32. The first motor 23 preferably is rotatable continually around the first axis 25 while the second motor 31 only needs to rotate through a limited arc or angle.

A pair of elongated links 37 each have a first end 38 and a spaced second end 39. The first end 38 of each link 37 is spaced from the second shaft 32 and pivotally connected to an arm 33. The second end 39 of each link is spaced from the second axis 35 and pivotally connected to the main mirror 18 so that rotation of the second shaft 32 by the second motor 31 rotates the main mirror 18 about the second axis 35. The arms 33 shown are positioned to extend from the second shaft 32 in the opposite direction as the second end 39 of each link 37 is spaced from the second axis 35, so that rotation of the second shaft 32 in a clockwise direction rotates the main mirror 18 counterclockwise. A pair of spaced sliprings 40 encircle the first shaft 24 and electrically connect to the second motor 31. Additional sliprings 40 may be required, depending on the second motor 31 that is used.

The main mirror assembly 14 shown has a main mirror 18 that is rotatable about the first and second axes 25 and 35 for acquisition of a two dimensional array of images. Alternatively, the main mirror assembly 14 can have a single mirror rotatable about a single axis for acquisition of a one dimensional array of images, or two separate mirrors, each rotatable about a different axis, for acquisition of a two dimensional array of images.

Referring to FIGS. 6, 7 and 8, the correcting mirror assembly 16 includes a base 42, a correcting mirror plate 43 with the correcting mirror 20 mounted thereon, and three actuators 44 that mount on the base 42 and move the correcting mirror plate 43 as described hereinbefore. The base 42 is a flat plate with a first face 46 and a spaced, oppositely facing second face 47. The base 42 shown has a pair of spaced, parallel, straight side edges 49 connected at the top by a convex, curved upper edge 50 and at the bottom by a straight lower edge 51. A circular aperture 52 extends through the base 42 from the first face 46 to the second face 47. The correcting mirror plate 43 shown is an equilateral triangle.

The actuators 44 each include a motor 54 with a driveshaft 55, an arm 56 attached and extending transversely to the driveshaft 55, and a rod 57 that rigidly attaches to the arm 56 opposite the driveshaft 55 and extends transversely to the arm 56 and to the driveshaft 55. The motors 54 are stepper motors or other precisely controllable motors. The motors 54 are mounted at 120 degrees relative to each other on the second face 47 of the base 42 with the driveshafts 55 pointing generally outwards, the arms 56 pointing generally inwards, and the rods 57 extending through the aperture 52. The correcting mirror plate 43 is spaced from the first face 46 with the correcting mirror 20 facing away from the first face 46 and with each corner of the correcting mirror plate 43 attaching to a rod 57 opposite the arm 56. Rods 57 are preferably made of a resilient material such as plastic or fiberglass so that the rod 57 flexes when the respective arm 56 moves. A pair of spaced, generally triangular mounting.
brackets 58 are rigidly mounted on the first face 46 at the side edges 49, extending transverse to the first face 46.

[0030] FIG. 9 shows an alternative actuator 60 having a motor 61 with a driveshaft 62 and an eccentric cam 63 mounted on the driveshaft 62. An elongated rod 64 is slidably mounted in a sleeve bearing 65, and has a rotably mounted cam follower 66 at one end and a shallow, cylindrical, flat bottomed first cavity 67 at the opposite end. Each corner of the correcting mirror plate 43 has a shallow, cylindrical, flat topped second cavity 68 of the same size as the first cavity 67. A precision steel ball 69 is sized to fit into the first and second cavities 67 and 68 and to allow a selected lateral or radial movement between the rod 64 and the correcting mirror plate 43. The cam follower 66 is positioned on the cam 63. A means for biasing 71, such as a spring or other tension member, biases the correcting mirror plate 43 toward the base 42. Other actuators, such as linear actuators can also be used.

[0031] Referring again to FIGS. 1, 2 and 3, the lens assembly 15 includes a base 74, a lens barrel 75 and the lens 19. The lens barrel 75 is sized and shaped to hold the lens 19. The lens 19 can be a single lens or a compound lens. The base 74 includes a cylindrical portion 76, sized to receive the lens barrel 75, and a radially outwardly extending, circular flange 77 attached to an end of the cylindrical portion 76. The flange 77 has a first side 78, on which the cylindrical portion 76 is attached, and a spaced oppositely facing second side 79. The mounting brackets 58 rigidly attach to the first side 78 of the flange 77, opposite the base 42 of the correcting mirror assembly 16, to mount the correcting mirror assembly 16 to the lens assembly 15 with the correcting mirror 20 at an angle relative to the lens 19.

[0032] An image detector assembly 80 includes the image detector 17 and associated electronics. An image detector bracket 81 extends between the third edges of the mounting brackets 58 opposite the base 42 of the correcting mirror assembly 16 and the first side 78 of the flange 77. The image detector assembly 80 mounts on and extends through the image detector bracket 81, with the image detector 17 facing the correcting mirror 20. The normal to the base 42 of the correcting mirror assembly 16 is aligned at an angle that is the bisector of the angle between the axis of the lens 19 and a line normal to the image detector 17. The image detector 17 can be a CCD array, a CMOS array or other electronic image detection device.

[0033] A motor housing 84 includes spaced, cylindrical first and second bands 85 and 86 connected by three circumferentially spaced bars 87. A flange 88 extends inwardly from the first band 85, opposite bars 87 to form an aperture 89. The aperture 89 is sized to receive the first motor 23 of the main mirror assembly 14. The first motor 23 mounts in the aperture 89 of the motor housing 84 with the bars 87 extending away from the first motor 23. Six elongated rods 91 extend in a zigzag pattern from the second band 86 of the motor housing 84 to the second side 79 of the flange 77 of the base 74 of the lens assembly 15 to rigidly hold the main mirror assembly 14 relative to the lens assembly 15, the correcting mirror assembly 16 and the image detector assembly 80.

[0034] The electronic imaging apparatus 11 is generally securely mounted for acquisition of images. Images are generated by acquisition of an array of subimages which are stitched or blended together with computer software. The subimages can overlap by as much as 10%. For scanning applications such as acquisition of an image of a flat object such as a document, the electronic imaging apparatus 11 is spaced from the object. The main mirror 18 is rotated about the first and second axes 25 and 35 to a selected position for acquisition of each subimage. The array of subimages is acquired by sequentially moving the main mirror 18 and then acquiring a subimage.

[0035] FIGS. 10 and 11 show the electronic imaging apparatus positioned for acquiring the image of a two dimensional object 93. For each subimage there is an image path 21 from the object 93 to the electronic imaging apparatus. Each image path 21 has a best focus region 95. FIG. 10 shows an electronic imaging apparatus 96, similar to the electronic imaging apparatus 11 described herein, but without a correcting mirror 20. The correcting mirror 20 could be replaced with a stationary mirror or the image detector 17 could be repositioned to be aligned with the lens 19. In FIG. 10 the object 93 is within the best focus region 95 only for the image path 21 that is normal to the object 93. The object 93 is rotated and beyond the best focus region 95 for all other image paths 21.

[0036] Moving all three of the actuators 44 of the correcting mirror assembly 16 equally moves the correcting mirror 20 linearly or in translation in a direction orthogonal to the base 42 of the correcting mirror assembly 16. This direction is intermediate the image path 21 from the lens 19 to the correcting mirror 20 and the image path 21 from the correcting mirror 20 to the image detector 17. Moving the correcting mirror 20 in translation in this direction shortens or lengthens the image path 21 from the lens 19 to the image detector 17, and thereby the distance of the best focus region 95 from the lens 19.

[0037] Moving the actuators 44 individually or by different amounts tilts the correcting mirror 20 relative to the direction of translation. Tilting the correcting mirror 20 has an effect equivalent to tilting the image detector 17 relative to the lens 19. Tilting the correcting mirror 20 rotates the best focus region 95 relative to the image path 21 from the object 93 to the electronic imaging apparatus 11. As shown in FIG. 11, by translating and tilting the correcting mirror 20, the best focus region 95 is moved and rotated such that the object 93 is in the best focus region 95 for all subimages. As the array of subimages is acquired by sequentially moving the main mirror 18 to a selected position for each subimage, the correcting mirror 20 is selectively moved for each subimage such that the portion of the object 93 associated with that subimage is entirely within the best focus region 95.

[0038] The electronic imaging apparatus 11 can be rotated 90 degrees from the position shown in FIG. 1, with the main mirror assembly 14 preferably towards the top, for panoramic photography and surveillance. For panoramic photography and surveillance the correcting mirror 20 is not required except where focus adjustment for close objects is needed. The main mirror assembly 14 moves the main mirror 18 rapidly and with precision. The moment of inertia of the parts that move around the first axis 25 of the main mirror assembly 14 is low due to the mounting of the second motor 31 along the first axis. The low moment of inertia allows the main mirror 18 to move rapidly between positions.
of subimage capture. The main mirror assembly 14 moves the main mirror 18 without gears. Gears have backlash that causes imprecision. The counter-rotation of the main mirror 18 around the second axis 35 relative to the second motor 31 minimizes the induced torque. The slips 40 allow the first shaft 24 of the first motor 23 to rotate in either direction continually around the first axis 25 while providing electrical power to the second motor 31.

[0039] When the electronic imaging apparatus 111 is used for panoramic photography and surveillance, the first axis 25 is substantially vertical. As the main mirror 18 rotates around the first axis 25, the subimages are rotated away from an upright or vertical orientation relative to the image detector. A method of generating a panoramic image includes the steps of providing an electronic imaging apparatus 11, with or without a correcting mirror, sequentially acquiring an array of subimages, stitching the subimages together and then rotating each subimage to an upright orientation.

[0040] A method of high resolution surveillance includes the steps of providing an electronic imaging apparatus 11, with or without a correcting mirror, sequentially acquiring an array of initial subimages, storing the initial subimages as stored subimages, then acquiring an array of new subimages, comparing each new subimage to the respective stored subimage, and if the new subimage is changed relative to the stored subimage, storing that new subimage. The initial subimages are acquired at high resolution while new subimages can be acquired at a lower resolution, by binning or other processes, for higher speed. If a new subimage is changed relative to the last respective stored subimage, a high resolution subimage can be acquired and stored.

[0041] The steps of storing the initial subimages, comparing, and storing the new subimage, described above, may be done at a central computer that is connected to the electronic imaging apparatus 11 by a communications path that might be electrical, fiber optic, or wireless. Alternatively, the image detector assembly 80 of the electronic imaging apparatus 11 can also include memory and processing capabilities. In this case the image detector assembly 80 could store the last stored subimage for each subimage location in the array. The step of comparing each new subimage to the respective stored subimage could thus be performed by the image detector assembly 80. After transmission to a central computer of the array of initial subimages from the electronic imaging apparatus 11, only changed subimages or portions thereof need to be subsequently transmitted. By providing the image detector assembly 80 with memory and processing capabilities, the amount of data transmitted from the electronic imaging apparatus 11 is minimized. Additional reduction of this data can be realized by use of conventional image or video compression methods in the image detector assembly 80 prior to transmission.

[0042] The area of surveillance or any selected region within the area can be displayed. Regions can be selected by an operator or can be automatically selected when motion or change is detected. The subimages of the area or the selected region are rotated to an upright orientation and stitched together into an image for display.

[0043] The electronic imaging apparatus 111 can be used in conjunction with a prior known pan and tilt camera or pan, tilt and zoom camera, with a fixed or zoom long focal length lens, respectively. Such a camera could be used, in combination with the electronic imaging apparatus 11, to acquire a small field of view, very high resolution image or video of a specific selected region. This might also be done with a second electronic imaging apparatus 11 with a longer focal length or zoom lens.

[0044] Although the present invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made by way of example and that changes in details of structure may be made without departing from the spirit thereof.

What is claimed is:
1. A method of generating a panoramic image comprising the steps of:
   providing electronic imaging apparatus including a mirror assembly rotatable about a vertical axis and having a mirror rotatable about a horizontal axis, a lens spaced along said vertical axis from said main mirror, and an image detector spaced along said vertical axis from said lens opposite said main mirror,
   acquiring an array of subimages by successively acquiring a said subimage from light reflected from said main mirror through said lens to said image detector, then moving said main mirror by one of rotating said main mirror assembly about said vertical axis and rotating said main mirror about said horizontal axis, and then acquiring a next said subimage,
   stitching said subimages together, and
   rotating all said subimages to an upright orientation.
2. A method of high resolution surveillance comprising the steps of:
   providing electronic imaging apparatus including a main mirror assembly having a main mirror rotatable about a vertical axis and about a horizontal axis, a lens spaced along said vertical axis from said main mirror, and an image detector spaced from said lens opposite said main mirror,
   acquiring an array of initial subimages by successively acquiring a said subimage from light reflected from said main mirror through said lens to said image detector, then moving said main mirror by rotating said main mirror about at least one of said vertical and horizontal axes, and then acquiring a next said subimage,
   storing said initial subimages as stored subimages,
   after said step of acquiring an array of initial subimages, acquiring new subimages of said array,
   then comparing each said new subimage with the respective said stored subimage, and
   if a said new subimage is a changed subimage relative to the respective said stored subimage, storing that said changed subimage as a stored subimage.
3. The method as set forth in claim 2 including the steps of:
   stitching said stored subimages together to generate an image,
rotating said stored subimages to an upright orientation, and
displaying said image.

4. The method as set forth in claim 3 wherein said stored subimages are a selected region of said array.

5. The method as set forth in claim 4 wherein said region is selected by an operator.

6. The method as set forth in claim 4 wherein said region is automatically selected when a said changed subimage is acquired.

7. The method as set forth in claim 2 wherein:

said step of acquiring an array of initial subimages includes acquiring said initial subimages at high resolution, and

said step of acquiring new subimages of said array includes acquiring said new subimages at a lower resolution than said initial subimages, and

said step of storing said changed subimages includes acquiring said changed subimage in high resolution before storing said changed subimage.

8. The method as set forth in claim 2 wherein said step of acquiring new subimages of said array includes continuously acquiring new subimages of said array.

9. The method as set forth in claim 2 wherein:

said electronic imaging apparatus includes an image detector assembly having said image detector, and having processing and memory capabilities, and

said image detector assembly performs said setup of comparing each said new subimage with the respective said stored subimage.

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