

AN IMAGING APPARATUS

Background of the Invention

The present invention relates to an apparatus for imaging, and in particular to an apparatus that is able to image distinct imaging regions.

5 Description of the Prior Art

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that the prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to
10 which this specification relates.

It is often required to image an area for general viewing, surveillance or the like. In order to maximise the effectiveness, a large field of vision is preferred so that a large viewing area can be maintained. This may be achieved, for example, by providing a system that can image in a panoramic format to thereby cover a large area of interest.

15 Generally, in order to obtain such a panoramic view, a parabolic mirror is used in conjunction with a detector, where the parabolic mirror directs radiation towards the detector's image plane. However, the system of using a parabolic mirror has numerous disadvantages. For example, the system does not fully utilise the whole detector image plane (only approximately 50%), has a low light collecting aperture, and therefore limits the range of
20 performance. Furthermore, the system requires a high resolution camera and sophisticated software processing to unfold the image. Additionally, as the image is stretched unequally, it provides a very distorted view and hence is usually very difficult to visualise.

Other methods of imaging include using a scanning system that scans in a 360 degrees direction and using image processing to stitch the image. However, such system needs to
25 have a scanning mechanism and is also based on a time sharing scheme, where the time lag and the range performance will depend on the scanning rate. Since the scanning system generally has moving parts, the system will generally be more complicated, less reliable, bigger and will consequently require more power consumption. Thus, the scanning system

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would not be suitable for continuous surveillance as a user would need to wait for the scanner to complete the full rotation prior to receiving further information with respect to a particular imaging area.

This identifies a need for an apparatus for imaging which overcomes or at least ameliorates problems inherent in the prior art.

Summary of the Present Invention

In a first broad form, there is provided, an apparatus for imaging, the apparatus including:

- a) a detector having a field of vision;
- b) at least one first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision; and,
- c) at least one second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective field of vision such that the first and second reflectors reflect radiation from distinct imaging regions to the detector, the detector being responsive to the radiation to image the distinct imaging regions.

Typically, the apparatus includes a second reflector positioned in each other of the first and second fields of vision for further dividing the respective field of vision.

Typically, the first reflector has an apex, the apex separating the reflector into portions, and wherein in use, the first reflector is positioned with the apex in the field of vision, such that each portion reflects radiation from a respective distinct imaging region to the detector.

Typically, the apex is positioned in the field of vision so as to divide at least one of:

- a) a horizontal field of view; and,
- b) a vertical field of view.

Typically, the detector has an axis, and wherein the apex is aligned with the axis.

Typically, each imaging region has a field of view and wherein either one or a combination of the first reflector, second reflector and the third reflector is positioned in the field of vision to optimise the field of view for each imaging region.

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Typically, the apparatus includes a number of modules, each module being formed from apparatus according to claim 1, and each module being aligned at relative angles to allow at four least four directional viewing.

Typically, the apparatus includes four modules arranged at an offset angle of 45 degrees.

- 5 Typically, the distinct imaging regions are from four different directions, thereby forming a four directional viewing.

Typically, the field of vision has a HFOV between 22.5 and 90 degrees relative to an axis of the detector, and a VFOV between 16.9 to 67.5 degrees, relative to the axis of the detector.

Typically, the HFOV x VFOV is 45 degrees x 8.4 degrees.

- 10 Typically, the apparatus further includes a processing system for processing images from the distinct imaging regions.

Typically, the apparatus further includes at least one display for displaying images.

Typically, the apparatus further includes a store for recording at least one image.

Typically, the detector includes a lens and a detector body.

- 15 Typically, any one or a combination of the first reflector, the second reflector, and the third reflector is placed between the lens and the detector body.

Typically, any one or a combination of the first reflector, the second reflector and the third reflector is a mirror.

Typically, the mirror is at least one of:

- 20 c) a folding mirror;
d) a concave mirror; and,
e) a convex mirror.

Typically, any one or a combination of the first reflector, the second reflector, and the third reflector is a prism.

- 25 Typically, the detector is a camera.

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Typically, the camera is at least one of:

- f) a day camera;
- g) a night camera; and,
- h) a thermal imaging camera.

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In a second broad form, there is provided an apparatus for imaging, the apparatus including:

- a) a first detector having a first field of vision substantially aligned along a first axis;
- b) a first reflector positioned in the first field of vision for reflecting radiation from a distinct first imaging region to the detector, the detector being responsive to the radiation to image the distinct first imaging region;
- c) a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis;
- d) a second reflector positioned in the second field of vision for reflecting radiation from a distinct second imaging region to the second detector, the second detector being responsive to the radiation to image the distinct second imaging region.

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Typically, the first detector and the second detector are in the same horizontal plane.

Typically, the apparatus further includes:

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- a) a third detector having a second field of vision substantially aligned along a third axis, the third detector being positioned with the third axis laterally spaced from the first axis and the second axis;
- b) a third reflector positioned in the field of vision for reflecting radiation from distinct third imaging regions to the third detector, the third detector being responsive to the radiation to image the distinct third imaging regions.

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Typically, third detector is spaced at a 60 degree angle from the second detector, and the second detector is spaced at a 60 degree angle from the first detector, thereby providing a 360 degree field of vision.

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Typically, the first detector is staggered on top of the second detector.

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In a third broad form, there is provided a method for imaging, the method including the steps of, in a detector having a field of vision:

- a) receiving radiation from at least one first distinct imaging region, the radiation being reflected by a first reflector, the first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision,
- b) receiving radiation from at least one second distinct imaging region, the radiation being reflected by a second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective fields of vision; and,
- c) imaging the distinct imaging regions.

In a fourth broad form, there is provided an apparatus for providing images for security surveillance of distinct imaging regions, the apparatus including:

- a) a detector having a field of vision;
- b) at least one first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision;
- c) at least one second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective field of vision such that the first and second reflectors reflect radiation from distinct imaging regions to the detector, the detector being responsive to the radiation to image the distinct imaging regions.

In a fifth broad form, there is provided a method for providing images for security surveillance of distinct imaging regions, the method including the steps of, in a detector having a field of vision:

- a) receiving radiation from at least one first distinct imaging region, the radiation being reflected by a first reflector, the first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision,
- b) receiving radiation from at least one second distinct imaging region, the radiation being reflected by a second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective fields of vision; and,
- c) imaging the distinct imaging regions.

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In a sixth broad form, there is provided an apparatus for providing images using a camera system, the apparatus including:

- a) a housing for coupling to the camera system, the camera system including a detector having a field of vision;
 - 5 b) a first reflector provided in the housing, such that as the housing is coupled to the camera system, the first reflector is positioned in the field of vision for dividing the field of vision into first and second fields of vision;
 - c) a second reflector provided in the housing, such that as the housing is coupled to the camera system, the second reflector is positioned in a respective one of the first and
10 second fields of vision for further dividing the respective field of vision such that the first and second reflectors reflect radiation from distinct imaging regions to the detector, the detector being responsive to the radiation to image the distinct imaging regions.
- 15 Typically, the camera system is a photographic camera system.

Typically, the housing includes a lens mount for coupling the housing to a body of the camera system.

20 In a seventh broad form, there is provided a method for providing images using a camera system, the method including:

- a) receiving radiation from at least one first distinct imaging region, the radiation being reflected by a first reflector, the first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision,
- 25 b) receiving radiation from at least one second distinct imaging region, the radiation being reflected by a second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective fields of vision; and,
- c) imaging the distinct imaging regions.

30 In an eighth broad form, there is provided a method for imaging, the method including the steps of:

- a) in a first detector having a first field of vision substantially aligned along a first axis:

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i) receiving radiation reflected by a first reflector, the first reflector positioned in the first field of vision, the first reflector being formed so as to reflect radiation from a first distinct imaging region to the detector; and,

ii) imaging the first distinct imaging regions;

5 b) in a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis:

i) receiving radiation reflected by a second reflector, the second reflector positioned in the second field of vision, the second reflector being formed so as to reflect
10 radiation from a second distinct imaging region to the detector; and,

ii) imaging the second distinct imaging region.

Typically, the method further includes forming an image including the imaged first distinct imaging region and the second distinct imaging region.

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In a ninth broad form, there is provided an apparatus for providing images for security surveillance of distinct imaging regions, the apparatus including:

a) a first detector having a first field of vision substantially aligned along a first axis;

b) a first reflector positioned in the first field of vision for reflecting radiation from a
20 distinct first imaging region to the detector, the detector being responsive to the radiation to image the distinct first imaging region;

c) a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis;

25 d) a second reflector positioned in the second field of vision for reflecting radiation from a distinct second imaging region to the second detector, the second detector being responsive to the radiation to image the distinct second imaging region.

In a tenth broad form, there is provided a method for providing images for security
30 surveillance of distinct imaging regions, the method including the steps of:

a) in a first detector having a first field of vision substantially aligned along a first axis:

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- i) receiving radiation reflected by a first reflector, the first reflector positioned in the first field of vision, the first reflector being formed so as to reflect radiation from a first distinct imaging region to the detector; and,
 - ii) imaging the first distinct imaging regions;
- 5 b) in a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis:
- i) receiving radiation reflected by a second reflector, the second reflector positioned in the second field of vision, the second reflector being formed so as to reflect
 - 10 radiation from a second distinct imaging region to the detector; and,
 - ii) imaging the second distinct imaging region.

In an eleventh broad form, there is provided an apparatus for providing images using a camera system, the apparatus including:

- 15 a) a housing for coupling to the camera system, the camera system including a first detector having a first field of vision substantially aligned along a first axis;
- b) a first reflector provided in the housing, such that as the housing is coupled to the camera system, the first reflector is positioned in the field of vision, for reflecting radiation from a distinct first imaging region to the first detector, the first detector
- 20 being responsive to the radiation to image the distinct first imaging region;
- c) the camera system further including a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis; and,
- d) a second reflector provided in the housing, the second reflector positioned in the
- 25 second field of vision for reflecting radiation from a distinct second imaging region to the second detector, the second detector being responsive to the radiation to image the distinct second imaging region.

Typically, the camera system is a photographic camera system.

30 Typically, the housing includes a lens mount for coupling the housing to a body of the camera system.

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In a twelfth broad form, there is provided a method for providing images using a camera system, the method including the steps of:

- a) in a first detector having a first field of vision substantially aligned along a first axis:
 - i) receiving radiation reflected by a first reflector, the first reflector positioned in the first field of vision, the first reflector being formed so as to reflect radiation from a first distinct imaging region to the detector; and,
 - ii) imaging the first distinct imaging regions;
- b) in a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis:
 - i) receiving radiation reflected by a second reflector, the second reflector positioned in the second field of vision, the second reflector being formed so as to reflect radiation from a second distinct imaging region to the detector; and,
 - ii) imaging the second distinct imaging region.

Brief Description of the Drawings

An example of the present invention will now be described with reference to the accompanying drawings, in which: -

Figure 1 is a schematic diagram of an example of an imaging system utilising a parabolic mirror;

Figures 2A and 2B are schematic diagrams of examples of segments of image coverage for the apparatus of Figure 1;

Figures 3A and 3B are examples of raw and stretched images generated using the apparatus of Figure 1;

Figure 4A is a schematic diagram of a first example of apparatus for imaging distinct imaging regions;

Figures 4B and 4C are schematic diagrams of examples of raw and inverted image segments for the apparatus of Figure 4A obtained by dividing the image plane horizontally into two parts; ;

Figures 4D is a schematic diagram of an example of image segments for the apparatus of Figure 4A by dividing the image plane vertically into two parts;

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Figures 5A and 5B are examples of raw and inverted images generated using the apparatus of Figure 4A;

Figure 6A is a schematic diagram of a second example of apparatus for imaging distinct imaging regions using two imaging modules to provide four directional viewing;

5 Figure 6B is a schematic diagram of an example of the image coverage provided on a single display for the apparatus of Figure 6A;

Figure 6C is a schematic diagram of an example variation of the apparatus of Figure 6A;

Figure 6D is a schematic diagram of an example of the two-directional image coverage provided by one of the modules of Figure 6C;

10 Figure 6E is a schematic diagram of an example of the four-directional image coverage provided by the modules of Figure 6C;

Figure 6F is a schematic diagram of a front view of another example of apparatus for imaging distinct imaging regions using two imaging modules to provide directional viewing;

Figure 6G is a schematic diagram of a side view of the apparatus of Figure 6F;

15 Figure 6H is a schematic diagram of a plan view of the apparatus of Figure 6F;

Figure 6I is a schematic diagram of a third example of modular apparatus for imaging distinct imaging regions using three imaging modules to provide six directional viewing;

Figure 6J is a schematic diagram of a side view of the example of Figure 6I;

Figure 6K is a schematic diagram of a side view of the example of Figure 6I, including a lens;

20 Figure 6L is a schematic diagram of a plan view of the example of Figure 6I;

Figure 6M is an example of the apparatus of Figure 6J using a right angle prism as the reflector;

Figure 6N is an example image received post-processing from Figure 6I;

25 Figure 7A is a schematic diagram of a fourth example of an apparatus for imaging distinct imaging regions to provide three directional viewing;

Figure 7B is a schematic diagram of a fifth example of an apparatus for imaging distinct imaging regions to provide four directional viewing;

Figure 7C is a schematic diagram of a front view of Figure 7B;

30 Figure 7D is a schematic diagram of a plan view of Figure 7B showing the division of the image plane and the direction of imaging;

Figure 7E and Figure 7F are schematic diagrams showing the FOV splits;

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Figure 7G is a schematic diagram of another example of an apparatus for imaging distinct imaging regions to provide four directional viewing, similar to that of Figure 7B, with the 360 degrees coverage;

Figure 7H is a schematic diagram of a side view of the apparatus of Figure 7G;

5 Figure 7I is a schematic diagram of a plan view of Figure 7D showing the division of the image plane and the direction of imaging;

Figures 8A and 8B are schematic diagrams showing the division of the image plane and the direction of image coverage for the apparatus of Figure 7A;

10 Figure 8C is an example of an image generated using the apparatus of Figure 7A by dividing the image plane vertically into four parts;

Figure 9 is a schematic diagram of the image coverage using four imaging modules formed from the apparatus of Figure 7A orientated to provide 360° coverage;

Figure 10A is an example of an image formed using the apparatus of Figure 7A dividing the image plane horizontally into four parts;

15 Figure 10B is an example of image formed using the apparatus of Figure 7A dividing the image plane vertically into four parts;

Figures 11A to 11C are schematic diagrams of alternative apparatus arrangements to divide the image plane immediately after the detector; and,

20 Figure 12 is a schematic diagram of an example of a processing system for performing image manipulation;

Figure 13 is a schematic diagram of an example application of the apparatus described; and,
Figure 14 is a schematic diagram of an example application of the apparatus described.

Detailed Description of the Preferred Embodiments

25 In the description below, for the purpose of explanation only, it is assumed that the apparatus includes a detector having an axis aligned in a vertical direction. Accordingly, the terms "vertical" and "horizontal" are intended to mean parallel and perpendicular to the detector axis, respectively. However, it will be appreciated that in practice the detector axis may be provided at any orientation and use of the terms "horizontal" and "vertical" is not intended to be limiting.

30 A method of providing panoramic viewing using a parabolic mirror is shown in Figure 1.

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In Figure 1, a detector 5, a parabolic reflector 15 and a lens 10 are arranged as shown. In use, the detector 5, such as a camera or the like, receives radiation shown generally at 8, from areas around the parabolic mirror 15, where the radiation is directed towards the detector 5 and focused by the lens 10, such that the camera can generate an image.

5 As shown in Figures 2A, 2B, 3A, and 3B the resulting image does not fully utilise the whole detector plane (only approximately 50% is used), and is usually distorted. Figure 2A shows the unused detector area 20 and used detector area 22. Generally, the used detector area 22 can be divided into front (F), Left (L), Back (B) and Right (R) views which are stretched to form an expanded view (as shown in Figures 2B and 3B). The operation of stretching the
10 image requires image-processing to generate the image shown in Figure 3B, which can be quite complex depending on the parabolic mirror used. Additionally, the the image is distorted which can represent a problem as the stretched image is not easy to visualise.

Figure 4A shows an example of an alternative imaging apparatus 25. The apparatus 25 includes a detector 28 that can image over an image plane 36, and a reflector 30 positioned in
15 the field of vision, so as to divide the image plane into two halves. The reflector 30 is arranged so as to reflect radiation 34 from distinct imaging regions 33A and 33B, to the detector 28, which is responsive to the radiation 34 to form an image of the distinct imaging regions 33A and 33B. Notably, the reflector 30 can have one or more reflecting surfaces. The reflecting surfaces can be plane, cylindrical or spherical. The apparatus 25 can also include a
20 lens system 32, which can be a part of the detector 28 or be separate to the detector 28, and which operates to focus the radiation on to the detector 28. The lens system 32 can be a single or group of lens to also expand or converge the field of view of the detector.

In one specific example, the reflector 30 has an apex 31 that separates the reflector 30 into portions 37A, 37B, each portion 37A, 37B reflecting radiation 34 from respective distinct
25 imaging regions 33A and 33B to the detector 28. Accordingly, the detector 28 receives an image formed from two distinct imaging regions 33A and 33B.

When the regions 33A, 33B are imaged, the arrangement of the reflector 30 causes the lower edge of each imaging region 33A, 33B, to be reflected towards the centre of the detector 28. Consequently, the images from the regions 33A, 33B are relatively inverted, as shown for
30 example, in Figure 4B. To obviate this, image-processing software may be used to correct

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the image inversion, by simply inverting one half of the resulting overall image as shown in Figure 4C, in which the image from the imaging region 33B is inverted, as shown. As this requires mere reflection of one half of the image, and does not require distortion correction, this is computationally simpler and can be performed on images relatively easy and fast.

- 5 An example of actual images captured using such an arrangement is shown in Figure 5A, which shows the raw image, with an example of an inversion corrected image being shown in Figure 5B.

10 In any event, it can be seen that the apparatus 25 utilises all of the available area image plane of the detector, and furthermore, by using planar reflectors 30 eliminates distortion and allows for the image to be made up of distinct, discrete images from each area. Thus, the apparatus 25 does not generally require complex image processing in order to obtain an image.

Due to the common aperture, there will some image overlap from the left to the right and vice versa. The amount of image overlap can be kept to a minimum by reducing the aperture of the camera 28 objective lens and placing the vertex of the reflecting surfaces further away from the camera 28. For practical purposes, a small amount of image overlap is acceptable to keep the reflecting surfaces small.

20 In one example, the detector 28 is a camera, CCD array, or the like, and the reflector 30 is a mirror (such as a plane mirror, cylindrical or spherical convex mirror, cylindrical or spherical concave mirror, or the like) or a prism.

Typically, a commercial imaging detector or camera has a standard format of 4:3 aspect ratio. This determines a horizontal field of view (HFOV) and a vertical field of view (VFOV) with the same aspect ratio. It will therefore be appreciated that the area of imaging region that can be viewed, may depend on relative alignment of the detector 28 and the reflector 30. Additionally, it may also depend on the angle of the reflector relative to the camera and shape of the reflector 30. Thus, in one example, a simple right angle reflecting prism is used so that the image is generally not distorted and only simple image processing is required. Additionally, in one example, the image processing performed is usually simplified as the

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processing can be performed separately for each distinct imaging region, and not necessarily of the entire image.

Thus, in the example of Figure 4B, reflector is aligned with the image plane 36 so that the VFOV of the detector 28 is split, such that aspect ratio of each imaging area 33A, 33B is 4:1.5. However, alternatively, the HFOV can be split, to provide images having aspect ratios of 2:3, as shown in Figure 4D.

This can be useful for example, when it is desired to image a wide area. For example, if it is required to provide a panoramic shot, using only two imaging areas, this requires the detector to have a 180° HFOV for each imaging region 33A, 33B. Assuming the VFOV is split, and assuming a 4:3 aspect ratio detector, each imaging area 33A, 33B will have a VFOV given by:

$$(180 \times 3/4)/2 = 67.5^\circ$$

However, if the HFOV is split, each imaging region 33A, 33B will have a VFOV given by:

$$(180 \times 4/3)/2 = 120^\circ$$

Accordingly, in some circumstances, it may be more appropriate to split the HFOV or the VFOV, depending on the output required.

The above described apparatus can also be used in modular form, thereby allowing the outputs from a number of modules to be combined, as shown for example in Figures 6A, 6C, 6F, 6G, 6I, 6M, and 14 .

Notably, elements of Figure 6A to 6N, which are similar to the elements of Figure 4A are referenced numerically with an increase of 600.

In this example, the apparatus of Figure 6A is formed from two modules 625A, 625B, each of which corresponds to the apparatus 25 shown in Figure 4A, with the two modules are aligned along a common axis and rotated at 90° about the axis with respect to each other for imaging distinct imaging regions, to thereby provide four directional views. Use of appropriate 90° FOV optics, allows this arrangement to provide a 360° coverage, as will now be described.

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Utilising the modular arrangement provides a greater degree of flexibility and in particular can be used to increase the area that can be imaged at higher magnification. Thus in this example, with two modules 625A, 625B, it is possible to image in four different directions. Furthermore, with both modules aligned along an axis 601, this allows four directions
5 extending radially outwardly from the axis to be imaged, thereby providing front 639A, back 639B, right 639C and left 639D views. An example of this is shown in Figure 6B, which represents the image segments as presented on a display, such as a TV monitor, or the like.

Accordingly, by providing modules with axes aligned in parallel to axis 601, and rotationally offset with respect to each other, this allows a number of different directions extending
10 radially outwardly from the unit to be imaged. Notably, in this example, the reflector 630A and 630B are identical, and in particular, the reflector 630A and 630B will only be identical if the centre line of sight is perpendicular to the axis of the detectors 628A, 628B.

Figure 6C shows an alternative version of the apparatus of Figure 6A, where a right angle reflecting prism is used as the reflectors 630A 630B. Notably, in this example, the angle of
15 elevation of the lower module 625B is not in line with the upper module 625A. The centre line of sight of the lower module 625B is pointing upward and the centre line of sight of the upper module 625A is pointing downwards. Accordingly, although identical reflectors 630A, 630B can be used, it may be required to use varying reflectors 630A, 630B, if the centre line of the field of view is not in the horizontal plane (as described below).

20 Thus, the apparatus of Figure 6C can be used to provide four directional views, by having each of the modules 625A, 625B provide a two-directional split (as shown in Figure 6D), to thereby provide four imaging areas (as shown in Figure 6E).

However, this form of arrangement generally only allows imaging to occur in a plane substantially perpendicular to the axis.

25 Accordingly, an alternative arrangement shown in Figures 6F to 6H may be used. In this example, two detectors 628A and 628B are provided, having respective axes 605A and 605B laterally spaced from each other. Each detector 628A and 628B is associated with a respective reflector 630A and 630B, with the reflectors 630A, 630B, being positioned in the respective detectors 628A, 628B field of vision for reflecting radiation from the distinct

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imaging regions to the respective detectors 628A, 628B, allowing the detectors 628A, 628B to image the distinct imaging regions.

In this particular example, as shown in Figures 6F to 6H, each detector 628A, 628B is associated with respective optics in the form of reflectors 630A, 630B, which divide the FOV
5 of the detectors 628A, 628B. As a result, each detector receives radiation from two opposite directions (as shown in Figure 6F). Notably, by arranging the detectors 628A, 628B in this way, where each detector 628A, 628B images over a 90° horizontal field of vision (as shown in Figure 6F), a 360 degree field of vision can be obtained. Furthermore, as shown in the
10 Figures 6G and 6H, the detectors 628A, 628B can be offset in a direction parallel to the axes, such that, for example, one detector 628A is at a higher horizontal plane than the detector 628B, to ensure an unobstructed view is provided in all directions.

It will be further appreciated that the examples shown in Figures 6F to 6H can provide numerous advantages, which can include:

- 15 • having identical modules consisting of detectors 628A, 628B and reflecting optics 630A and 630B so that production/manufacturing of the device is more efficient
- the image distortion of views 1 to 4 as shown in Figures 6F to 6H are similar, which can make image processing easier
- the image overlap of view 1 and 3, and image overlap of view 2 and 4 are similar, which can also make image processing easier (as shown in Figure 6H)
- 20 • the vertical field of view is enhanced as it is double that of when a single detector is used
- the apparatus is able to image not only in a plane perpendicular to the axis, but also in other directions, allowing imaging to be performed over a hemisphere by using appropriate reflectors and detector positioning, which cannot be achieved
25 using the configuration of Figure 6A

Furthermore, it will also be appreciated that the apparatus of Figures 6F to 6H can provide advantages over that of Figure 6A. For example, as the apparatus of Figure 6F to 6H are not axially aligned, the apparatus can be manufactured so that it is a relatively smaller in an axial direction than the apparatus of Figure 6A. This reduced length can allow for ease of
30 manufacturing (due to reduced volume), ease of storage, use and the like.

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Additionally, it will be appreciated that in comparison to the example of Figure 6A, when the apparatus of Figures 6F to 6H is placed on a surface, the apparatus does not extend from the surface as far as the apparatus of Figure 6A, due to the reduced overall length. This can allow for imaging closer to the particular surface as well as a reduction in the overall height of the apparatus, making the apparatus suitable for use in a wider range of applications.

In another example, Figures 6I to 6N show modules 625A, 625B, 625C, each of which have parallel axes, with the three modules being rotationally offset by 60° . Notably, each module 625A, 625B, 625C, includes respective reflectors 630A, 630B, 630C, which divert the field of view of each respective detector 628A, 628B, 628C into two opposite directions.

By arranging three modules 625A to 625C, each having 60° field of vision (as shown in Figure 6L), a 360° field of vision can be obtained. This allows 6 different directions to be imaged (these directions are indicated as 1 to 6 in Figure 6L). This in turn enables all round surveillance with a 60° FOV optics to provide higher magnification of imaged objects at further distance.

Notably, the modules 625A to 625C in this example are placed in the same horizontal plane. Furthermore, Figures 6J and 6K show an example side view of the module 625C, where Figure 6K is an alternative example including a lens 632.

It will be appreciated that the example shown in Figures 6I to 6M can provide certain advantages. These advantages can include:

- the use of identical modules so that the device is easier to produce/manufacture
- the example shown has a lower image distortion as the FOV of each module is generally smaller than if two detectors are used
- the example shown can use a smaller reflector as the FOV of the module is also relatively small (in comparison to using two detectors). This is usually important for use in optics with large apertures such as a thermal imaging cameras and low light CCD cameras
- a higher resolution is typically provided since the FOV of the modules is generally smaller than if two detectors are used
- the design is scalable to provide longer range performance

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Consequently, by providing a suitable number of modules and detectors, this can allow for a number of desired directions to be imaged. An example of an image obtained by the apparatus of Figure 6I to 6M is shown in Figure 6N. Fig 6M is a picture of an example apparatus of Figure 6I.

5 Figures 7A to 7I show another example of an apparatus for imaging where the apparatus includes a detector 728 and a plurality of reflectors 730A and 730B, such as reflecting mirrors or the like, to further sub-divide each imaging region, and allow additional imaging regions to be formed.

10 Notably, elements of Figure 7A to 7I, which are similar to the elements of Figure 4A are referenced numerically with an increase of 700.

15 In particular, Figure 7A shows a detector 728 having a field of vision, a first reflector 730A positioned in the field of vision for dividing the field of vision into first and second fields of vision (not shown), and a second reflector 730B positioned in either of the first and second fields of vision, such that radiation 734 reflected from the first and second reflectors 730A, 730B can be used by the detector 728 to image the imaging regions.

20 Figure 7B shows an alternative example to the apparatus shown in Figure 7A, where an extra reflector 730C is also used to image a fourth imaging region. Thus, in this example, a combination of the prisms 730A and reflective mirrors 730B, 730C are used to provide four directional views using a single camera 728, by dividing the image plane 736 into four parts, to thereby provide four imaging areas. Again, this can be done by splitting the detector's VFOV, into four effective parts, front 39A, back 39C, right 39B and left 39D, as shown in Figures 8A and 8B. This effectively increases the detector's HFOV by four times. Alternatively, the HFOV can be split, as shown in Figure 8C.

25 It will be appreciated that any number of and different shape of reflectors can be used and that they can be placed in any particular position around the detector, depending on the regions that are to be imaged.

In particular, Figures 7C and 7D show reflectors 730A to 730C, diverting the FOV of the detector 728 into 4 orthogonal directions. In this example, the first and second reflecting surfaces divide the field-of-view into the left and right directions. The reflected FOVs are

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further divided by another 2 reflecting surfaces to redirect part of the FOV to forward and backward directions. The FOV obtained is shown in Figure 7D (with the direction being indicated as 1 to 4), with each split being shown in Figures 7E and 7F.

In another example, Figures 7G and 7H show the apparatus of Figure 7C having lenses 732 placed in varying positions around the detector 728 and the reflectors 730A to 730C. By designing appropriate curvature on the reflecting surfaces of the reflectors 730C with appropriate cylindrical lenses 732 to provide a horizontal FOV of 90 degrees in each direction, a complete 360 degrees FOV image can be obtained. This direction is indicated as 1 to 4 in Figure 7I.

It will be appreciated that the device described in Figures 7A to 7I can provide numerous advantages, including but not limited to:

- only one camera is required to provide 360 degrees FOV
- the image distortion is low compared to parabolic mirror solutions
- almost 100% utilization of the camera active detector pixels (trade off between size and overlap of images)
- no effect on the camera resolution, hence the range performance is as good as the camera itself
- no effect on the aperture of the camera. Hence the sensitivity of the camera remains as effective under low light condition.
- simple image processing to invert and align the image.
- low latency as the image processing is relatively simple.

Notably, the design of the apparatus shown in Figures 7A to 7I is scalable to provide longer range performance. Figure 9 is an example of four modules concept basing on Figures 7A to 7I. In this case, the horizontal FOV of each camera is reduced to 22.5 degrees.

A further variation is for the reflector 730A to split the HFOV of the detector, whilst the additional reflectors 730B, 730C, effectively split the VFOV (or vice versa), so that original aspect ratios are maintained, albeit at a reduced resolution.

The configuration shown in Figures 7A to 7I can again be used in a modular fashion to provide an effective 360° HFOV. An example of this is shown in Figure 9, in which four

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detectors 40A, 40B, 40C, 40D are provided in separate modules, with each module being offset at an angle of 45 deg. as shown. In this example, each detector has its VFOV split, to thereby image corresponding regions A1, A2, A3, A4,

The outputs from the detectors 40A, 40B, 40C, 40D are provided to a processing system 50, which operates to display the resulting imaging areas as shown at 42A, 42B, 42C, 42D. In this instance, it can be seen that appropriate alignment of the images on the display allows quadrants Q1, Q2, Q3, Q4 to be displayed as shown. An example of the resulting image of each detector is shown in Figure 10A.

In this example, the VFOV of each detector 40 is split to provide the respective imaging region. Accordingly, assuming each detector has a HFOV of 22.5° and VFOV of 16.9° , the total HFOV becomes 90° (22.5×4) for each detector, which provides 360° coverage over all four detectors. In this instance, the VFOV will be approximately 4.2° . However, the HFOV can be any value, but is typically has a HFOV between 22.5 and 90 degrees relative to the detector axis, and a VFOV between 16.9 to 67.5 degrees relative to the detector axis,

However, if the VFOV is too small, then the system and modules can be designed to divide the HFOV into four directions, thereby giving a larger VFOV, as shown for example in Figure 10B. In this example, more detectors may be needed to provide an equivalent HFOV, although this will depend on the original FOV of the detectors.

It will be appreciated by persons skilled in the art, that alternative configurations of the apparatus 25 are possible. In one example, reflectors 30 can be placed immediately after the detector 28, with a variety of lens systems 37, as show in Figures 11A to 11C. Further variations are also possible by changing the angle of the apex or positioning of the reflectors and using cylindrical or spherical concave or convex mirrors. Use of such means can provide a device with adjustable angle of elevation and adjustable vertical field of view

As mentioned above, image processing may be used to invert images. This is typically performed by a processing system, such as the processing system 50 of Figure 9 or a processor embedded within or forming a part of the detector. It will be appreciated that image processing can be performed by any suitable processing system, and an example of a suitable system will now be described with respect to Figure 12.

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In this example, the processing system 50 includes at least a processor 52, a memory 56, an input/output (I/O) device 54, such as a keyboard, and display, and an external interface 58, coupled together via a bus 60 as shown. The processing system can include or is able to communicate with a data store or the like 62.

5 Thus, in a particular example, the image formed can be displayed on the display or any other I/O device 54, and in surveillance applications, the images displayed can be recorded and stored in the data store 62, either prior to, or post manipulation.

10 Accordingly, it will be appreciated that the processing system 50 may be formed from any suitable processing system, such as a suitably programmed PC, Internet terminal, lap-top, hand-held PC, or the like, which is typically operating applications software to enable image manipulation, recordal and display.

15 Accordingly, the above described systems operate by using a reflector to divide the detector image plane into discrete sections. This has the effect of changing the format of the generated images from a standard 4:3 to 8:1.5, 16:0.75, 6:2 or 12:1, or the like, depending on the particular configuration used. This allows standard and existing detectors to be used to cover as much of an area of interest with almost 100% (with a small allowable image overlap) use of the effective detector area, whilst providing low distortion images. Furthermore, by scaling the system through the use of multiple modules, this can provide all round surveillance at far distance.

20 Accordingly, the systems described above can provide numerous advantages. The apparatus is a simple and effective optical device for all round surveillance system or photograph taking and video recording. It is essentially a low cost solution with no moving parts and requires a minimal number of cameras for operation.

25 Additionally, the image generated is often clear and distortion is minimal, thereby facilitating visualisation. The apparatus 25 is also generally easy to set up and simple and easy to implement. Additionally, the image processing required is generally straightforward and simple, thereby improving the efficiency of the system.

Furthermore, the system provided uses a non-scanning method that is simple and reliable. The system also uses continuous staring thereby providing the possibility of near real time

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surveillance, uses the full detector view and is thus efficient, is scalable in order to provide longer range performance (as in the modular design), and the system is low cost and easy to use thereby providing the potential for 24 hour availability

5 It will be appreciated that the potential applications and implementations for the apparatus described can include but are not limited to an add on device to a personal camera for 360 degrees photography, a mast mounted system for situation assessment, a navigation system for unmanned vehicle, a vehicle mounted system for driving, a ceiling mounted system for room surveillance, a wall mounted system for perimeter surveillance, stabilised mounting on a boat for search and rescue operations, a mounted system in the upright position for aerial
10 surveillance, or an inverted system for ground surveillance (as shown in Figure 13), a device for surveillance both inside and outside a vehicle (as shown in Figure 14) and as a balloon mounted system for situation control and crowd management. The above described techniques can be applied to both day and night cameras.

15 In one particular example, Figure 14 shows the apparatus described used as a surveillance device mounted on the driver's rear-view mirror. This can be used by the driver to provide a 360° view of both inside and outside of the car, for driving or for security purposes. Thus, the driver may be able to obtain images on a screen mounted in the dashboard, or via a network from a remote location to the car, for checking the security of the car. It will be appreciated that the dimensions and angles shown in Figure 14 are for illustrative purposes only.

20 It will further be appreciated that when used to provide for 360° photography, the apparatus may be formed from a housing enclosing any required lenses 32, and the reflector 30, and which can be coupled to the body of an existing camera. This allows the camera detector, to be used as the detector 28, as will be appreciated by persons skilled the art. This may be achieved through the use of a suitable coupling as provided for example on digital or film
25 based SLR (single-lens reflex) cameras.

Furthermore, given that the system is able to direct and maximise the usage of detector image plane, it is particularly suited for systems requiring expensive detector systems, or in situations in which the number of pixels in the imaging array is limited, as occurs for example, in thermal imaging detectors, or the like.

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Persons skilled in the art will appreciate that numerous variations and modifications will become apparent. All such variations and modifications which become apparent to persons skilled in the art, should be considered to fall within the spirit and scope that the invention broadly appearing before described.

AN IMAGING APPARATUS

CLAIMS

- 1) An apparatus for imaging, the apparatus including:
 - a) a detector having a field of vision;
 - 5 b) at least one first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision; and,
 - c) at least one second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective field of vision such that the first and second reflectors reflect radiation from distinct imaging regions to the detector, the
10 detector being responsive to the radiation to image the distinct imaging regions.
- 2) The apparatus of claim 1, wherein the apparatus includes a second reflector positioned in each other of the first and second fields of vision for further dividing the respective field of vision.
- 3) The apparatus of claim 1, wherein the first reflector has an apex, the apex separating the
15 reflector into portions, and wherein in use, the first reflector is positioned with the apex in the field of vision, such that each portion reflects radiation from a respective distinct imaging region to the detector.
- 4) The apparatus of claim 3, wherein the apex is positioned in the field of vision so as to divide at least one of:
 - 20 a) a horizontal field of view; and,
 - b) a vertical field of view.
- 5) The apparatus of claim 3 or claim 4, wherein the detector has an axis, and wherein the apex is aligned with the axis.
- 6) The apparatus of any one of the claims 1 to 5, wherein each imaging region has a field of
25 view and wherein either one or a combination of the first reflector, second reflector and the third reflector is positioned in the field of vision to optimise the field of view for each imaging region.
- 7) The apparatus of any one of the claims 2 to 6, wherein apparatus includes a number of modules, each module being formed from apparatus according to claim 1, and each
30 module being aligned at relative angles to allow at four least four directional viewing.
- 8) The apparatus of claim 7, wherein the apparatus includes four modules arranged at an offset angle of 45 degrees.

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- 9) The apparatus of claim 2, wherein the distinct imaging regions are from four different directions, thereby forming a four directional viewing.
- 10) The apparatus of claim 9, wherein the field of vision has a HFOV between 22.5 and 90 degrees relative to an axis of the detector, and a VFOV between 16.9 to 67.5 degrees, relative to the axis of the detector.
- 11) The apparatus of claim 11, wherein the HFOV x VFOV is 45 degrees x 8.4 degrees.
- 12) The apparatus of claims 1 to 11, wherein the apparatus further includes a processing system for processing images from the distinct imaging regions.
- 13) The apparatus of claim 12, wherein the apparatus further includes at least one display for displaying images.
- 14) The apparatus of claim 12 or claim 13, wherein the apparatus further includes a store for recording at least one image.
- 15) The apparatus of any one of the claims 2 to 15, wherein the detector includes a lens and a detector body.
- 16) The apparatus of claim 15, wherein any one or a combination of the first reflector, the second reflector, and the third reflector is placed between the lens and the detector body.
- 17) The apparatus of any one of claims 2 to 16, wherein any one or a combination of the first reflector, the second reflector and the third reflector is a mirror.
- 18) The apparatus of claim 17, wherein the mirror is at least one of:
- a) a folding mirror;
 - b) a concave mirror; and,
 - c) a convex mirror.
- 19) The apparatus of any one of claims 2 to 18, wherein any one or a combination of the first reflector, the second reflector, and the third reflector is a prism.
- 20) The apparatus of any one of claims 1 to 19, wherein the detector is a camera.
- 21) The apparatus of claim 23, wherein the camera is at least one of:
- a) a day camera;
 - b) a night camera; and,
 - c) a thermal imaging camera.
- 22) An apparatus for imaging, the apparatus including:
- a) a first detector having a first field of vision substantially aligned along a first axis;

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- b) a first reflector positioned in the first field of vision for reflecting radiation from a distinct first imaging region to the detector, the detector being responsive to the radiation to image the distinct first imaging region;
- c) a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis;
- d) a second reflector positioned in the second field of vision for reflecting radiation from a distinct second imaging region to the second detector, the second detector being responsive to the radiation to image the distinct second imaging region.

23) The apparatus of claim 22, wherein the first detector and the second detector are in the same horizontal plane.

24) The apparatus of any one of claims 22 and 23, wherein the apparatus further includes:

- a) a third detector having a second field of vision substantially aligned along a third axis, the third detector being positioned with the third axis laterally spaced from the first axis and the second axis;
- b) a third reflector positioned in the field of vision for reflecting radiation from distinct third imaging regions to the third detector, the third detector being responsive to the radiation to image the distinct third imaging regions.

25) The apparatus of claim 24, wherein the third detector is spaced at a 60 degree angle from the second detector, and the second detector is spaced at a 60 degree angle from the first detector, thereby providing a 360 degree field of vision.

26) The apparatus of claim 22, wherein the first detector is staggered on top of the second detector.

27) A method for imaging, the method including the steps of, in a detector having a field of vision:

- a) receiving radiation from at least one first distinct imaging region, the radiation being reflected by a first reflector, the first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision,
- b) receiving radiation from at least one second distinct imaging region, the radiation being reflected by a second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective fields of vision; and,
- c) imaging the distinct imaging regions.

28) The method of claim 27, the method being performed using the apparatus of any one of claims 1 to 21.

29) An apparatus for providing images for security surveillance of distinct imaging regions, the apparatus including:

- 5 a) a detector having a field of vision;
- b) at least one first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision;
- c) at least one second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective field of vision such that the first and second reflectors reflect radiation from distinct imaging regions to the detector, the
10 detector being responsive to the radiation to image the distinct imaging regions.

30) The apparatus of claim 29, wherein the apparatus is the apparatus of any one of claims 1 to 21.

31) A method for providing images for security surveillance of distinct imaging regions, the
15 method including the steps of, in a detector having a field of vision:

- a) receiving radiation from at least one first distinct imaging region, the radiation being reflected by a first reflector, the first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision,
- b) receiving radiation from at least one second distinct imaging region, the radiation
20 being reflected by a second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective fields of vision; and,
- c) imaging the distinct imaging regions.

32) The method of claim 31, the method being performed using the apparatus of any one of claims 1 to 21.

25 33) An apparatus for providing images using a camera system, the apparatus including:

- a) a housing for coupling to the camera system, the camera system including a detector having a field of vision;
- b) a first reflector provided in the housing, such that as the housing is coupled to the camera system, the first reflector is positioned in the field of vision for dividing the
30 field of vision into first and second fields of vision;
- c) a second reflector provided in the housing, such that as the housing is coupled to the camera system, the second reflector is positioned in a respective one of the first and

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second fields of vision for further dividing the respective field of vision such that the first and second reflectors reflect radiation from distinct imaging regions to the detector, the detector being responsive to the radiation to image the distinct imaging regions.

- 5 34) The apparatus according to claim 33, wherein the camera system is a photographic camera system.
- 35) Apparatus according to claim 34, wherein the housing includes a lens mount for coupling the housing to a body of the camera system.
- 36) Apparatus according to any one of the claims 33 to 35, wherein the apparatus is apparatus
10 according to any one of the claims 1 to 21.
- 37) A method for providing images using a camera system, the method including:
- a) receiving radiation from at least one first distinct imaging region, the radiation being reflected by a first reflector, the first reflector positioned in the field of vision for dividing the field of vision into first and second fields of vision,
 - 15 b) receiving radiation from at least one second distinct imaging region, the radiation being reflected by a second reflector positioned in a respective one of the first and second fields of vision for further dividing the respective fields of vision; and,
 - c) imaging the distinct imaging regions.
- 38) A method according to claim 35, wherein the method is performed using the apparatus of
20 any one of the claims 33 to 36.
- 39) A method for imaging, the method including the steps of:
- a) in a first detector having a first field of vision substantially aligned along a first axis:
 - i) receiving radiation reflected by a first reflector, the first reflector positioned in the first field of vision, the first reflector being formed so as to reflect radiation from a
25 first distinct imaging region to the detector; and,
 - ii) imaging the first distinct imaging regions;
 - b) in a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis:
 - 30 i) receiving radiation reflected by a second reflector, the second reflector positioned in the second field of vision, the second reflector being formed so as to reflect radiation from a second distinct imaging region to the detector; and,

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ii) imaging the second distinct imaging region;

40) The method of claim 39, wherein the method further includes forming an image including the imaged first distinct imaging region and the second distinct imaging region.

41) The method of any one of claims 39 to 40, the method being performed using the apparatus of any one of claims 22 to 26.

42) An apparatus for providing images for security surveillance of distinct imaging regions, the apparatus including:

a) a first detector having a first field of vision substantially aligned along a first axis;

b) a first reflector positioned in the first field of vision for reflecting radiation from a distinct first imaging region to the detector, the detector being responsive to the radiation to image the distinct first imaging region;

c) a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis;

d) a second reflector positioned in the second field of vision for reflecting radiation from a distinct second imaging region to the second detector, the second detector being responsive to the radiation to image the distinct second imaging region.

43) The apparatus of claim 42, wherein the apparatus is the apparatus of any one of claims 22 to 26.

44) A method for providing images for security surveillance of distinct imaging regions, the method including the steps of:

a) in a first detector having a first field of vision substantially aligned along a first axis:

i) receiving radiation reflected by a first reflector, the first reflector positioned in the first field of vision, the first reflector being formed so as to reflect radiation from a first distinct imaging region to the detector; and,

ii) imaging the first distinct imaging regions;

b) in a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis:

i) receiving radiation reflected by a second reflector, the second reflector positioned in the second field of vision, the second reflector being formed so as to reflect radiation from a second distinct imaging region to the detector; and,

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ii) imaging the second distinct imaging region.

45) The method of claim 44, the method being performed using the apparatus of any one of claims 22 to 26.

46) An apparatus for providing images using a camera system, the apparatus including:

- 5 a) a housing for coupling to the camera system, the camera system including a first detector having a first field of vision substantially aligned along a first axis;
- b) a first reflector provided in the housing, such that as the housing is coupled to the camera system, the first reflector is positioned in the field of vision, for reflecting radiation from a distinct first imaging region to the first detector, the first detector
10 being responsive to the radiation to image the distinct first imaging region;
- c) the camera system further including a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis; and,
- d) a second reflector provided in the housing, the second reflector positioned in the
15 second field of vision for reflecting radiation from a distinct second imaging region to the second detector, the second detector being responsive to the radiation to image the distinct second imaging region.

47) An apparatus according to claim 46, wherein the camera system is a photographic camera system.

20 48) Apparatus according to claim 47, wherein the housing includes a lens mount for coupling the housing to a body of the camera system.

49) Apparatus according to any one of the claims 46 to 48, wherein the apparatus is apparatus according to any one of the claims 22 to 26.

50) A method for providing images using a camera system, the method including the steps of:

- 25 a) in a first detector having a first field of vision substantially aligned along a first axis:
 - i) receiving radiation reflected by a first reflector, the first reflector positioned in the first field of vision, the first reflector being formed so as to reflect radiation from a first distinct imaging region to the detector; and,
 - ii) imaging the first distinct imaging regions;
- 30 b) in a second detector having a second field of vision substantially aligned along a second axis, the second detector being positioned with the second axis laterally spaced from the first axis:

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- i) receiving radiation reflected by a second reflector, the second reflector positioned in the second field of vision, the second reflector being formed so as to reflect radiation from a second distinct imaging region to the detector; and,
 - ii) imaging the second distinct imaging region.
- 5 51) A method according to claim 50, wherein the method is performed using the apparatus of any one of the claims 22 to 26.