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(54) DISTANCE DETECTING APPARATUS

(71) We, HONEYWELL INC., a Corporation organised and existing under the laws of the State of Delaware, United States of America of Honeywell Plaza, Minneapolis, Minnesota 55408, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to distance detecting apparatus and has particular application to cameras and to automatic focussing systems therefor.

According to the invention, there is provided apparatus for detecting the distance of an object from the apparatus, comprising first and second radiation detectors each including a linear array of elements each responsive to radiation to produce an electrical signal, the arrays being part of an integrated circuit chip; first and second optical means for forming on the first and second detectors respectively first and second images of the object; a signal processor formed on said chip and electrically connected to the elements to compare the signal from each element of one array with that from a corresponding element of the other array to produce an output signal; a housing providing a common support for integrated circuit chip and the said first and second optical means; means for permitting relative movement between one of the detectors and its respective image to enable the radiation distributions on the detectors to be brought into a condition of best correspondence, thereby to decrease the value of the output signal toward a minimum value indicative of said best correspondence condition; and means responsive to the output signal to detect the occurrence of said minimum, the extent of said relative movement being representative of the distance of the object from the apparatus.

An embodiment of the invention will now be described by way of example only with reference to the accompanying drawings in which:—

Figure 1 is a schematic diagram of an automatically focussing camera;

Figure 2 is a schematic diagram of a modification of the camera of Figure 1 and in accordance with the present invention;

Figure 3 is a front view of the light responsive element of Figure 2.

Figures 4 to 8 are further modifications of the camera of Figure 1 in accordance with the present invention.

Referring to the drawings in more detail, the camera includes a first detector 1 and a second detector 3. Each detector is made up of a linear array of a plurality of individual light responsive elements. In the present example, the first detector 1 includes four light responsive elements, 5, 7, 9 and 11. The second light detector 3 also includes four light responsive elements 13, 15, 17 and 19. The light responsive elements are photo-resistive elements. The elements in the first detector 1 have a common terminal 21 connected to a first reference potential +V. The photo-resistive elements of the second detector means 3 also have a common terminal 23 which is connected to a second reference potential -V. Each photo-resistive element is insulated from the others by an insulating material 25. Although but four light responsive elements are shown in each detector in the illustrative example, it will be appreciated that any number of detector elements may be used. The more elements that are used in each of the detectors, the greater will be the definition and reliability of the results obtained therefrom. A first lens 27 and a second lens 29 represent means for forming a first and second image of a relatively distant object. The two detectors 1 and 3 are positioned in coplanar relationship with respect to each other. Although the schematic representation in Figure 1 shows the faces of the light detector means 1 and 3, it is understood that the faces which include the light responsive elements of the first and second detectors 1 and 3 are in actual construction facing the first and second lenses 27 and 29 to receive the radiation passing there-through. A first image is therefore formed 100

on the face of the first detector 1 from the radiation passing through the first lens 27, and a second image is formed on the face of the second detector 3 from the radiation passing through the second lens 29. It is not essential that the first and second images be precisely focussed at the plane of the detectors; it is only necessary that the light pattern distribution of the two images can be matched with regard to the respective detectors. In that connection the two images may be significantly out of focus at the plane of the detectors so long as each light pattern formed on the plane of the detectors exhibits a distinguishable spatial radiation distribution.

As illustrated, both lenses 27 and 29 are arranged to form images of the same portion of the remote object or scene. It will be appreciated that both means are arranged to respond to a relatively small angle of view, for example of the order of 1—10 degrees. The image formed by the first lens will be centered with respect to the detector 1, the first lens and detector being positionally fixed and coordinated with respect to a reference point in an associated view finder (not shown). That image will produce a signal at each of the light sensitive elements in the first detector 1, each signal having a magnitude which is a function of the light level of that portion of the image which impinges on that individual element. As the second lens 29 is moved in a direction parallel to that of the linear displacement of the light responsive elements in the second detector 3, the light distribution pattern falling on the second detector 3, which is substantially the same as the light distribution pattern formed on the first detector means 1 through the first lens 27, will be shifted in the direction of the linear displacement of the individual light responsive elements in the second detector 3. Each light responsive element 5, 7, 9 and 11 of the first detector 1 has a corresponding light responsive element 13, 15, 17 and 19, respectively, in the second detector 3. The correspondence is based on the relative location of each light responsive element with respect to the particular array or detector of which it forms a part. As hereinbefore mentioned, each light responsive element in the first and second light detector 1 and 3 has a common terminal connected to a first and second reference potential, respectively. The other terminals of corresponding ones of the light responsive elements 5, 7, 9 and 11 and 13, 15, 17 and 19, are connected together at a common point 31, 33, 35 and 37, respectively, which, in turn, provide respective resultant signals A, B, C, and D for application to a signal processor 39. The signal processor 39 provides an output signal F which is applied

to a control circuit 41. The control circuit is arranged to control the hereinbefore described movement of the second lens 29 and also the focussing movement of an objective lens means 43. The objective lens 43 is arranged to focus a principal image of the object on a light sensitive film 45. To distinguish the image formed on the light sensitive film 45 from the first and second images formed on the first and second detectors 1 and 3, the image formed on the light sensitive film 45 will be hereinafter referred to as the principal image, whereas the first and second images formed on the first and second detectors 1 and 3 will be hereinafter referred to as the first and second auxiliary images.

The control circuit 41 includes a selectivity operable switching member 47. The switching member 47 may be arranged to initiate the focus detecting function of the present apparatus. The switching member 47 is coupled to a switching member 49 which provides a contact closure between a battery 51 and a source of illumination 53. A lens 55 concentrates the illumination from the source onto the object. Thus, the focus detecting system of the present apparatus may be rendered effective, even in an environment having limited ambient illumination, by coupling the simple light producing circuit including the lamp 53 to the control circuit of the focus detecting system of the present apparatus.

If the light intensities falling on the corresponding photo-resistive elements 5 and 13, for example, are equal, the potential drop across the two series-connected corresponding photo-resistive elements 5 and 13 will be equally divided, and therefore the signal A will be substantially zero volts. The common connection between the corresponding photo-resistive elements acts as a comparing means for comparing the intensity of light falling on the corresponding light responsive elements to provide resultant signals A, B, C, and D indicative thereof. The resultant signals, A, B, C and D, when the system is properly focussed will all be substantially zero. The resultant signals are summed in processor 39 and the output signal F from the signal processor 39 will be a minimum when the system is properly focussed. That minimum or valley is detected by the control circuit 41 which, in turn acts to terminate the movement of the second auxiliary lens 29 and the main objective lens 43 when the principal image is properly focussed at the predetermined plane of the light sensitive film 45.

It should be remembered that the first and second auxiliary images appearing on the first and second detectors 1 and 3 do not have to be focussed in order for the present focus detecting apparatus to function

properly. Even when the first and second auxiliary images are not focussed, similar light distribution patterns 65 and 67 will appear upon the faces of the first and second detectors 1 and 3.

When the principal image is not properly focussed, the relative position of the second auxiliary image 67 will be displaced with respect to the second detector. That relative displacement of the second auxiliary image with respect to the second detector 3 will vary as a function of the distance between the camera, for example, and the object to be photographed. The present apparatus operates to sense that displacement and realign the light distribution pattern of the second auxiliary image with the second detector 3 and concurrently move the objective lens 43 in such a manner that the light distribution pattern 67 of the second auxiliary image is made to be coextensive with respect to the second detector 3 proportionately as a light distribution pattern 65 of the first auxiliary image is coextensive with the first detector 1, at which time the principal image formed on the light sensitive film 45 is in focus.

Referring to Figure 2, there is illustrated a different, modular arrangement of the auxiliary image conducting or producing means for the use of a single substrate detector configuration.

Accordingly, in the Figure 2 arrangement, a common substrate detector configuration, including the light responsive elements making up first and second detector arrays 213 and 215, is included as a portion of an integrated circuit chip 217 which, in turn, is included in a module 219. The latter also includes first and second auxiliary lenses 221 and 223, respectively, and a reflecting prism or mirror 225. The chip 217 also includes the signal processor 39 and desirably the control circuit 41, as necessary to cause the chip to produce a logic output signal which shifts from one logic state to the other only upon the occurrence of a minimum difference in the light distribution of the two auxiliary images on the respective detectors 213 and 215.

In addition to the first auxiliary lens 221 and a portion of the prism 225, the means for producing the first auxiliary image on the first detector 213 includes a mirror 227 and an aperture 229. In addition to the second auxiliary lens 223 and a portion of the prism 225, the means for producing the second auxiliary image on the second detector 215 includes a mirror 231 and an aperture 223. The apertures 229 and 233 are desirably so positioned and sized as to confine each of the auxiliary images to the corresponding detector without vignetting either image on the corresponding detector. The paths over which the light passes in

forming the two auxiliary images are shown by light dashed lines in Figure 2.

In the Figure 2 arrangement, the shifting of the second auxiliary image on the second detector, to shift the image light distribution thereon, is accomplished by rotating the mirror 231 about an axis defined by a mirror-supporting shaft 235. To this end, the Figure 2 arrangement includes a motor drive circuit 237 and a motor 239. The latter is coupled to the mirror shaft 235 by a suitable linkage 241 so that rotation of the motor 239 rotates the shaft 235 and hence rotates the mirror 231. A conductor 243 is connected between the output of the chip 217 and the input of the drive circuit 237 to apply to the latter the logic output signal produced by the chip 217. The output of the drive circuit 237 is connected by a conductor 245 to the motor 239. The drive circuit may be simply a transistor power amplifier or switch which energizes the motor 239 for rotation when the logic output signal from the chip 217 has said one logic state, and which stops the rotation of the motor 239 as soon as said logic output signal shifts to said other state, indicative of best auxiliary image light distribution correspondence.

Lens 247 is arranged to produce on a light sensitive film 249 a principal image of the object whose auxiliary images are formed on the detectors 213 and 215. The lens 247 is coupled by a suitable linkage 251 to the motor 239 for simultaneous and correlated movement with the mirror 231. This coupling is so arranged that, when the movement of the mirror 231 by the motor 239 is terminated at the position giving best auxiliary image light distribution correspondence on the detectors 213 and 215, the movement of the lens 247 is simultaneously terminated at the position which gives the best focus of the principal image on the film 249. The mirror 227 is desirably made to be rotatable about its axis to facilitate the initial calibration of the arrangement as necessary to obtain this correlated action.

The operation of the Figure 2 arrangement is the equivalent of that of the Figure 1 arrangement. Thus if the distance from the apparatus to the object changes from one at which the lens 247 was in the position of best focus, the condition of best light distribution correspondence of the auxiliary images of the object on the detectors is lost. The resulting light sensitive element unbalance signals then cause the chip output signal to assume said one state, and the motor 239 is energized to rotate the mirror 231 and to move the lens 247. This rotation of the mirror 231 brings the second auxiliary image light distribution back toward correspondence with the light distribution of the first auxiliary image. When the best

auxiliary image light distribution correspondence is achieved, a signal in the chip circuitry equivalent to the signal F arrives at minimum value. The chip circuitry detects the occurrence of this minimum signal value and switches the chip output signal to its said other state. The operation of the motor 239 is then terminated, with the lens 247 in the position of best focus for the new object distance.

In Figure 3 there is illustrated a desirable configuration for the light responsive elements of the detectors 213 and 215 on the integrated circuit chip 217 of Figure 2. Figure 3 shows each of the detectors 213 and 215 as consisting of eight light responsive elements or areas lying in two slightly vertically displaced horizontal rows along a line or path on the surface of the chip substrate, with the elements of one row of each detector being staggered with respect to the elements of the other row of that detector. The elements of each of the detectors lie very closely together along their path, with the elements forming the detector 213 lying immediately adjacent and coplanar with the elements forming the detector 215. Figure 3 shows the lenses 221 and 223 positioned with respect to the chip 217 so as to produce the auxiliary images on the elements of the corresponding detector.

The elements making up the detector 213 and 215, along with the above-noted signal processor interconnecting those elements, can desirably be formed on the chip 217 using the known large scale integration processes and techniques. Said circuitry includes the necessary amplifiers and connections for connecting the elements of the detector 213 in pairs with the corresponding elements of the detector 215 to permit the comparisons of the outputs of the elements of each pair described hereinbefore.

If necessary, due to any inability to so fabricate the chip 217 that all of the light responsive element pairs and their associated amplifiers match to the required degree, the chip 217 can be provided with more elements and associated amplifiers than are actually needed. Then the ones of these elements and their amplifiers which provide the best match can be selected and utilized, and the remaining elements are amplifiers left unused.

Figure 4 illustrates a modified form of the embodiment of Figure 2 wherein the module 219 is turned end-for-end from the position which it occupies in the Figure 2 embodiment. As is apparent from Figure 4, this orientation of the module 219 minimizes the required depth of the camera or other device which is to house the focus controlling apparatus.

Figure 5 illustrates another modification of the Figure 2 embodiment wherein the

apertures 229 and 233 flank a reflector 253 which is included in the camera containing the focus controlling apparatus. The reflector 253 forms a part of an electronic flash device which is useful in such a camera. The location of the apertures 229 and 233 at the opposite ends of the reflector 253 gives a desirable amount of separation between the mirrors 227 and 231, using only a minimum additional amount of camera width over that required for the reflector.

Figure 6 illustrates still another modification of the Figure 2 embodiment wherein means are provided for changing the field of view from which the auxiliary images are formed. This means consists of lenses 255 and 257 located in the path of the light which forms the first auxiliary image, and lenses 259 and 261 located in the path of the light which forms the second auxiliary image. More specifically, the lens 255 is located adjacent the aperture 229, while the lens 257 is located adjacent the side of the prism 225 which reflects the light of the first auxiliary image. Similarly, the lens 259 is located adjacent the aperture 233, while the lens 261 is located adjacent the side of the prism 225 which reflects the light of the second auxiliary image. By making the lenses 255 and 259 positive and the lenses 257 and 261 negative, as illustrated, the field of view is decreased. The field of view can be increased by interchanging the positive and negative lenses in sign and power.

Figure 7 illustrates yet another modification of the Figure 2 embodiment wherein the optical positions of the prism 225 and the lenses 221 and 223 are interchanged. Specifically, the lenses 221 and 223 receive the light from the object before it is reflected by the prism 225 to the detectors 213 and 215. This permits the depth of the module 219, and hence the depth of the entire arrangement, to be significantly reduced. It also permits the diameter of the lenses 221 and 223 to be increased, thereby increasing the lower end of the absolute light level range over which the arrangement can be operated satisfactorily.

Figure 8 illustrates another modification to the embodiment of Figure 1 which makes it possible to dispose the first and second detectors very closely together on a single substrate while allowing the auxiliary image producing means to be separated the required amount at the light collecting location. Accordingly, the Figure 8 arrangement which carries the detectors 213 and 215, and which is connected to the motor 239 by the conductors 243 and 245 and the motor drive circuit 237. Also the Figure 8 arrangement includes the lens 247 which is to be adjusted by the motor 239 through the linkage 251 to focus the image of an object onto the film 249.

The means in Figure 8 for conducting the first auxiliary image to the detector 213 include a lens 263, a prism 265 an aperture 267, and a prism 269. Light coming from the object passes along an optical axis or path, shown by the light dashed line, through the lens 263. The axis and light are then bent toward the detector 213 by the prism 265. The light then passes through the aperture 267, which is so sized and positioned that the detector 213 views an exit pupil which is symmetrical with respect to the optical axis. The light then passes through the prism 269, which is arranged to cause the light to fall on the detector 213 along an axis normal to the surface of the detector. The presence of the aperture 267 and the prism 269 prevent the image on the detector 213 from experiencing the undesirable extensive vignetting, or gradual shading off at the edges, which the prism 265 would introduce in the absence of the aperture 267 and the prism 269.

The second auxiliary image is conducted to and produced on the detector 215 in the same manner as that just described for the first image. Thus, the light from the object passes through a lens 271, a prism 273, an aperture 275, and a prism 277 to form the second auxiliary image on the detector 215. Again, the presence of the aperture 275 and the prism 277 significantly reduces the vignetting of the image which would otherwise be produced.

In the Figure 8 arrangement, the shifting of the second auxiliary image on the detector 215 is accomplished by moving the lens 271, the prism 273, and the aperture 275 as a unit. Accordingly, these three elements are shown as being included in an assembly 279 which is moved by the motor 239 in the direction shown, by means of a linkage 281, as the motor 239 moves the lens 247. This moving of the assembly 279 produces the same results as are obtained by moving the lens 29 in the Figure 1 arrangement, or by rotating the mirror 231 in the arrangements of Figures 2 and 3 to 8.

The operation of the Figure 8 arrangement is the equivalent of that described hereinbefore for the arrangement of Figure 2. Thus, a change in object distance from one for which the lens 247 is in the position of best focus disturbs the condition of best light distribution correspondence of the auxiliary images on the detectors. This causes the chip 217 output signal to energize the motor 239 until the resulting repositioning of the assembly 279 restores the condition of best light distribution correspondence for the auxiliary images for the new object distance. At that time, the operation of the motor 239 is terminated, with the lens 247 in the position of best focus for the new object distance.

WHAT WE CLAIM IS:—

1. Apparatus for detecting the distance of an object from the apparatus, comprising first and second radiation detectors each including a linear array of elements each responsive to radiation to produce an electrical signal, the arrays being part of an integrated circuit chip; first and second optical means for forming on the first and second detectors respectively first and second images of the object; a signal processor formed on said chip and electrically connected to the elements to compare the signal from each element of one array with that from a corresponding element of the other array to produce an output signal; a housing providing a common support for the integrated circuit chip and said first and second optical means; means for permitting relative movement between one of the detectors and its respective image to enable the radiation distributions on the detectors to be brought into a condition of best correspondence, thereby to decrease the value of the output signal toward a minimum value indicative of said best correspondence condition; and means responsive to the output signal to detect the occurrence of said minimum, the extent of said relative movement being representative of the distance of the object from the apparatus.

2. Apparatus according to claim 1, wherein the arrays are immediately adjacent each other and are formed on a single planar substrate.

3. Apparatus according to claim 1 or 2, wherein each optical means includes along its optical path a lens for receiving radiation from the object, a first prism for directing the last mentioned radiation towards a corresponding one of said arrays, an aperture to pass said last mentioned radiation and to cause said corresponding array to view an exit pupil which is symmetrical with respect to said corresponding optical path, and a second prism to cause said last mentioned radiation to impinge on said corresponding array along a portion of said corresponding optical path which is substantially normal to the surface of said corresponding array, the spacing between said lenses of said first and second optical means being significantly greater than the spacing between said arrays.

4. Apparatus according to any one of the preceding claims, including control means connected to receive and to be responsive to said output signal for effecting said relative movement between at least one of said images and the corresponding one of said arrays along said line of the said elements thereof.

5. Apparatus according to claim 4 as appendant to claim 3, wherein said control means is coupled to move said lens, said

The means in Figure 8 for conducting the first auxiliary image to the detector 213 include a lens 263, a prism 265 an aperture 267, and a prism 269. Light coming from the object passes along an optical axis or path, shown by the light dashed line, through the lens 263. The axis and light are then bent toward the detector 213 by the prism 265. The light then passes through the aperture 267, which is so sized and positioned that the detector 213 views an exit pupil which is symmetrical with respect to the optical axis. The light then passes through the prism 269, which is arranged to cause the light to fall on the detector 213 along an axis normal to the surface of the detector. The presence of the aperture 267 and the prism 269 prevent the image on the detector 213 from experiencing the undesirable extensive vignetting, or gradual shading off at the edges, which the prism 265 would introduce in the absence of the aperture 267 and the prism 269.

The second auxiliary image is conducted to and produced on the detector 215 in the same manner as that just described for the first image. Thus, the light from the object passes through a lens 271, a prism 273, an aperture 275, and a prism 277 to form the second auxiliary image on the detector 215. Again, the presence of the aperture 275 and the prism 277 significantly reduces the vignetting of the image which would otherwise be produced.

In the Figure 8 arrangement, the shifting of the second auxiliary image on the detector 215 is accomplished by moving the lens 271, the prism 273, and the aperture 275 as a unit. Accordingly, these three elements are shown as being included in an assembly 279 which is moved by the motor 239 in the direction shown, by means of a linkage 281, as the motor 239 moves the lens 247. This moving of the assembly 279 produces the same results as are obtained by moving the lens 29 in the Figure 1 arrangement, or by rotating the mirror 231 in the arrangements of Figures 2 and 3 to 8.

The operation of the Figure 8 arrangement is the equivalent of that described hereinbefore for the arrangement of Figure 2. Thus, a change in object distance from one for which the lens 247 is in the position of best focus disturbs the condition of best light distribution correspondence of the auxiliary images on the detectors. This causes the chip 217 output signal to energize the motor 239 until the resulting repositioning of the assembly 279 restores the condition of best light distribution correspondence for the auxiliary images for the new object distance. At that time, the operation of the motor 239 is terminated, with the lens 247 in the position of best focus for the new object distance.

WHAT WE CLAIM IS:—

1. Apparatus for detecting the distance of an object from the apparatus, comprising first and second radiation detectors each including a linear array of elements each responsive to radiation to produce an electrical signal, the arrays being part of an integrated circuit chip; first and second optical means for forming on the first and second detectors respectively first and second images of the object; a signal processor formed on said chip and electrically connected to the elements to compare the signal from each element of one array with that from a corresponding element of the other array to produce an output signal; a housing providing a common support for the integrated circuit chip and said first and second optical means; means for permitting relative movement between one of the detectors and its respective image to enable the radiation distributions on the detectors to be brought into a condition of best correspondence, thereby to decrease the value of the output signal toward a minimum value indicative of said best correspondence condition; and means responsive to the output signal to detect the occurrence of said minimum, the extent of said relative movement being representative of the distance of the object from the apparatus.

2. Apparatus according to claim 1, wherein the arrays are immediately adjacent each other and are formed on a single planar substrate.

3. Apparatus according to claim 1 or 2, wherein each optical means includes along its optical path a lens for receiving radiation from the object, a first prism for directing the last mentioned radiation towards a corresponding one of said arrays, an aperture to pass said last mentioned radiation and to cause said corresponding array to view an exit pupil which is symmetrical with respect to said corresponding optical path, and a second prism to cause said last mentioned radiation to impinge on said corresponding array along a portion of said corresponding optical path which is substantially normal to the surface of said corresponding array, the spacing between said lenses of said first and second optical means being significantly greater than the spacing between said arrays.

4. Apparatus according to any one of the preceding claims, including control means connected to receive and to be responsive to said output signal for effecting said relative movement between at least one of said images and the corresponding one of said arrays along said line of the said elements thereof.

5. Apparatus according to claim 4 as appendant to claim 3, wherein said control means is coupled to move said lens, said



first prism, and said aperture of one of said optical means as a unit to effect said relative movement.

- 5 6. Apparatus according to any one of the preceding claims, wherein the signal processor compares signals from said corresponding elements to produce a resultant signal and sums the resultant signals to produce said output signal.

7. Apparatus for detecting the distance of an object from the apparatus substantially as herein described with reference to Figure 1 as modified by any one of Figures 2 to 8 of the accompanying drawings.

8. A photographic camera incorporating apparatus according to any one of the preceding claims.

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