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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 applications 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, said apparatus comprising first and second means for forming spaced first and second auxiliary images respectively of the same part of the object; first and second detectors for receiving radiation from the first and second images respectively and each including an array of elements each responsive to radiation to produce an electrical signal; means for comparing the electrical signal from each element of one array with that from a corresponding element of the other array to produce a resultant signal, each resultant signal being a ratio of the radiation intensities on corresponding pair of elements; means for processing the resultant signals to produce an output signal; means for permitting relative movement between one of the detectors and its respective image to enable the radiation distributions on said 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 in conjunction with the accompanying drawings in which:—

Figure 1 is a schematic diagram of an automatically focussing camera, and

Figure 2 is a schematic diagram of a modification of the camera of Figure 1 and 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. Although shown physically separate for illustration purposes, the light detectors 1 and 3 of this embodiment may form portions of a monolithic integrated circuit chip. 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 therethrough. A first image is therefore formed 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 means 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 selectively 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 the 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.

In the arrangement disclosed so far, each of the resultant signals from a corresponding pair of light responsive elements, such as the resultant signal A, represents the difference between the intensities of the light falling on the corresponding two light responsive elements. While this procedure provides the useful results hereinbefore described, even more desirable results can be obtained if each resultant signal is made to represent the ratio, instead of the difference, of the intensities of the light falling on the corresponding two light responsive elements.

The reason for the foregoing is that, when the resultant signal represents the difference of the two light intensities, the value of the resultant signal, for any given percentage of non-similar light distribution on the two detectors or degree of light intensity unbalance, varies as the scene or object absolute light level or brightness varies. Since the detection of the minimum signal, indicative of best focus, becomes unreliable if the resultant signals have too wide a range of variation due to absolute light level variation, the use of resultant signals representing light intensity differences significantly restricts the range of absolute light level over which the arrangements can be successfully used.

On the other hand, when each resultant signal is made to represent the ratio of the corresponding two light intensities, the value of the resultant signal is essentially independent of the absolute light level within wide limits. This permits the apparatus to operate successfully and focus accurately over a significantly wider range of scene brightness than is possible when the resultant signals represent light intensity differences. One desirable way of making each resultant signal represent the ratio of the corresponding two light intensities is to make this resultant signal represent the difference between two signals which, in turn, respectively represent the logs of these light intensities. One con-

venient way of accomplishing this is to make each resultant signal the output signal of a differential amplifier, and to make each input signal for the amplifier representative of, or proportional to, the log of the light intensity on the corresponding light responsive element. One desirable way of obtaining such log signals is to place a diode in series with each light responsive element and to take the element signal for the differential amplifier input from across the diode. An arrangement so using diodes and differential amplifiers, for providing resultant signals A, B, C, and D representing the ratios of the light intensities on corresponding pairs of light responsive elements, is illustrated by way of example in Figure 2.

The arrangement of Figure 2 is shown as receiving and comparing the signals from the light responsive elements of the two detectors 1 and 3 of Figure 1. Accordingly, the Figure 2 arrangement represents a modification to a portion of the Figure 1 arrangement. For the purposes of the present illustration, the elements 5, 7, 9, 11, 13, 15, 17, and 19 of the detector 1 and 3 are considered to be photodiodes employed as current generators. Thus, in Figure 2, one terminal of the element 5 of the detector 1 is connected by a conductor 165 to one input terminal of a differential amplifier 167, and the second input terminal of the latter is connected by a conductor 169 to one terminal of the corresponding element 13 of the detector 3. The output terminal of the amplifier 167 is connected to a conductor 171 on which the resultant signal A is produced.

Similarly, one terminal of each of the elements 7 and 15 is connected by a corresponding one of conductors 173 and 175 to the corresponding one of the two input terminals of a differential amplifier 177. The output terminal of the latter is connected to a conductor 179 on which the resultant signal B is produced. Further, one terminal of each of the elements 9 and 17 is connected by a corresponding one of conductors 181 and 183 to the corresponding one of the two input terminals of a differential amplifier 185, the output terminal of which is connected to a conductor 187 on which the resultant signal C is produced. Finally, one terminal of each of the elements 11 and 19 is connected by a corresponding one of conductors 189 and 191 to the corresponding one of the two input terminals of a differential amplifier 193, the output terminal of which is connected to a conductor 195 on which the resultant signal D is produced.

In order to cause the element signals applied to the inputs of the differential amplifiers to represent the logs of the light intensities on the corresponding elements, diodes 197, 199, 201, 203, 205, 207, 209, and 211 are connected, respectively, between the

conductors 165, 169, 173, 175, 181, 183, 189, and 191 and a common reference point, which is also the common reference point for the amplifiers 167, 177, 185, and 193. The remaining or common terminals 21 and 23 of the elements of the detectors 1 and 3 are also effectively connected to said common reference point by being connected to the positive terminal +V of a suitable source of bias voltage, the negative terminal of which (not shown) is connected to said common reference point. The purpose of this bias voltage is to assure that all photocarriers produced in the photodiodes are collected, and the value of this voltage is desirably made to be such as to achieve this result. In those instances where such a bias voltage is not required, it can be omitted, in which case the common terminals 21 and 23 would be connected directly to the common reference point.

As a result of the construction just described, each of the amplifiers 167, 177, 185, and 193 compares or responds to the difference between the two signals appearing across the corresponding two of the diodes 197 through 211. Thus, each of said amplifiers compares two signals which represent the logs of the intensities of the light falling on the light responsive elements of the corresponding pair of those elements. As a result, each of the resultant signals A, B, C, and D represents the ratio of the intensities of the light falling on the elements of the corresponding pair. If desired, transistors connected to function as diodes could be used in place of the diodes 197, etc. Moreover, more than one diode or transistor could be associated with each light responsive element as necessary to obtain the degree of log response desired. Further, the necessary log response could be obtained in other ways than illustrated, as by the use of very high input impedance amplifiers, or by the use of feedback amplifiers having diodes included in their feedback loops.

WHAT WE CLAIM IS:—

1. Apparatus for detecting the distance of an object from the apparatus, said apparatus comprising first and second means for forming spaced first and second auxiliary images respectively of the same part of the

object; first and second detectors for receiving radiation from the first and second images respectively and each including an array of elements each responsive to radiation to produce an electrical signal; means for comparing the electrical signal from each element of one array with that from a corresponding element of the other array to produce a resultant signal, each resultant signal being a ratio of the radiation intensities on a corresponding pair of elements; means for processing the resultant signals to produce an output signal; means for permitting relative movement between one of the detectors and its respective image to enable the radiation distributions on said 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. The apparatus of claim 1, wherein the signal ratio is effected by obtaining the logarithms of the electrical signals and subtracting them.

3. The apparatus of claim 2, including a plurality of diodes each electrically connected to a respective one of the elements, and wherein the logarithm signals are produced across the diodes.

4. The apparatus of any one of the preceding claims, wherein the elements are photodiodes.

5. The apparatus of any one of the preceding claims, wherein the sensors are portions of a monolithic integrated circuit chip.

6. Distance detecting apparatus substantially as herein described with reference to the accompanying drawings.

7. A photographic camera incorporating apparatus according to any one of the preceding claims, wherein the focussing of the principal image is effected simultaneously with the adjustment of the relative position of the detectors.

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