

PATENT SPECIFICATION

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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 sensors each operable to produce an electrical signal which varies with the intensity of radiation impinging upon a radiation receiving surface thereof; first and second means for directing radiation from the object onto the radiation receiving surfaces of the first and second sensors respectively; a signal processor for receiving and comparing the electrical signals from the first and second sensors and producing an output signal; means for permitting relative movement between one of the sensors and its respective impinging radiation to enable the radiation to enable the radiation distributions on said sensors to be brought into a condition of best correspondence thereby to decrease the value of the output signal toward a true minimum value indicative of said best correspondence condition, the output signal exhibiting other minor minima as it is reduced toward said minimum value; signal limiting means for preventing the value of the output signal from exceeding an upper limit lying between the lowest of said minor minima and said true minimum value; and detecting means responsive to the output signal to detect the occurrence of said true 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 according to the invention,

Figure 2 is a circuit diagram of a signal processor of the camera of Figure 1, and

Figure 3 is a graph illustrating the operation of the signal processor.

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 conveniently 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.

The signal processor 39 (Figure 2) substantially comprises a rectifier and summer circuit. The resultant signals A, B, C and D are applied to corresponding amplifiers 89, 91, 93, and 95 respectively, all of which are referenced to a common point. Each of the amplifiers 89, 91, 93 and 95 has its output terminal connected through the anode to cathode path of an associated diode 97, 99, 101 and 103 to a first common point 105. Each output terminal of the amplifiers 89, 91, 93, and 95 is also connected through the cathode to anode path of another associated diode 107, 109, 111, and 113, respectively, to a second common point 115. The second common point 115 is connected to a first input terminal of an inverting amplifier 117. A second input to the amplifier 117 is connected to the common reference. A feedback resistor 119 is connected between the first input of the amplifier 117 and its

output terminal. The output terminal of the amplifier 117 is connected through a resistor 121 to a first input terminal of an output amplifier 123. The first input terminal of the amplifier 123 is also connected to the first common point 105. The amplifier 123 has a second input terminal connected to the common reference. A feedback resistor 125 connects the first input terminal of the amplifier 123 with its output terminal. The output terminal of the amplifier 123 provides the output signal F of the signal processor 39.

If any one of the resultant signals A, B, C or D at any time has a positive magnitude, that signal will be passed through its associated amplifier 89, 91, 93 or 95 respectively, and will forward bias one of the diodes 97, 99, 101, and 103 connected to the output terminal of the particular amplifier. The forward biased diodes pass the applied signal therethrough to be summed at the first common point 105. If the output of any of the amplifiers 89, 91, 93, or 95 is negative, its associated diode 107, 109, 111, or 113, will become forward biased and pass that signal therethrough to be summed at the second common point 115 and applied to the input terminal of the inverting amplifier 117. That signal in turn will be inverted by the amplifier 117 and added to the signal appearing at the first common point 105 to provide the input signal to the amplifier 123. Therefore, any negative resultant signals will be inverted and added to any positive resultant signals to provide the output signal F of the signal processor 39. It will be helpful to recall, that the output signal F decreases as the condition of best focus for the lens 43 is approached. Specifically, the output signal F decreases toward a minimum value as the means 41, which is controlled by this signal, moves the second lens 29 toward the position giving the most similar light distributions of the auxiliary images on the detector means 1 and 3, and concurrently moves the main objective lens 43 toward the position of best focus for the particular object distance then existent. The means 41 stops moving the lenses 43 and 29 when the means 41 senses that the signal F has reached its minimum value, thereby stopping the movement of the lens 29 in the position of best auxiliary image light distribution correspondence on the detector means, and stopping the movement of the lens 43 in the position of best focus.

It has been found that, as the above-described focussing operation takes place, the decreasing signal F is often subject to minor dips or minima before the primary or true minimum value, indicative of best focus, is reached. These minor minima are related to the complex interaction which

4
5 exits between image brightness distribution and image position on the detector means as the focussing action proceeds, and may also be introduced by camera motion occurring while this action is taking place. An example of the way in which such minor minima affect the signal F during a typical focussing operation is shown by the curve 157 of Figures 3. This curve shows the value of the signal F plotted against the position of the lens 43 for movement of the latter from either extreme position to the position of best focus for a particular object distance.

15 The presence of the above-described minor minima in the value of the signal F as illustrated by the curve 157 has been found to be disadvantageous. This is so because there is a tendency for the means 41 to respond to one or another of these minima, and to prematurely terminate the focussing operation before the true signal minimum and the best focus position of the lens 43 are reached. It is thus desirable to make the present apparatus insensitive to these minor minima, so that any tendency for the apparatus to terminate its focussing movement of the lens 43 prematurely and improperly will be positively avoided.

30 A preferred way of accomplishing the foregoing is to provide a voltage clamping of limiting action which will prevent the means 41 from seeing or responding to any minimum condition of the output signal other than the true minimum, and which will therefore prevent the termination of the focussing action by other than the occurrence of this true minimum. Thus, the signal processor additionally includes a clamping diode 159. This diode is connected between a terminal of a suitable source of negative biasing voltage $-V_c$ and a conductor 161 on which the output signal F is produced. As a result, the signal F produced by the signal processor is clamped at a value, determined by the value of the biasing voltage $-V_c$, which is made to be sufficiently low to prevent the signal F from experiencing said minor minima, and which is made to be sufficiently high to assure that the true minimum value falls below the clamp level, even for objects which produce a non-zero true minimum value.

55 The manner in which such a clamped output signal F varies as the lenses 29 and 43 are moved is illustrated by the typical curve 163 of Figure 3. It is apparent from this curve that the signal processor will not cause the means 41 to stop the movement of the lenses until the occurrence of the true minimum value of the signal F. Therefore, the signal processor will position the lens 43 for best focus with a high degree of accuracy, reliability, and consistency. It

is noted that, instead of the diode 159, other means, such as a saturating feedback amplifier, may be employed to limit the signal F and to prevent the focussing action from being prematurely terminated.

Attention is drawn to our Patent No. 1,448,424 in which is described and claimed a focussing system having many of the features herein described.

WHAT WE CLAIM IS:—

1. Apparatus for detecting the distance of an object from the apparatus comprising first and second radiation sensors each operable to produce an electrical signal which varies with the intensity of radiation impinging upon a radiation receiving surface thereof; first and second means for directing radiation from the object onto the radiation receiving surfaces of the first and second sensors respectively; a signal processor for receiving and comparing the electrical signals from the first and second sensors and producing an output signal; means for permitting relative movement between one of the sensors and its respective impinging radiation to enable the radiation distributions on said sensors to be brought into a condition of best correspondence thereby to decrease the value of the output signal toward a true minimum value indicative of said best correspondence condition, the output signal exhibiting other minor minimas as it is reduced toward said minimum value; signal limiting means for preventing the value of the output signal from exceeding an upper limit lying between the lowest of said minor minima and said true minimum value; and detecting means responsive to the output signal to detect the occurrence of said true minimum, the extent of said relative movement being representative of the distance of the object from the apparatus.

2. Apparatus as claimed in claim 1, wherein the signal limiting means includes a biased diode for limiting the upper level of the output signal.

3. Apparatus as claimed in claim 1 or 2 wherein said sensors are portions of a monolithic integrated circuit chip.

4. Apparatus according to claim 1, 2 or 3 including control means operable to effect relative movement between one of the sensors and the corresponding radiation directing means in a direction to decrease the level of the output signal, and wherein said detecting means is operable to terminate said relative movement when the true minimum value is attained.

5. Apparatus according to any one of the preceding claims wherein each sensor includes a linear array of radiation sensitive elements; and including means for



exits between image brightness distribution and image position on the detector means as the focussing action proceeds, and may also be introduced by camera motion occurring while this action is taking place. An example of the way in which such minor minima affect the signal F during a typical focussing operation is shown by the curve 157 of Figures 3. This curve shows the value of the signal F plotted against the position of the lens 43 for movement of the latter from either extreme position to the position of best focus for a particular object distance.

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2. Apparatus as claimed in claim 1, wherein the signal limiting means includes a biased diode for limiting the upper level of the output signal.

3. Apparatus as claimed in claim 1 or 2 wherein said sensors are portions of a monolithic integrated circuit chip.

4. Apparatus according to claim 1, 2 or 3 including control means operable to effect relative movement between one of the sensors and the corresponding radiation directing means in a direction to decrease the level of the output signal, and wherein said detecting means is operable to terminate said relative movement when the true minimum value is attained.

5. Apparatus according to any one of the preceding claims wherein each sensor includes a linear array of radiation sensitive elements; and including means for

5 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, and means for summing the resultant signals to produce said output signal.

6. Apparatus for detecting the distance of an object from the 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.

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