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(54) FOCUS DETECTING APPARATUS

(71) We, HONEYWELL INC. a Corporation organised and existing under the laws of the State of Delaware, United States of America of 2701 Fourth Avenue South, 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 a focusing system and in particular to a focusing system for a still or motion picture camera. According to the invention, there is provided a focusing system comprising means for focusing a principal image of an object or scene on a predetermined plane; first and second means for forming spaced first and second auxiliary images respectively of the same part of the object or scene; 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; means for processing the resultant signals to produce an output signal representative of the condition of focus of the principle image; and means operable to adjust the relative position of one of the auxiliary images and its respective detector.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawing; in which:—

Figure 1 is a schematic diagram of one embodiment of a focusing system according to the present invention;

Figure 2 is a schematic diagram of the system of Figure 1 in a condition when the

principal image is focused;

Figure 3 is a schematic diagram of the system of Figure 1 in a condition when the principal image is defocused in a first direction,

Figure 4 is a schematic diagram of the embodiment shown in Figure 1 showing the relative locations of the component parts when the principal image is defocused in another direction;

Figure 5 is a schematic diagram of one embodiment of the signal process as shown in Figure 1;

Figure 6 is a schematic diagram of another embodiment of the signal processor shown in Figure 1;

Figure 7 is a schematic diagram of still another embodiment of the signal processor shown in Figure 1;

Figure 8 is a schematic diagram of yet another embodiment of the signal processor shown in Figure 1;

Figure 9 is a schematic diagram illustrating a modification to the embodiment depicted in Figure 1;

Figure 10 is a schematic diagram illustrating another modification to the embodiment shown in Figure 1; and

Figure 11 is a schematic diagram illustrating still another modification to the embodiment shown in Figure 1.

Referring to Figure 1, the focusing system includes a first detector 1 and a second detector 3, each 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 in the exemplarily embodiment of Figure 1 are photo resistive elements. The elements in the first detector 1 have a common terminal 21 connected to a first reference 90

potential plus V. The photo resistive elements of the second detector 3 also have a common terminal 23 which is connected to a second reference potential minus 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 means 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 or scene. The two detectors 1 and 3 are shown as being positioned in coplaner relationship with respect to each other. Although the schematic representation in Figure 1 shows the faces of the light detectors 1 and 3 as being remote from lens 27 and 29, 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 focused 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.

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 lenses are arranged to respond to a relatively small angle of view, for example on 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 the individual elements. As the second lens 29 is moved in a direction parallel to that of the linear dis-

placement of 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 1 through the first lens 27, will be shifted in the direction of the linear displacement of light responsive elements in the second detector 3 as is more clearly illustrated in Figures 2, 3 and 4. 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 detectors 1 and 3 has a common terminal connected to a first and second reference potentials, 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 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 43. The object lens 43 is arranged to focus a principal image of the object on a light sensitive film 45, for example. 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 switch 47. The switch 47 may be arranged to initiate the focus detecting function of the present focusing system. The switch 47 is coupled to a switch 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 present focusing system 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 system.

In explaining the operation of the embodiment shown in Figure 1, reference is

made to Figure 2, 3, 4 wherein components similar to those in Figure 1 are shown with identical numerical designations. Figure 2 shows the focusing system when the principal image formed on the light sensitive film 45 is in focus. Radiation beams or rays 56 and 58 from a point 57 on an object 59 to be focussed pass through the main objective lens 43 to form a principal image including the point 57' on the light sensitive film 45 of a camera for example. Radiation beams or rays 61 and 63 also emanate from the point 57 and pass through the center of the first auxiliary lens 27 and the second auxiliary lens 29, respectively, to form first and second auxiliary images on the first detector 1 and the second detector 3, respectively. It should be noted that as the distance between the object 59 to be photographed and the focusing system increases, the angle between the rays 61 and 63 will decrease. In Figure 2, if the point 57 were a bright spot on an object 59 to be photographed, radiation from that bright spot would pass through the center of the first auxiliary lens 27 and fall on the second light responsive element 7 in the first detector 1. Radiation from the point 57 would also pass through the second auxiliary lens 29 and fall on the second light responsive element 15 of the second detector means 3. Using a similar analysis, it can be readily seen that both the first and second auxiliary images will have similar radiation intensity distribution patterns 65 and 67. When the principal image on the light sensitive film 45 is properly focussed, the radiation intensity distribution patterns 65 and 67 will be coextensive with the first and second detectors 1 and 3 upon which they fall. Therefore, the difference between corresponding light responsive elements in the first and second detector means or arrays will be substantially zero when the principal image is properly focussed.

With the photo resistive elements used in the embodiment of Figure 1, if the light intensity 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 in the embodiment shown in Figure 1 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. In that case, 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 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 noted 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 focusing system 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 3 as is more clearly illustrated in Figures 3 and 4. 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 focusing system 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 Figure 3, the focus system is illustrated with the second auxiliary lens 29 and the main objective lens 43 shown in one extreme position. For purposes of explanation, the direction designations F (forward) and R (reverse), are used to indicate corresponding movements of the main objective lens 43 and the second auxiliary lens 29. For example, when the main objective lens 43 moves to the right or in the reverse direction R, the second auxiliary lens 29 moves down in its reverse direction R. Similarly, when the main objective lens moves to the left in its forward direction F the second auxiliary lens 29 moves up in its forward direction F. It is noted that when the main objective lens 43 is in the position shown in Figure 3, the principal image appearing on the light sensitive film 45 is not properly focussed. This can be seen since the rays 56 and 58 from the

point 57 on the object 59 to be focussed do not form a unitary image of the point 59 on the light sensitive film 45 but rather intersect ahead of the film 45. The ray of light 61 passing through the center of the first auxiliary lens 27 falls on the second photo responsive element 7 of the first detector 1. However, unlike Figure 2, the ray 63 passing through the second auxiliary lens 29 from the point 57 does not fall on the corresponding photo responsive element 15 in the second detector 3. Rather, the ray 63 from the point 57 passes through the secondary lens 29 and falls on the first light responsive element 13 in the second detector 3. Therefore, following a similar analysis for every point on the object 59, it will be seen that the light distribution pattern 67 of the second auxiliary image falling on the second detector 3 is not correspondingly aligned with the light responsive elements in the second detector 3 as is the light distribution pattern 65 aligned with the light responsive elements of the first detector 1. Therefore, comparing the signals representative of the intensity of light falling on corresponding light responsive elements in Figure 3 will provide resultant signals A, B, C, and D which are not substantially zero. Therefore, the output signal F from the signal processor 39 will not be at a minimum value, as was the case in Figure 2, and the principal image is not properly focussed. The control circuit 41 will act in response to the signal processor output signal to continue to move the main objective lens 43 concurrently with the second auxiliary lens 29 until such a minimal signal, representative of a properly focussed principal image, is received.

In Figure 4, the main objective lens 43 and the second auxiliary lens 29 are in their respective extreme reverse positions. The principal image on the light sensitive film 45 is again unfocussed since the image of the point 57 is formed behind the light sensitive film 45. The ray 61 passing through the center of the first auxiliary lens 27 falls on the second light responsive element 7 on the first detector 1 while the ray 63 from the point 57 on the object 59 passes through the second auxiliary lens 29 and falls on the third light responsive element 17 of the light detector 3. Accordingly, the intensity distribution pattern of the second auxiliary image falling on the second light detector 3 is displaced downwardly with respect to the second detector 3 as compared to the intensity distribution pattern 65 of the first auxiliary image appearing on the first detector 1. Therefore, again, there will exist a difference in radiation intensity falling on corresponding light responsive elements of

the first and second detectors 1 and 3, thereby providing one or more resultant signals A, B, C, and D which are not substantially zero. Those resultant signals, as hereinbefore explained in connection with Figure 3, are effective to continue the movement of the main objective lens 43 and the second auxiliary lens 29 until no difference in intensity exists between corresponding light responsive elements of the first and second detectors 1 and 3 and the resultant signals applied to the signal processor 39 are substantially zero. At that time, the principal image on the light sensitive film 45 will be properly focussed and the control circuit will terminate the movement of the main objective lens 43 and the second auxiliary lens 29.

Figures 5, 6, 7 and 8 show alternative arrangements of the signal processor 39 shown in Figure 1. In Figure 5 the signal processor 39 includes four absolute value circuits 69, 71, 73, and 75. The resultant signals A, B, C, and D are applied to the absolute value circuits 69, 71, 73 and 75, respectively. The absolute value circuits derive the absolute value from the resultant signals A, B, C and D and sum those absolute values at a common junction 77 thereby providing the output signal F of the signal processor 39. When the resultant signals A, B, C, and D are substantially zero, i.e. when no difference in illumination exists between corresponding light responsive elements of the first and second detectors 1 and 3, the output signal F from the signal processor 39 will be at a minimal value which may be substantially zero. If any illumination difference exists between any pair of corresponding light responsive elements of the first and second detectors 1 and 3, one or more of the corresponding resultant signals A, B, C, and D will have either a positive or negative magnitude. For example, if the light distribution pattern of the second auxiliary image falling on the second detector 3 is shifted in one direction with respect to the second detector 3, the radiation intensity falling on the first light responsive element 5 of the first detector 1 will not be the same as the intensity of radiation falling on the first light responsive element 13 of the second detector 3. If a greater amount of radiation falls on the photo resistive element 5 than falls on the photo resistive element 13, the effective resistance of the element 5 will be less than that of the element 13 and the common junction 31 between the corresponding photo resistive elements 5 and 13 will have a positive magnitude. On the other hand, if a greater amount of radiation falls on the photo resistive element 13 than falls on the photo resistive element 5, the effective resistance

of the photo resistive element 13 will be less than that of the corresponding photo resistive element 5 and the resultant signal A will have a negative value since a greater potential drop will appear across the photo resistive element 5 than appears across the photo resistive element 13. In either case, the signal processor of Figure 5 will take the absolute value of the resultant signals and sum those values to provide the output signal F without regard to the sign. Changing the sign of all negative resultant signals before summing them, obviates having some positive signals sum with some negative signals to produce a spurious zero or minimum. Therefore, the signal processor 39 will provide an output signal indicative of a non-focus condition whenever the intensity distribution pattern of the second auxiliary image is not identically aligned with the second detector 3 as the intensity distribution pattern of the first auxiliary image is aligned with the first detector 1, regardless of the direction of the misalignment.

The signal processor 39 shown in Figure 6 comprises four squaring circuits 79, 81, 83 and 85. The resultant signals A, B, C, and D are applied to the squaring circuits 79, 81, 83 and 85 which in turn provide output signals, the values of which are all positive, representative of the absolute values of the signals A, B, C, and D. Those signals are summed at a common output terminal 87 to provide the output signal F of the signal processor 39.

The signal processor 39 shown in Figure 7 is substantially comprised of 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 to 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 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.

Figure 8 shows another version of the signal processor 39 wherein the resultant signals A, B, C, and D are referenced with respect to each other, thereby emphasizing the difference in illumination of corresponding light responsive elements. The arrangement shown in Figure 8 will also compensate for differences in the optical transmission of each auxiliary lens which would unbalance other systems. The signal processor 39 in Figure 8 includes three amplifiers 127, 129 and 131. Each amplifier receives as inputs thereto a sequential pair of resultant signals and provides a correlated signal representative of each of the sequential comparisons, which is in turn applied to a rectifier and summer circuit 133. The rectifier and summer circuit 133 may be similar to the rectifier and summer circuit shown in Figure 7 with one of the amplifiers and its associated diodes removed. The comparing amplifier 127 receives the resultant signals A and B and provides correlated signal at the output thereof. Similarly, comparator amplifier 129 receives resultant signals B and C and comparator amplifier 131 receives resultant signals C and D, each providing its respective correlated signal for application to the rectifier and summer circuit 133.

Figure 9 shows the light responsive elements of the first and second detectors 1, 3 of Figure 1 disposed on a single substrate 132. The first four light responsive

elements 5, 7, 9 and 11, comprise the first detector while the second four light responsive elements 13, 15, 17, and 19, comprise the second detector. By having all of the light responsive elements disposed on a single substrate, more uniformity between the electrical characteristics of the light responsive elements is obtained and the variances in those electrical characteristics with the passage of time may be reduced to a minimum. The first and second auxiliary images formed by the first and second auxiliary lenses 27 and 29 fall on an auxiliary image plane 134. A first bundle of light pipes 135 defines a first selectively variable radiation path between the auxiliary image plane 134 and the first detector comprising the first set of four light responsive elements. A second bundle of light pipes 137 defines a selectively variable radiation path between the auxiliary image plane 134 and the second detector comprising the second set of four light responsive elements on the common substrate 135. The first bundle of light pipes 135 is arranged to transmit the radiation intensity distribution from the first auxiliary image formed by the first auxiliary lens 27 from the auxiliary image plane 134 to the first detector; the second bundle of light pipes 137 is arranged to transmit the radiation intensity distribution of the second auxiliary image formed by the second auxiliary lens 29 from the auxiliary image plane 134 to the second detector on the common substrate 132. Through the use of the bundles of light pipes 135 and 137, a greater degree of flexibility in design is provided whereby optimum advantage may be taken of the available space in the particular application of the focusing system. That is of great advantage when the application is to a hand-held camera which is desirably small and easy to handle. For example, although the first and second detector 1 and 3 are displaced colinearly with the linear displacement of the light responsive elements of each detector in Figure 1, the use of light pipes would allow the first and second detectors to be displaced side-by-side, one on top of the other, i.e. to be displaced parallelly with respect to the direction of linearly displacement of the elements, as shown in Figure 11. Further, the use of light pipes would permit movement of the bundle of light pipes 137 with respect to the second radiation intensity distribution pattern on the plane 134 as an alternative to the movement of the second auxiliary lens 29.

In Figure 10 a first auxiliary lens 139 forms a first auxiliary image. A second auxiliary lens 141 is arranged to form a second auxiliary image. In the embodiment

shown in Figure 10, both auxiliary lens 139 and 141 are stationary. The first light detector which is arranged to sense the intensity distribution of the first auxiliary image comprises the light responsive elements 5, 7, 9 and 11. The second detector which is arranged to detect the radiation intensity distribution of the second auxiliary image comprises light responsive elements 13, 15, 17, and 19. The light responsive elements of the first and second detectors may be connected to a signal processor and control circuit as shown in Figure 1. A prism 143 is arranged between the second auxiliary lens 141 and the second detector array comprising the light responsive elements 13, 15, 17 and 19. The prism 143 shifts or alters the course of the second auxiliary optical path and therefore shifts the radiation intensity distribution of the second auxiliary image, intact, along the second detector. A common substrate 145 upon which all of the light responsive elements are disposed, is arranged to move in forward and reverse directions as indicated. The movement of the common substrate 145 including all of the light responsive elements is coordinated with the movement of the main objective lens 43 which forms the principal image on the light sensitive film 45. Since the prism 43 does not substantially adulterate or modify the radiation intensity distribution of the second auxiliary image, but merely alters the angle of incidence of the second optical path with the second detector, the movement of the common substrate in forward and reverse directions effectively accomplishes the shifting of the radiation intensity distribution of the second auxiliary image along the second detector comprising the light responsive elements 13, 15, 17 and 19. That effective shifting of the radiation distribution of the second auxiliary image by means of the prism 143 with the movement of the common substrate 145 accomplishes the same function as the movement of the second auxiliary lens 129 with respect to the second detector means 3 in Figure 1. Therefore, when the radiation intensity distribution of the first auxiliary image falling on the first detector is in the same position with respect to the first detector as the radiation distribution of the second auxiliary image with respect to the second detector, the principal image formed by the main objective lens 43 and appearing on the light sensitive film 45 will be properly focussed.

Figure 11 shows an arrangement of the first and second detectors wherein each light responsive element of the first detector 1' is displaced vertically from its corresponding light responsive element in the second detector 3'. That arrangement is in

contradistinction to the arrangement shown in Figure 1, for example, wherein corresponding light responsive elements are displaced in the same direction as the displacement of sequential light responsive elements in each detector. The physical arrangement of the light responsive elements shown in Figure 11 may advantageously use the light pipe bundles 135, and 137 as was hereinbefore explained in connection with Figure 9. Figure 11 further illustrates that the light responsive elements may also be photo-voltaic in nature rather than photo-resistive in nature as heretofore shown. The first light detector 1' includes the photo-voltaic elements 5', 7', 9' and 11'. The second detector 3' includes the photo-voltaic corresponding light responsive elements 13', 15', 17', and 19', respectively. Each photo-voltaic element provides a voltage representative of the intensity of the light falling thereon. When photo-voltaic elements are used, an additional comparator circuit 147 may be used to provide resultant signals A', B', C' and D' similar to those of Figure 1. The comparator circuit 147 includes four comparator amplifiers 149, 151, 153, and 155. Each comparator amplifier receives as inputs thereto the signals generated by corresponding photo-voltaic elements. For example, comparator amplifiers 149 receives signals from the corresponding photo-voltaic elements 5' and 13'. Similarly, comparator amplifiers 151, 153, and 155 receive the signals generated by corresponding photo-voltaic elements 7' and 15', 9' and 17', and 11' and 19', respectively. The resultant signals A', B', C' and D' from the comparator circuit 147 may be applied to the signal processor 39 shown in Figure 1. When the intensity of the radiation falling on corresponding photo-voltaic elements 5' and 13', for example, is equal, the resultant signal A' will be substantially zero. If the intensity of the radiation falling on the photo-voltaic element 5' is greater than the intensity of the radiation falling on the photo-voltaic element 13' the resultant signal A' will have the positive value. Concurrently, when the intensity of the radiation falling on the photo-voltaic element 13' the resultant signal A' will have the positive value. Conversely, when the intensity of the radiation falling on the photo-voltaic element 13' is greater than the intensity of the radiation falling on the photo-voltaic element 5' the resultant signal A' will have a negative value. Therefore, the embodiment shown in Figure 11 accomplishes the same result by using photo-voltaic light responsive elements as the embodiment shown in Figure 1 accomplished with the use of the photo-resistive light responsive elements.

It will be apparent that in the above

described focusing system, the analysis images do not require the attainment of exact focus in synchronism with the exact focus of the principal image, the auxiliary lens need not be matched to the focal characteristics of the main objective lens, and no complex mechanical linkages need be provided for the proper operation of the system.

WHAT WE CLAIM IS:—

1. A focusing system comprising means for focusing a principal image of an object or scene on a predetermined plane; first and second means for forming spaced first and second auxiliary images respectively of the same part of the object or scene; 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; means for processing the resultant signals to produce an output signal representative of the condition of focus of the principle image; and means operable to adjust the relative position of one of the auxiliary images and its respective detector.

2. The system of claim 1, wherein said last mentioned means includes means for moving one of said first and second means in a direction parallel to the plane of its respective auxiliary image.

3. The system of claim 1 or 2, wherein the elements of each array are spaced from each other along a straight line, and wherein the relative motion between said one auxiliary image and its respective detector is in the direction of said line.

4. The system of claim 1, 2 or 3, wherein the first and second means are provided by first and second lens respectively.

5. The system of any one of the preceding claims, wherein said last mentioned means is operable to adjust the focusing of the principal image conjointly with the adjustment of the relative position of one of the auxiliary images and its respective detector.

6. The system of any one of the preceding claims, wherein the elements are photo-voltaic elements.

7. The system of any one of the preceding claims, wherein the elements are photo-resistive elements.

8. The system of any one of the preceding claims, wherein the signal processing means includes means for providing a set of signals each representative of the absolute value of a respective resultant signal, and means for summing the absolute

contradistinction to the arrangement shown in Figure 1, for example, wherein corresponding light responsive elements are displaced in the same direction as the displacement of sequential light responsive elements in each detector. The physical arrangement of the light responsive elements shown in Figure 11 may advantageously use the light pipe bundles 135, and 137 as was hereinbefore explained in connection with Figure 9. Figure 11 further illustrates that the light responsive elements may also be photo-voltaic in nature rather than photo-resistive in nature as heretofore shown. The first light detector 1' includes the photo-voltaic elements 5', 7', 9' and 11'. The second detector 3' includes the photo-voltaic corresponding light responsive elements 13', 15', 17', and 19', respectively. Each photo-voltaic element provides a voltage representative of the intensity of the light falling thereon. When photo-voltaic elements are used, an additional comparator circuit 147 may be used to provide resultant signals A', B', C' and D' similar to those of Figure 1. The comparator circuit 147 includes four comparator amplifiers 149, 151, 153, and 155. Each comparator amplifier receives as inputs thereto the signals generated by corresponding photo-voltaic elements. For example, comparator amplifiers 149 receives signals from the corresponding photo-voltaic elements 5' and 13'. Similarly, comparator amplifiers 151, 153, and 155 receive the signals generated by corresponding photo-voltaic elements 7' and 15', 9' and 17', and 11' and 19', respectively. The resultant signals A', B', C' and D' from the comparator circuit 147 may be applied to the signal processor 39 shown in Figure 1. When the intensity of the radiation falling on corresponding photo-voltaic elements 5' and 13', for example, is equal, the resultant signal A' will be substantially zero. If the intensity of the radiation falling on the photo-voltaic element 5' is greater than the intensity of the radiation falling on the photo-voltaic element 13' the resultant signal A' will have the positive value. Concurrently, when the intensity of the radiation falling on the photo-voltaic element 13' is greater than the intensity of the radiation falling on the photo-voltaic element 5' the resultant signal A' will have a negative value. Therefore, the embodiment shown in Figure 11 accomplishes the same result by using photo-voltaic light responsive elements as the embodiment shown in Figure 1 accomplished with the use of the photo-resistive light responsive elements.

It will be apparent that in the above

described focusing system, the analysis images do not require the attainment of exact focus in synchronism with the exact focus of the principal image, the auxiliary lens need not be matched to the focal characteristics of the main objective lens, and no complex mechanical linkages need be provided for the proper operation of the system.

WHAT WE CLAIM IS:—

1. A focusing system comprising means for focusing a principal image of an object or scene on a predetermined plane; first and second means for forming spaced first and second auxiliary images respectively of the same part of the object or scene; 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; means for processing the resultant signals to produce an output signal representative of the condition of focus of the principle image; and means operable to adjust the relative position of one of the auxiliary images and its respective detector.

2. The system of claim 1, wherein said last mentioned means includes means for moving one of said first and second means in a direction parallel to the plane of its respective auxiliary image.

3. The system of claim 1 or 2, wherein the elements of each array are spaced from each other along a straight line, and wherein the relative motion between said one auxiliary image and its respective detector is in the direction of said line.

4. The system of claim 1, 2 or 3, wherein the first and second means are provided by first and second lens respectively.

5. The system of any one of the preceding claims, wherein said last mentioned means is operable to adjust the focusing of the principal image conjointly with the adjustment of the relative position of one of the auxiliary images and its respective detector.

6. The system of any one of the preceding claims, wherein the elements are photo-voltaic elements.

7. The system of any one of the preceding claims, wherein the elements are photo-resistive elements.

8. The system of any one of the preceding claims, wherein the signal processing means includes means for providing a set of signals each representative of the absolute value of a respective resultant signal, and means for summing the absolute



values to provide said output signal.

9. The system of any one of claims 1 to 7, wherein the signal processing means includes means for providing a set of signals each representative of the square of a respective resultant signal, and means for summing the squared values to provide said output signal.

10. The system of any one of claims 1 to 7, wherein the signal processing means includes means for rectifying the resultant signals, and means for summing the rectified resultant signals.

11. The system of any one of claims 1 to 7, wherein the signal processing means includes means for comparing the resultant signals from each sequential pair of elements to provide a correlated signal representative of each of the comparisons, and means for summing the absolute values of the correlated signals to provide said output signal.

12. The system of claim 1, including an optical means for altering the direction of the optical path of one of the first and second means, and wherein said last mentioned means is operable to provide relative movement between the detectors and

the first and second means.

13. The system of any one of claims 1 to 4, including means defining variable shaped paths for transmitting radiation from the auxiliary images to their respective detectors.

14. The system of claim 13, wherein the path defining means includes first and second bundles of radiation transmitting elements for the arrays of the first and second detectors respectively.

15. The system of claim 1, wherein the elements of both arrays are formed on a single planar substrate.

16. The system of claim 1, including control means responsive to said output signal and operable to automatically focus the principal image.

17. The system of claim 1, including means operable to illuminate the object while the auxiliary images are being formed.

18. A focussing system substantially as herein described with reference to and as illustrated in Figures 1 to 4, Figure 9, Figure 10 or Figure 11, or Figures 1 to 4 as modified by any one of Figures 5 to 8.

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