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(54) A PHOTO-ELECTRIC RANGE FINDER

(71) We, KARL VOCKENHUBER, of 118, Potzleinsdorfstrasse, Vienna 18, and RAIMUND HAUSER, of 2, Goldeggasse, Vienna 4, both Austria, both Austrian citizens, 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:—

The invention relates to a photo electric range finder, such as of the type described in our copending application No. 29498/72 (Serial No. 1389848).

In a previously described range finder there were provided two lines of photodiodes, each of which extended in the corresponding partial image along the dividing line between the two partial images. These partial images were cut-images, whereby for instance the lower partial image reproduced the lower part of the scene, whereas the upper partial image reproduced the upper part of the scene. Such a construction however has the disadvantage that satisfactory results are only obtained if the object shows chiefly vertical lines. Should such a range finder be used for objects of which the picture content of the upper part differs widely from the lower part, the results are as bad as with objects with sloping or even horizontal lines.

The present invention consists in a range finder having an optical system providing two separate images of a scene to be ranged which are always substantially identical or mirror images of each other when the range setting of the optical system corresponds to the range of the scene, and a photoelectric system which views corresponding parts of the two images when the range setting of the optical system and the range of the scene correspond.

The invention will now be described in more detail, by way of example, and with reference to the accompanying diagrammatic drawings, in which:

Figures 1a, 1b show a known range finder in two different settings of a scene;

Figure 2 represents the same scene in a range finder according to the invention;

Figures 3 and 4 show alternative constructions of an optical system for getting the effect shown in Figure 2;

Figures 5, 6, 7a and 7b show a way of interrogating a line of photocells;

Figure 8 shows in simplified form an optical system for use in a camera;

Figures 9a and 9b shows images appearing in the plane of the photocells of Fig. 8 at insufficient focus; and

Figure 10 shows a second arrangement of the photocells.

In the accompanying drawings corresponding parts of different embodiments are correspondingly referenced.

With a known range finder employing the cut-image principle, a scene in the mountains may at correct setting look as shown in Figure 1a. At each side of the line of division S there are provided lines of photocells n-1 to n-19 and n-1' to n-19', respectively. Two pairs of photocells with the same number, for instance n-1 and n-1', n-2 and n-2' are switched together in a reference circuit in which identity of the signals of the two photocells indicates a correct range setting. As shown in Figure 1a, the signals of the photocells n-7 and n-8 do not correspond with those of the photocells n-7' and n-8'. Probably this applies also to the following two pairs of photocells, but it certainly applies to the photocells n-11 and n-11', and also to most of the following pairs of photocells, as it is clearly demonstrated in Figure 1a. For this reason a range finder of this known kind can indicate a wrong setting of the scene, though the distance setting is correct.

For certain scenes this known range finder indicates "wrong setting" even at correct visual setting, and the signal "correct setting" may appear for scenes which to the human eye appear clearly to be wrong. This is demonstrated in Figure 1b referring to the same scene. With corresponding displacements of the two cut-images, the image on the photocell n-7 accidentally corresponds with the image on the photocell n-11' in Figure 1a. Upon displacement by the width of four

photocells there then results the same intensity of illumination for the photocells $n-7$ and $n-7'$. But in Figure 1b the rest of the pairs of photocells are also equally illuminated, so that the known range finder wrongly indicates with the setting in Figure 1b a "correct setting".

Referring to Figure 2, it will be apparent that the two scene images are substantially identical and are mirror images of one another. The use of mirror images allows the photocells to be disposed side-by-side on a common support. It is also possible to use a single photocell, which scans the different image spots one after the other, but in that case a storage for the signals furnished by the photocell becomes necessary.

The optical arrangement for obtaining mirror images is known *per se* and offers no difficulties. Normally there are used two objectives arranged on the base, whereby the light rays of one of the partial images pass through an inverting arrangement. In Figure 3 there is shown an optical system in which instead of two objectives a single one is provided with an attachment 1 which directs an image of the scene to be photographed through a semi-transparent mirror 4 and a basic lens 2 onto a film. The semi-transparent mirror 4 reflects partial images 5 and 6 of the scene transmitted along the paths S_1 , S_2 towards a cutter prism assembly 3. In the path of the partial image 6 there is provided an inverting prism 7, which may consist of an Abbe-King prism or a Dove prism. The function of the prism assembly 3 is to transmit mirror images of the scenes viewed along G_1 and G_2 cut along a common baseline which thus forms a division line S between the two images 5, 6. In some cases, the space for the prism 7 may be very small, so that the embodiment according to Figure 4 may be preferable.

In this figure, from which the basic lens 2 is omitted, a prism 8 is arranged behind the semi-transparent mirror 4. This prism includes on half its diagonal a reflector surface 9 for the image 5. The image 6 passes to a deviating mirror 10 which directs it through a further prism 11 and an auxiliary lens 12 to the cutter prism assembly 3.

The image 5 deviated from the reflector surface 9 is led through an inverting pentagon prism 13 which directs it towards the prism 11. The prism 11 includes on half its diagonal a reflector surface 14 which reflects the image 5 towards the cutter prism assembly 3 through an auxiliary line 12. The optical paths of the partial images 5, 6 may be balanced by means not shown.

Behind the cutter prism assembly there is provided an array of photodiodes connected into the circuit shown in Figure 5.

In this circuit a pulse generator 15 produces a cadence signal A composed of interrogation pulses shown in Figure 6. A further

pulse generator 16 produces a signal pulse B of much lower frequency determining the repetition frequencies of the scanning of the photodiode lines in Figure 2. The synchronization of the phase position between the cadence signal A and a starting pulse C or D furnished to the photodiode lines n or n' , respectively, is carried out by a synchronizing circuit 17, which also determines the pulse length of the starting pulses C, D.

While however the line n receives its starting pulse C directly, the starting pulse D first passes an intermittently effective delay mechanism 18 controlled by a frequency divider 19. The frequency divider 19 divides the starting pulse B from the starting generator 16 in the ratio 1:2 as shown at E. The delay mechanism 18 thus delays only alternate starting pulses D, whereas the remaining starting pulses D are allowed to pass undelayed as shown in Figure 6. The two diode lines n and n' are in one case read together and simultaneously when starting pulse C coincides with starting pulse D, whereas in the other case they are read with a certain relative delay caused by the interval between the starting pulses C and D, which simulates a deviation of the two partial images relative to each other. The successive interrogation of diode-lines is controlled by a circuit not shown and commences operation when a starting pulse is received.

The video signals received from the interrogation of the photocell lines n , n' are amplified in amplifiers 20, 20', and pass through high-pass filters 21, 21', which suppress the effects of ambient light. The signals are further amplified in amplifier 22 or 22' to appropriate threshold values to trigger electronic switches in the form of Schmitt-Triggers 23 and 23'. The Schmitt-Triggers digitize the video signals and so render possible their subsequent digital treatment.

It is essential that the signal paths behind the diode lines n and n' are matched so that they show equal amplification, equal frequency characteristics and equal threshold values.

The amplifier 20 furnishes a control voltage for the control of the repetition frequency of the starting pulses and in that way also controls the sensitivity of the diode line. A low repetition frequency results in a higher integration period of the photodiodes and consequently in a higher sensitivity. Time sharing means 24 ensure operation of the amplifiers 20, 20' only during the periods that they are receiving video signals.

The outputs of the schmitt-trigger switches 23, 23' are fed in opposite senses to an EXCLUSIVE-OR gate 25. An output signal at this gate 25 therefore occurs only when the input signals are unequal. If the interrogated signals from the two photodiode lines n , n' are the same when simultaneously inter-

rogated with an undelayed starting pulse D, the output of the gate 25 is a minimum. An integrator 26 is provided to receive the signal from the gate 25. The output H of the integrator 26 comprises a signal consisting of unidirectional pulses, the period between adjacent pulses being equal to half of the period of the signal E. For any given adjustment of the range-finder, alternate pulses of the output H have equal amplitude. If the range-finder is adjusted so as to correspond to focussing in front of the correct adjustment, the signal H is as shown in Figure 7a, whereas, if the range-finder is adjusted so as to correspond to focussing behind the correct adjustment, the signal H is as shown in Figure 7b. When the range-finder is adjusted so as to correspond to correct focussing, the signal H comprises a string of pulses of equal magnitude. This latter adjustment corresponds to the partial images being displaced from their correctly adjusted position by an amount corresponding to half the displacement corresponding to the delay introduced by the delay circuit 18 in response to the signal E, i.e. the displacement of one of the split images as detected by vertically adjacent photodiodes when signals C and D coincide is equal and opposite to the displacement of the one split image with respect to the other split image as detected by the photodiodes when signal D is delay with respect to signal C.

In a reading amplifier 27 a modulation signal J is obtained from the signal H (see Figures 7a, 7b). The reading amplifier 27 is controlled in similar manner to the amplifiers 20, 20' by a monostable trigger stage 28, which generates a gating signal G to ensure operation of the amplifier 27 only when signals requiring amplification are being received. The modulation signal J issued by the reading amplifier 27 is reduced to zero when the correct range is found and at which the camera will naturally be in sharp focus. If, however, the modulation signal J is not equal to zero, the magnitude and polarity is indicative of the deviation of the set range from the correct range.

A measure of the range error may, for example, be obtained by lamps 29, 30 if the modulation signal J is led through a high-pass filter 31 to two bistable trigger stages 32, 33, this arrangement forming a phase-sensitive detector. The trigger stage 32 is set to 1 when signal E and signal K are simultaneously 1, and the trigger stage 33 is set to 1 when signal E is 0 and signal K is 1. Both trigger stages are reset to 0 for signal combinations other than those described above. At correct distance setting the lamps 29, 30 then give no signal, whereas in the case of deviation in one direction the lamp 29 flashes in time with the signal L (Figure 7a) and in the case of deviations in the other direction, the lamp 30 flashes in time with the signal M (see

Figure 7b). Of course it is also feasible and useful to lead the signals L, M to a focussing motor for automatic focussing of, for instance, a camera objective, instead of to the pilot lamps 29, 30.

If required, data storage means may be provided for storing signals based on the output of the photocell lines and connected, for instance, to the output of the gate 25.

In Figure 8 a light path is defined in a camera 40 by an objective 41 and leads through a beam splitter to a film plane 44. This film plane corresponds to a focal plane 44' in the path of rays reflected by the beam splitter 42. The image from the focal plane 44' is magnified in an image plane 45 by means of an intermediate optical system L3, whereby approximately half of the rays are subsequently led to a photocell 47 by means of a beam splitter 46 through a measuring lens L1 of relatively short focal length.

The rays reflected by the beam splitter 46 reach a further photocell 48 after having passed a measuring lens L2 of relatively long focal length.

With the aid of the system L1 of short focal length an object is now reproduced in a focal plane in which lies the photocell 47. Likewise the system L2 of long focal length reproduces the object in a focal plane in which lies the photocell 48. The size of the object image and the image in the focal plane 44' have a 1:1 ratio. If the object distance changes the reproduction scale changes, with the optical system of short focal length much more than with that of long focal length. Now the two images are no longer the same size. How this may be in an extreme case is shown in Figure 9.

In Figure 9a the image is illustrated on photocell 48 and in Figure 9b on photocell 47, at unsharp setting. Out of a scene a tree with a trunk 49 is reproduced on photocell 48. In the plane of the photocell 47 this trunk 49 appears much larger, but also much more out of focus. By the change of scale there results not only a change of brightness on the photocell 47, but also by magnification of the image in comparison to the image on photocell 48, a change of image sharpness.

It is clear that the two optical systems L1, L2 must be adjusted so that upon focusing of the objective 41 of the camera 40, the image on the two photocells 47, 48 must have the same reproduction scale. If, by a wrong focusing of the objective 41, a reproduction occurs in front or behind the plane of sharpness 44', a respectively smaller or larger image will be obtained on the photocells 47, 48, the change of scale being much smaller on photocell 48. From the difference of image size a control signal is obtained, which may be used for the control of a servomotor for focusing the objective 41. For this purpose a reference circuit between photocell 47 and photocell 48

is necessary. The required direction of displacement is found by the ratio of the reproduction scales on the two photocells 47, 48. If the reproduction on photocell 47 is larger than on photocell 48, the objective 41 must be adjusted in the direction of a shorter distance, if the reproduction is smaller than that on photocell 48, the adjustment has to be made in the "infinite" direction. In both cases the movement of adjustment of the objective 41 has to be performed until the reproduction on the photocells is equally large. It may be mentioned here that preferably only a small part of the scene to be taken is used for measuring.

The larger the magnification of the objective 41, the more sensitive becomes the measurement on the photocells 47, 48. The reason for this is that the scale of depth changes with the square of the lateral magnification of the image. Since the magnification ratio of the objective 41 may not be optionally chosen, however, it is efficient to provide a magnification system L3 behind the beam splitter 42, so that at given magnification ratio of the objective 41, the sensitivity of the measurement on the photocells 47, 48 may be im-

proved. It has been found that by such a design a change of the reproduction scale in the range of +13% and -11% for the depth of field may be obtained, which corresponds to an increase of 28% and a decrease of 23% in area. The image that is formed in the plane of the front limit of depth of field is, with respect to its surface measure, consequently larger by 66% compared to an image in the rear limit of depth of field.

If for instance an object image in the focal plane 44 corresponds to a depth interval between two objects, situated at the limits of depth of field for open diaphragm, of 72 μ , and there is a fourfold magnification by means of the magnification optical system L3 a depth interval of 1,15 mm can be achieved in the focal plane 45 situated in front of the beam splitter 46.

With an optical system L3 giving a fourfold magnification and at a focal length of $f_1=5$ mm of the system L1 and $f_2=50$ mm of the system L2 the following reproduction scales for the images of objects situated at the depth of field limits are obtained. The reproduction scale in the focal plane 45 in front of the beam splitter 46 is 1.

55	Example 1:	$f_1=5$ mm	$f_2=50$ mm
	reproduction in the rear limit of depth of field	$\beta_1=1,13$	$\beta_2=1,01$
	reproduction in the front limit of depth of field	$\beta_1=0,895$	$\beta_2=0,99$

60 There results a change of the reproduction scale in the range of -10 to +12%.

	Example 2:	$f_1=10$ mm	$f_2=25$ mm
	reproduction in the rear limit of depth of field	$\beta_1=1,06$	$\beta_2=1,02$
65	reproduction in the front limit of depth of field	$\beta_1=0,945$	$\beta_2=0,973$

There results, at a ratio of the focal lengths of the lens systems L1 and L2 of 1:2,5, a scale difference of -3 to +4%. The scale difference however depends on other factors as well as the difference of focal length, one such factor being the lens aperture sizes. A difference of focal length giving a ratio of more than 1:2 is advantageous, however.

In Figure 8 only a single photocell 47 and 48 in each image plane has been specified. Better data about focusing may be obtained if instead of a single, stationary photocell there is used either a photocell which passes different image spots of the images projected by the optical systems L1 and L2 or if lines of photocells are used. A preferred arrangement of photocells is shown in Figure 10, in which photo-resistors are arranged in concentric rings. Identical ring arrangements must then either be provided in the image planes of the optical systems L1 and L2 or such an arrangement must be transferable

between the image planes. The interrogation can take place only if photo-resistors of the two groups of photocells lying on the same radius are connected together in a differential circuit; preferably an interrogation circuit as shown in Figure 5 is used. By the concentric arrangement of the photocells, the scale comparison is more easily made. In a single photocell arrangement, which is transferable between the image planes, data storage means for the information received in each of the image planes must be provided. In such an embodiment there must be provided operating means to move the photocell from position $n-1$ to $n-19$ and then from $n-19'$ to $n-1'$ or vice versa. The operating means may include manual operation means, such as a shutter release button itself, or a motor. Instead of moving a single cell over both lines of photodiodes $n-1$ to $n-19$ and $n-1'$ to $n-19'$ respectively, two photocells may be used each guided along a respective one of the two

lines. In this way compensating for the reversal of the direction of movement in the photo-electric receiver is avoided.

WHAT WE CLAIM IS:—

5 1. A range finder having an optical system providing two separate images of a scene to be ranged which are always substantially identical or mirror images of each other when the range setting of the optical system corresponds to the range of the scene, and a photo-electric system which views corresponding parts of the two images when the range setting of the optical system and the range of the scene correspond.

15 2. A range finder as claimed in claim 1, in which there is provided in the optical system prism means for splitting light from the scene into two partial beams, which form the two images, and for inverting one image with respect to the other.

20 3. A range finder as claimed in claim 2, in which at least one deviating mirror is disposed in the path of light from the scene passing through the optical system.

4. A range finder as claimed in claim 1 25 in which the two images are produced by two parts of the optical system having different focal lengths.

5. A range finder as claimed in claim 4, in which a plurality of photocells are provided in at least one of the two image planes, the photocells being arranged concentrically to the optical axis of the associated part of the optical system. 30

6. A range finder as claimed in claim 4 35 or 5, in which the ratio of the focal lengths of the two parts of the optical system is at least 1:2.

7. A range finder as claimed in any of claims 4 to 6, in which an optical magnifying system is arranged between the two parts of the optical system and a beam splitter for splitting the light from the scene which passes through the optical system. 40

8. A range finder according to claim 1 and 45 substantially as herein described with reference to the accompanying drawings.

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10 the range setting of the optical system corresponds to the range of the scene, and a photo-electric system which views corresponding parts of the two images when the range setting of the optical system and the range of the scene correspond.

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5. A range finder as claimed in claim 4, in which a plurality of photocells are provided 30 in at least one of the two image planes, the photocells being arranged concentrically to the optical axis of the associated part of the optical system.

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7. A range finder as claimed in any of claims 4 to 6, in which an optical magnifying 40 system is arranged between the two parts of the optical system and a beam splitter for splitting the light from the scene which passes through the optical system.

8. A range finder according to claim 1 and 45 substantially as herein described with reference to the accompanying drawings.

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