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⑤④ Optic correlator for object co-ordinate acquisition in real-time display processing systems.

⑤⑦ The optic correlator comprises a lens (L') for shooting the image of a display (S') to be processed, a splitter assembly (D) for splitting the short image and a pair of split image supporting elements (V₁, V₂), each to receive a respective split image thereon, behind each image supporting element there being arranged a respective image processing assembly including a respective transparency (T₁₂, T₂₂), lens and sensor, (L", L", S₁, S₂), the output of the latter being supplied to electronic combinatory circuitry to be differentiated therein.

TITLE MODIFIED

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^{see front page}
"OPTIC CORRELATOR PARTICULARLY FOR USE IN REAL TIME TV
DISPLAY PROCESSING SYSTEMS TO ACQUIRE THE COORDINATES
OF OBJECTS HAVING ANY SHAPES AND SIZES"

This invention relates to an optic correlator particularly for use in real time TV display processing systems to acquire the coordinates of objects having any shapes and sizes.

5 As is known, the cross correlation algorithm of images having given shapes can be utilized to recognize either stationary or moving objects. Further details on this are to be found in Italian Patent Application No. 21458 A/83 by Fondazione Pro Juventute Don Carlo
10 Gnocchi having for its designated inventors Antonio Pedotti and Giancarlo Ferrigno, and in Italian Patent Application No. 23733 A/83, also by Fondazione Pro Juventute Don Carlo Gnocchi and having the same designated inventors.

15 In both of the cited Italian Patent Applications, the correlator was formed from electronic components the number whereof was of necessity to increase as the size of the objects to be recognized increased. This involved, in addition to a more complex construction,
20 a considerable increase in cost.

Accordingly, it is an object of this invention to provide a correlator, particularly for use in real time TV display processing systems to acquire the coordinates of objects having a known shape, which is
25 constructionally simple and can be readily adapted, without involving any increased constructional complexity thereof, for recognition of objects having any sizes.

Another object of this invention is to provide a correlator, for the above-specified application, which

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can operate at an extremely high processing rate.

It is a further object of this invention to provide a correlator, which can recognize objects of any shapes.

5 These and other objects, such as will be apparent hereinafter, are achieved by a correlator of the optical type, particularly for use in real time TV display processing systems, and adapted for the acquisition of coordinates of known shape objects,
10 according to the characterizing portion of Claim 1.

Further features of the correlator of this invention are pointed out in the subclaims.

Still more features and advantages of the optic correlator particularly for use in real time TV display
15 processing systems to acquire coordinates of known shape objects, will be apparent from the following detailed description of a presently preferred embodiment thereof, as illustrated by way of example and not of limitation in the accompanying drawings, where:

20 Figure 1 illustrates diagrammatically the operation of an incoherent light optic correlator of a known type;

Figures 2 and 3 show arrangement diagrams and operation diagrams of the correlator according to this
25 invention; and

Figure 4 is a general block diagram illustrating one possible way of interconnecting the optic correlator of this invention within a real time TV display processing system for the acquisition of coordinates of

objects having any shapes and sizes; and

Fig. 5 shows a further configuration when the objects to be detected are sufficiently far from the subject system.

5 Making now specific reference to Figure 1, there is shown a constitutive and operation diagram for a correlator of a known type. More precisely, the diagram of Figure 1 relates to an incoherent light device capable of correlating cross fashion two transparen-
10 cies T_1 , T_2 . In Figure 1, S denotes a source of incoherent extended light, L a lens, f the focal length, F the focal plane, and Z_0 the distance between the two transparencies.

15 Assuming diffraction to be negligible, or details of T_1 and T_2 not close to the wavelength of the light from S, said mounting effects the cross correlation between T_1 and T_2 .

20 More precisely, on each point P,Q on the focal plane there impinge the light rays from any directions. Let us take into particular consideration the direction of director cosines p and q. The ray passing through the point (x,y) of T_1 meets T_2 at $(x+pz_0, y + qz_0)$ where, as mentioned, z_0 is the distance between T_1 and T_2 . The strength of the ray, after
25 going through the transparencies is:

$$I^*(p,q) = T_1(x,y) \cdot T_2(x+pz_0, y+qz_0)$$

All the rays from this direction converge into the point (P,Q) having coordinates $P=pf$ and $Q=qf$ of the

focal plane F. Since the strengths add together at this point, the overall strength at P,Q is:

$$I(P,Q) = \iint T_1(x,y) \cdot T_2(x + pz_0, y + qz_0) dx dy$$

In other words, the mounting or arrangement effects a
5 real cross correlation. The only problem which arises in this case is that the transparency T_2 which represents the reference shape can only assume positive values. The main object of this invention is, in essence, that of solving the latter problem in order to apply the
10 optic correlator to recognition of images in a system of the type described in the above-mentioned Italian Patent Applications.

The solution to such a problem is set forth in Figure 2.

15 In that figure, S' denotes the display to be processed, L' the object lens, D a device (prism, semi-reflecting mirror, crystal of a particular type, and so forth) for splitting the image which is projected onto two glazed glasses V_1 and V_2 . In
20 particular V_1 and V_2 have in such a case the functions of the transparency T_1 (they may also be omitted in practice). The splitting element may be practically eliminated for displays shot from a long distance by using two object lenses as in Figure 5, because the
25 offset due to distance between the two object lenses becomes negligible as the distance D increases). Two mountings of the type of Figure 1 are placed behind V_1 and V_2 , on the focal plane whereof are placed two

image detectors or sensors, for example of the CCD or tube types. On each element of the sensors there is generated a charge proportional to the cross correlation of T_{i2} ($i = 1,2$) with S' . Naturally, T_{12} and T_{22} will
 5 only have positive values. In the assumption of perfect alignment of the two images on the sensors, the limitation on the sign may be overcome.

In fact, the reference function $C(X,Y)$ is factorized into two:

$$\begin{aligned} 10 \quad C(x,y) &= C^+(x', y') + C^-(x'', y'') = \\ &= C^+(x', y') - |C^-(x'', y'')| \end{aligned}$$

with $x' \neq x''$ and $y' \neq y''$

where C^+ denotes a function equal to C where this is positive or nil and nil where this is negative. C^- is
 15 a function equal to C where this is negative and nil where this is positive or nil. The transparency T_{12} is thus "modulated" by the function C^+ , whilst the T_{22} is modulated by the function $|C^-|$. The outputs from the two sensors 1 and 2 are then combined as follows (see
 20 Figure 3)(pixel by pixel):

$$Q_{out} = Q_1 - Q_2$$

It will be demonstrated herein below how this coincides with having at the output (Q_{out}) the correlation between the display S' and the reference
 25 function C . The output charge Q is proportional to the intensity I on the individual pixel ($Q=KI$).

$$Q_{out} = Q_1 - Q_2 = KI_1 - KI_2$$

$$\begin{aligned}
 &=K \iint S(x',y') \cdot T_{12}(x'+Pz_0,y'+qz_0) dx'dy' - \\
 &-K \iint S(x'',y'') \cdot T_{22}(x''+Pz_0,y''+qz_0) dx''dy'' = : \\
 &=K \iint S(x',y') \cdot C^+(x'+Pz_0,y'+qz_0) dx'dy' - \\
 &-K \iint S(x'',y'') \cdot C^-(x''+Pz_0,y''+qz_0) dx''dy'' = \\
 5 \quad &=K \left\{ \iint S(x',y') C^+(x'+pz_0,y'+qz_0) dx'dy' + \right. \\
 &\left. + \iint S(x'',y'') C^-(x''+pz_0,y''+qz_0) dx''dy'' \right\} = \\
 &=K \iint S(x,y) \left[C^+(x'+pz_0,y'+qz_0) + C^-(x''+pz_0,y''+qz_0) \right] dx'dy' = \\
 &=K \iint S(x,y) C(x+Pz_0,y+qz_0) dx'dy'
 \end{aligned}$$

The output of the combination of Figure 3 is,
 10 therefore, directly the cross correlation
 between the display S' and the reference
 shape C . In particular the partial cross correlation
 functions are in the form of light intensity modulation
 and converted into electric signals (e.g. charges)
 15 through two photoelectric sensors (e.g. of the CCD or
 tube TV camera types). The electric information is
 combined as in Figure 3, point by point, or from each
 element of the scanning matrix 1 there is subtracted
 the value of the corresponding element of the matrix 2.
 20 Thus the end cross correlation actual function
 may be calculated.

The matrix points may also be scanned by rows or lines (TV raster type).

By operating as illustrated in the aforementioned Italian Patent Applications, one can arrive at
5 recognizing objects of any shapes and sizes. That recognition is effected by means of an extremely simple system of the optical type and including a minimum of components and extremely economical. In particular by using for T_{12} and T_{22} transparencies
10 adapted to be "modulated" such as liquid crystal matrices, it becomes possible to adaptively vary, as outlined in the aforementioned Italian Patent Application No. 23733 A/83, the reference function C with consequent adaptivity of the recognition.

15 Finally, in Figure 4, there is shown a possible block diagram wherein the optic correlator of this invention may be used for recognition in a real time TV display processing system for acquisition of coordinates of objects of any known shapes and sizes.
20 That block will be no further discussed because already illustrated extensively in the two cited Italian patent applications.

It may be appreciated from the foregoing that the invention fully achieves its objects. In particular,
25 an optic correlator has been provided having a very high processing rate, being very simple construction-wise, and capable of recognizing objects of any shapes and sizes. The optic correlator of this invention operates on an incoherent extended light source,
30 and in particular, dodges the basic problem of the

known incoherent optic correlator consisting of the
transparency representing the reference shape only
taking positive values. Thus, the correlator of this
invention is optimally adapted to replace the complex
5 electronic correlator employed in the system of the
cited Italian patent applications.

While the invention has been illustrated in
connection with a particular embodiment thereof, it
is susceptible to many modifications and variations
10 without departing from the purview of the inventive
concept.

CLAIMS

1 1. An optic correlator, particularly for use in
2 real time TV display processing systems to acquire
3 coordinates of objects having any shapes and sizes,
4 characterized in that it comprises an object lens means
5 (L') for shooting the image of a display to be processed,
6 said display including at least one object of any shape
7 and size, a means (D) adapted to split the image shot by
8 said object lens means, and a pair of split image
9 support elements (V_1, V_2), each to receive a respective
10 split image thereon from said image splitting means (D),
11 and behind each image support element in said pair, a
12 respective assembly comprising a respective transparency
13 means (T_{12}, T_{22}), respective lens (L'', L'''), and respec-
14 tive sensor (S_1, S_2), the outputs from said two sensors
15 (S_1, S_2) being supplied to electronic combinatory means
16 adapted to provide the differences thereof.

1 2. An optic correlator according to Claim 1,
2 characterized in that each of said sensors (S_1, S_2) com-
3 prises a plurality of elements effective to generate
4 a potential electric charge or other electrical quantity
5 proportional to the cross correlation between said
6 respective means and said display.

1 3. An optic correlator according to Claim 1,
2 characterized in that said electronic combinatory means
3 is adapted to combine pixel by pixel the outputs from
4 said two sensors (S_1, S_2) to supply as the resulting out-
5 put the correlation between said display and the refer-
6 ence function.

1 4. An optic correlator according to Claim 1,

2 characterized in that said transparency means (T_{12}, T_{22})
3 comprises a transparency of the type adapted to be
4 modulated.

1 5. An optic correlator according to Claim 3,
2 characterized in that said transparency means (T_{12}, T_{22})
3 comprises liquid crystal matrices.

1 6. An optic correlator according to Claim 1,
2 characterized in that said image splitting device (D)
3 comprises a prism, semireflecting mirror and/or the
4 like.

1 7. An optic correlator according to Claim 1,
2 characterized in that said image support elements (V_1, V_2)
3 comprise glazed glasses.

1 8. An optic correlator according to Claim 1,
2 characterized in that said sensors (S_1, S_2) are of the
3 CCD type.

1 9. An optic correlator according to Claim 1,
2 characterized in that said sensors (S_1, S_2) are of the
3 tube type, said sensors being each arranged on the
4 respective focal plane of said lenses (L'', L''').

