United States Patent

[11] **3,555,179**

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[73] Assignee
the United States of America, as represented by the Secretary of the Navy

[54] **ANALOGUE VIDEO CORRELATOR FOR POSITION FIXING OF AN AIRCRAFT**
6 Claims, 10 Drawing Figs.

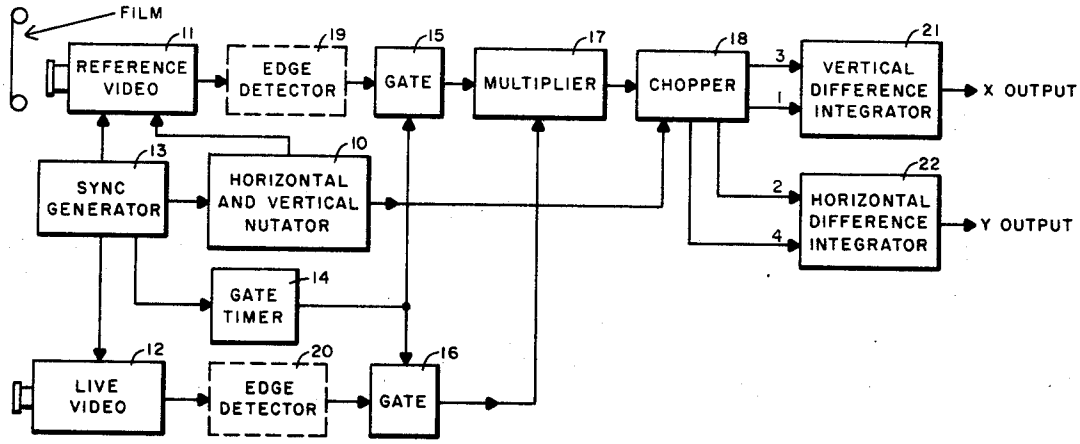
[52] **U.S. Cl.** **178/6.8,** 343/5, 328/132
[51] **Int. Cl.** **H04n 1/00,** H03k 5/153, G01s 5/00
[50] **Field of Search** ..... 178/6.8, 6AIR, 6IND, 6NAV; 343/5MM, 5CM, 6TV; 340/149; 35/10.2; 328/132, 135, (Inquired), 162, 142(Cursory), 150(Cursory); 307/(Inquired), 229(Cursory), 235(Cursory), 260(Cursory), 263(Cursory), 264(Cursory)

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ABSTRACT: An in-flight analogue video correlator for position fixing of an aircraft using edges of scenes derived from relatively high contrast reference and live video signals. Several horizontally displaced video edge outputs, obtained by passing reference edge pulses through parallel delay lines, are first widened and then individually multiplied with the edge widened line video output to determine coincidence. Static and dynamic matching is used to first obtain the approximate position of correlation and then given continuous directional information.



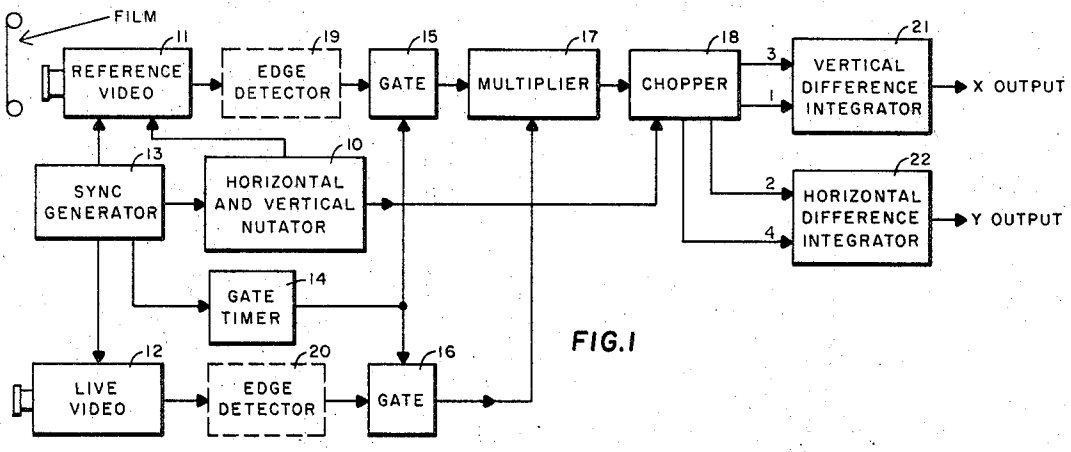


FIG. 1

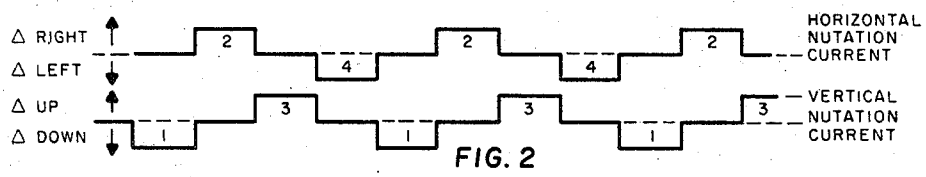


FIG. 2

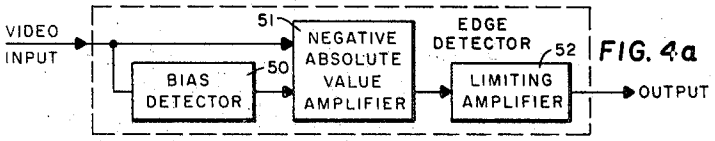


FIG. 4a

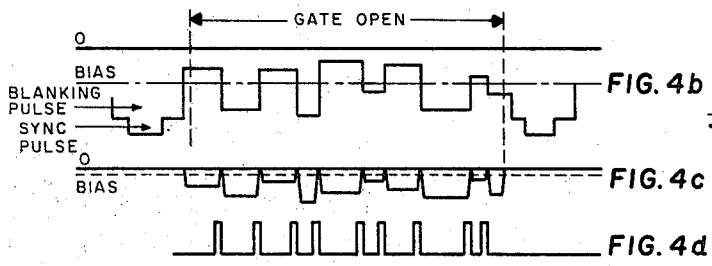


FIG. 4b

FIG. 4c

FIG. 4d

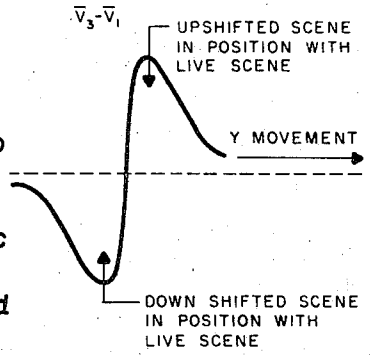


FIG. 3a

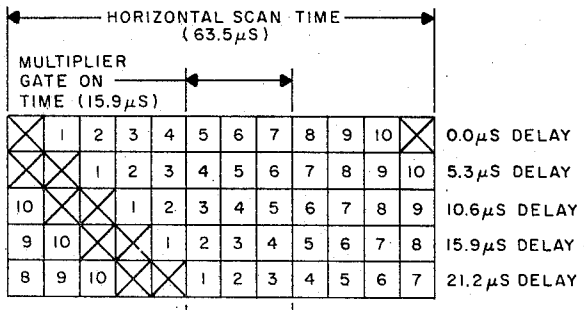


FIG. 5

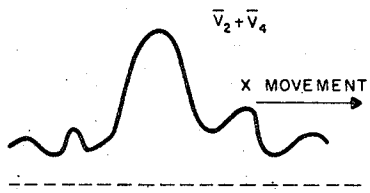


FIG. 3b

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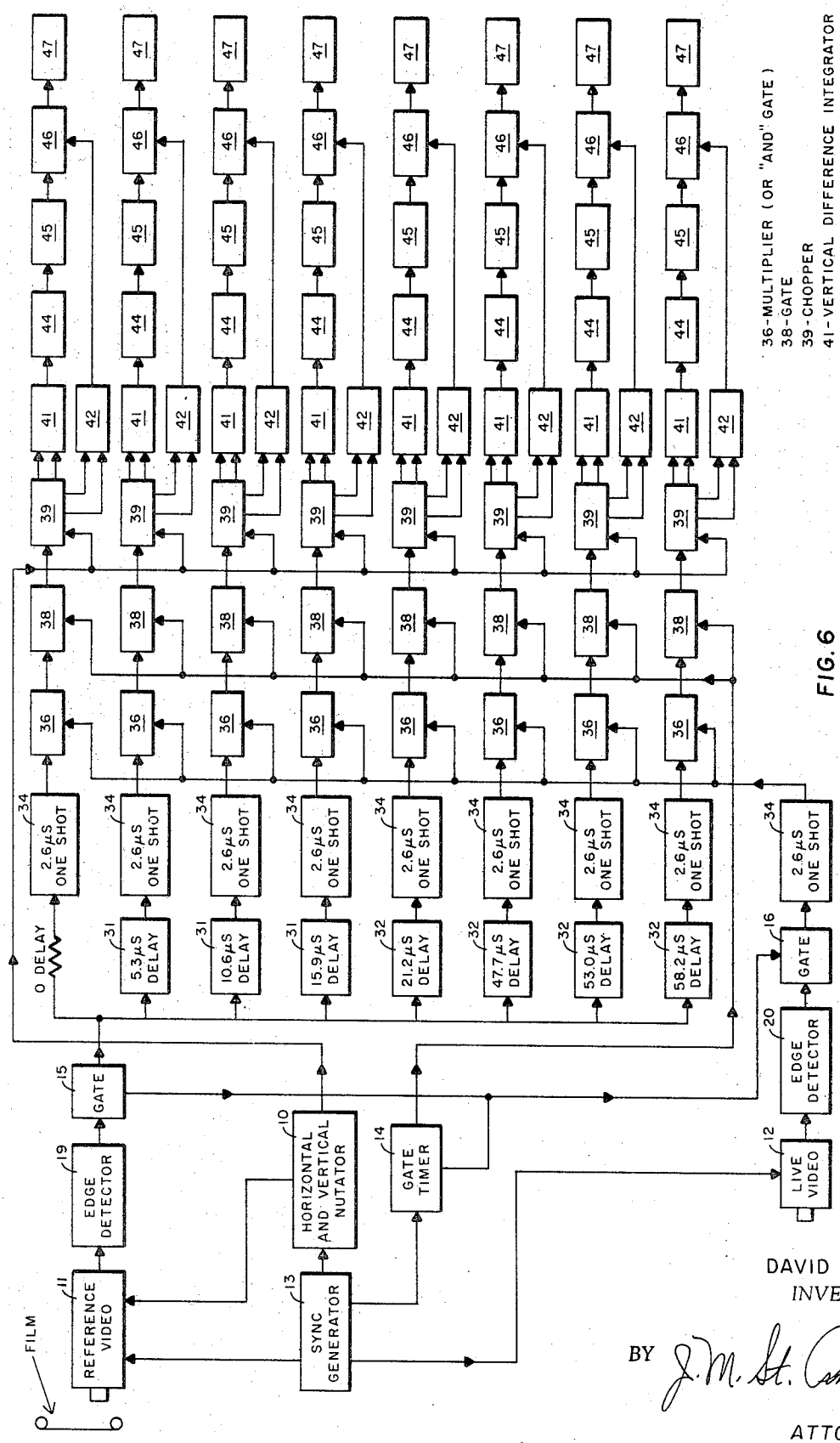


FIG. 6

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ANALOGUE VIDEO CORRELATOR FOR POSITION FIXING OF AN AIRCRAFT

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

Correlation of one scene with another by means of light passing through transparencies or films is well known and has been used for years. Light output from an optical device showing the area below an aircraft can be directed through a reference film of that area, a voltage derived proportional to that light, and a "static match" correlation curve obtained. Mechanical nutation of the reference provides a "dynamic match" curve, essentially a derivative of the static match curve. Zero crossover (no output) of the dynamic match curve occurs during the maximum of the static match.

When reference and live scenes are dissimilar inform, i.e., TV and radar, it is necessary to either make a synthetic from the reference scene to correspond to the live scene or else utilize the correlation between common features of the two.

Digital computers have been used to store reference scenes by "weighing" of channels, the number stored in a particular channel corresponding to the light intensity of the associated area. It is also possible to mathematically construct edges of the two scenes by taking derivatives of the scene intensity. This edge process decreases the chances of obtaining false correlation points. The computer can be programmed to functionally move one of these scenes over the other and thereby determine the corresponding correlation.

The mechanical method of correlation is restricted to the use of optical information only, is relatively slow, and cannot correlate over large areas.

Digital computers are expensive, fast speeds and large channel capacities would be needed to define edges and correlate over large areas. For continuous navigation much more channel capacity would be needed for sequential storage and erasure of the changing reference.

In the video correlator of this invention, edges of scenes are first derived from both the reference and live video signals. Video pulses corresponding to the edges of the reference signal are sent through parallel delay lines to obtain several horizontally displaced video outputs. These edge outputs are first widened and then individually multiplied with the edge widened live video output. A combination of static and dynamic matching is used to first obtain the approximate position of correlation and then give continuous directional information. Being entirely analogue the present device eliminates the use of a digital computer. Accuracy is mostly a function of delay channels. For example, for 2.5 microsecond edges a TV screen with a 4:3 raster ratio would contain about 300 separate picture elements, which is adequate, although many more elements can be obtained by adding more delay channels and decreasing their edge widths.

Other objects and many of the attendant advantages of this invention will become readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 shows a single channel video dynamic match correlator;

FIG. 2 illustrates horizontal and vertical nutation currents for camera scan purposes;

FIGS. 3*a* and 3*b* show resultant output curves for vertical and horizontal correlation movement, respectively;

FIG. 4*a* shows an edge detector circuit of the invention;

FIGS. 4*b*, 4*c* and 4*d* describe the operation of the edge detector;

FIG. 5 illustrates typical delay times for the various delay channels of the multiple channel correlator of the invention; and

FIG. 6 is a block diagram of a preferred embodiment of the invention.

A single channel video dynamic match correlator such as shown in FIG. 1 operates as follows: A horizontal and vertical

nutator 10 adds small currents to the horizontal and vertical deflection coils of reference video camera 11. The currents illustrated in FIG. 2 cause the camera to scan alternately down, right, up, and left in a counterclockwise piecewise rotation. Each shift lasts for 1/60 second, a total nutation cycle lasting 1/15 second, (i.e., two TV frames).

Live video camera 12 and reference video camera 11 are synchronized by sync generator 13 which also provides reference timing for gate timer 14 and nutator 10. Gate timer 14 operates gates 15 and 16.

The output of both the reference video camera 11 and the line video camera 12 is gated by gates 15 and 16, respectively, sent to a multiplier 17 and the resulting multiplied video pulses are fed to chopper 18 except during blanking intervals. The outputs of video cameras 11 and 12 can be edge detected by edge detectors 19 and 20, shown by dashed lines in FIG. 1 and later described. If only the center sections of the live and reference scenes are to be correlated gates 15 and 16 can be closed for all but selected intervals.

Chopper 18 is controlled by nutator 10; outputs 3, 1, 2, 4 from chopper 18 correspond to the nutation intervals 3, 1, 2, 4 of FIG. 2. Suppose the vertically shifted up scene (interval 3) corresponds more to the live scene than the vertically shifted down scene (interval 1). The multiplied video pulses of interval 3 will integrate in vertical difference integrator 21 to a larger DC value than the multiplied pulses of interval 1. The difference $(V_3 - V_1)$ will be positive. If the down shifted scene corresponded more closely to the live scene $(V_3 - V_1)$ would be negative. If the two scenes are centered horizontally and vertical movement brings the scenes through exact correlation, the resultant Y output b appear as shown in FIG. 3*a*. The horizontal difference integrator 22 gives the same type result for the left-right nutated scenes.

Horizontal static match may be obtained by adding chopper outputs 2 and 4. If the scenes were centered, vertically and the reference camera 11 moved horizontally an output curve as shown in FIG. 3*b* would result.

Edge detectors 19 and 20 can be used between both video cameras and multiplier 17, as shown by the dashed lines in FIG. 1.

Edge detection can be accomplished by the use of operational amplifiers in a manner as shown in FIG. 4*a*. Bias detector 50 is a DC amplifier which averages the video input voltage except during intervals where the input exceeds some given voltage (i.e. the blanking level). The video input is thereby averaged except during blanking intervals. The gain of bias detector 50 is set so that its output corresponds to the average video level, as if this average level extended through the blanking interval. This is the "BIAS" level shown in FIG. 4*b*.

The negative absolute value amplifier 51 gives a negative output voltage proportional to the voltage input above or below the BIAS level. As shown in FIG. 4*c*, whenever the input voltage goes through the bias level the output goes to zero and then negative. Fast changes of input voltage (corresponding to video "edges") cause positive going output pulses such as shown in FIG. 4*d*; the minimum width of these pulses is determined by the rise times of the DC amplifiers in negative absolute value amplifier 51. The limiting amplifier 52 saturates only when its input is more positive than some set bias (FIGS. 4*c* and 4*d*). The output of limiting amplifier 52 consists of positive pulses occurring whenever there is a large change in video input. A TV monitor used at this point (i.e. the edge detector output) would show thin white outlines of both black and white objects.

A simple differentiator circuit can be used to enhance edges and thus also be used for edge detection; however, the differentiator would also enhance high frequency noise which would have to be filtered out. The output pulses from the differentiator must then be made unipolar.

The multiple channel correlator, shown in FIG. 6, will function much like eight single channel correlators, i.e., one live camera correlated with eight displaced reference cameras.

Assume a horizontal blanking interval of 10.6 μ sec., for example. These intervals are denoted by XX in FIG. 5. Reference camera 11 looks at areas 1 through 10 in FIG. 5 and produces edges corresponding to large intensity changes. The output of each delay line (FIG. 6) contains displaced edges. Each output is equivalent to a camera displaced a given distance to the right or left of center. The 5.3, 10.6, 15.9 and 21.2μs delay lines 31 show edge scenes at the center of the monitor just as if the camera was pointed progressively to the left. The 47.7, 53.0 and 58.3μs delay lines 32 produce edges of scenes starting from the right and moving toward center. Delays are graduated in steps of 5.3μs, for example, from zero to approximately 58.2μs or some desired maximum delay with the exception of delay lines which would cause correlation during horizontal blanking intervals (e.g. between the 21.2μs and 47.7μs delays as shown in FIG. 5).

In the multiple channel correlator of FIG. 6 the one reference camera 11 gives eight different edge scenes. One shot multivibrators 34 widen the edges of each output line before separately being multiplied with the nondelayed widened live edge scene in multipliers 36. Multipliers 36 are simultaneously gated "ON" for only 15.9μs by gates 38 and the widened edges fed to choppers 38.

The addition of separately delayed channels is therefore a method of simultaneously obtaining several match curves for scenes displaced horizontally from each other.

Choppers 39 separate the multiplied video edge signal of each delay channel. Multiplied edge video, during the nutated "UP" times, are integrated and subtracted from multiplied video during nutated "DOWN" times by vertical difference integrators 41. The resultant DC outputs are sent to zero crossover detectors 44. These detectors 44 DC comparators with hysteresis) are arranged so that small changes around zero volts input do not change their output polarity. A large change in input polarity (which occurs at the time of peak correlation) at one of the detectors 44 causes a change of output polarity. This change triggers the following one shot multivibrator 45, opening its gate 46 for a few seconds. Choppers 39 also provide multiplied video outputs during nutated "left" and nutated "right" times. These outputs are summed by horizontal summing integrators 42 and the DC outputs are sent to gates 46. If gate 46 was triggered "ON" the DC output of 42 is displayed by indicator 47.

The summed outputs of each of the horizontal summing integrators 42 (horizontal static match) corresponds to correlation coefficients obtained simultaneously from horizontally displaced edge scenes.

Normally only one of the gates 46 would be open due to vertical dynamic match. If vertical crossover took place simultaneously for more than one channel (crossing perpendicular to a large river, etc.) position would be derived by observing the channel having the largest horizontal static match indication. The aircraft would correct position until the zero-delayed channel produced the best horizontal static match. Navigation could then be performed using the single zero-delayed channel in a dynamic match mode as in FIG. 1 using a horizontal difference integrator rather than a sum integrator and the outputs taken directly from both integrators. In a dynamic match mode a different polarity output is obtained if the aircraft is to the right or left of the reference, similarly forward or behind. In dynamic match it is also possible to use these potentials to automatically correct flight position.

I claim:

1. An analogue video correlator for position fixing, comprising:

a. a reference video source;

b. a live video camera;

c. a nutator means connected to said reference video source for causing said reference video to scan in a desired manner;

d. a reference video gate means and a live video gate means;

e. a gate timer connected to said reference video gate means and said line video gate means;

f. synchronizing means for synchronizing said reference video source and said live video camera, and for providing reference timing for both said gate timer and said nutator means;

g. a multiplier means;

h. the output of said reference video source being connected to said multiplier means via said reference video gate means and the output of said live video camera being connected to said multiplier means via said live video gate means;

i. a chopper means connected to the output of said multiplier means, said chopper means having up and down outputs and right and left outputs;

j. said chopper means also being connected to and controlled by said nutator means;

k. resulting multiplied video pulses from said multiplier being fed to said chopper means except during desired blanking intervals;

l. a vertical difference integrator whose output provides a vertical movement output signal and a horizontal difference integrator whose output provides a horizontal movement output signal;

m. up and down outputs from said chopper means connected to said vertical difference integrator, and right and left outputs from said chopper means connected to said difference integrator; and

n. the signal outputs of said vertical and horizontal integrators corresponding to respective shifts in the live video scene from the reference video scene required to cause vertical or horizontal movement to bring the scenes into exact correlation.

2. A device as in claim 1 wherein a first edge detector is connected between said reference video source and said reference video gate means and a second edge detector is connected between said live video camera and said live video gate means, said edge detectors providing a pulse output whenever the video input level changes by a significant amount.

3. A device as in claim 2 wherein said edge detector comprises:

a. a negative absolute value amplifier;

b. a bias detector whose output is connected to said negative absolute value amplifier;

c. a video input to said bias detector and said negative absolute value amplifier;

d. said bias detector averaging the video input voltage except during intervals where the input exceeds a given blanking level voltage, the gain of said bias detector corresponding to average video level, the bias level;

e. said negative absolute value amplifier giving a negative output voltage proportional to the voltage input above or below the bias level;

f. a limiting amplifier which saturates only when its input is more positive than some set bias;

g. the output of said negative absolute value amplifier connected to said limiting amplifier; and

h. the output of said limiting amplifier consisting of a positive pulse occurring whenever there is a large change in video input.

4. An analogue video correlator for position fixing and providing continuous directional information, comprising:

a. a reference video source;

b. a live video camera;

c. a nutator means connected to said reference video source for causing said reference video to scan in a desired manner;

d. a first edge detector connected to the output of said reference video and a second edge detector connected to the output of said live video camera;

e. a reference video gate connected to the output of said first edge detector and a live video gate connected to the output of said second edge detector;

f. a gate timer connected to said reference video gate and said live video gate;

g. synchronizing means for synchronizing said reference video source and said live video camera and for providing reference timing for both said gate timer and said nutator means;

h. a plurality of parallel separately delayed correlator channels which vary from zero delay to some maximum delay except during blanking intervals for simultaneously obtaining several signals for scenes displaced horizontally from each other being connected to the output of said reference video gate, each correlator channel comprising:

1. a delay line;

2. a means for widening the edges of each delay line output;

3. a multiplier connected to the output of said edge widening means;

4. a first channel gate connected to the output of said multiplier;

5. a chopper means connected to the output of said first channel gate, said chopper means having up and down outputs and right and left outputs;

6. a vertical difference integrator whose output provides a vertical movement output signal and a horizontal sum integrator whose output provides a horizontal output signal;

7. up and down outputs from said chopper means connected to said vertical difference integrator and right and left outputs from said chopper means connected to said horizontal sum integrator;

i. the output of said live video gate being connected to a live video edge widening means;

j. the output of said live video edge widening means being connected to the multiplier in each of said plurality of separated delayed channels where it is separately multiplied with the signal from the edge widening means in each of the respective channels;

k. the gate timer also being connected to each of said first channel gates;

l. said nutator means also being connected to each of said channel chopper means which separate the multiplied video edge signal of each delay channel; and

m. the signal outputs of the vertical and horizontal integrators of each channel corresponding to respective shifts in the live video scene from the reference video scene required to cause vertical or horizontal movement to bring the scenes into exact correlation.

5. A device as in claim 4 wherein said edge detectors comprise:

a. a negative absolute value amplifier;

b. a bias detector whose output is connected to said negative absolute value amplifier;

c. a video input to said bias detector and said negative absolute value amplifier;

d. said bias detector averaging the video input voltage except during intervals where the input exceeds a given blanking level voltage, the gain of said bias detector corresponding to average video level, the bias level;

e. said negative absolute value amplifier giving a negative output voltage proportional to the voltage input above or below the bias level;

f. a limiting amplifier which saturates only when its input is more positive than some set bias;

g. the output of said negative absolute value amplifier connected to said limiting amplifier; and

h. the output of said limiting amplifier consisting of a positive pulse occurring whenever there is a large change in video input.

6. An a edge detector comprising:

a. a negative absolute value amplifier;

b. a bias detector whose output is connected to said negative absolute value amplifier;

c. a video input to said bias detector and said negative absolute value amplifier;

d. said bias detector averaging the video input voltage except during intervals where the input exceeds a given blanking level voltage, the gain of said bias detector corresponding to average video level, the bias level;

e. said negative absolute value amplifier giving a negative output voltage proportional to the voltage input above or below the bias level;

f. a limiting amplifier which saturates only when its input is more positive than some set bias;

g. the output of said negative absolute value amplifier connected to said limiting amplifier; and

h. the output of said limiting amplifier consisting of a positive pulse occurring whenever there is a large change in video input.