US006229550B1

(12) **United States Patent**
**Gloudemans et al.**

(10) **Patent No.: US 6,229,550 B1**
(45) **Date of Patent: May 8, 2001**

(54) **BLENDING A GRAPHIC**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/160,428**

(22) Filed: **Sep. 24, 1998**

**Related U.S. Application Data**

(60) Provisional application No. 60/099,262, filed on Sep. 4, 1998.

(51) **Int. Cl.**$^7$ .................................................... **G06F 15/00**

(52) **U.S. Cl.** ............................................................ **345/435**

(58) **Field of Search** .................................... 345/419, 427, 345/418, 435, 113, 114

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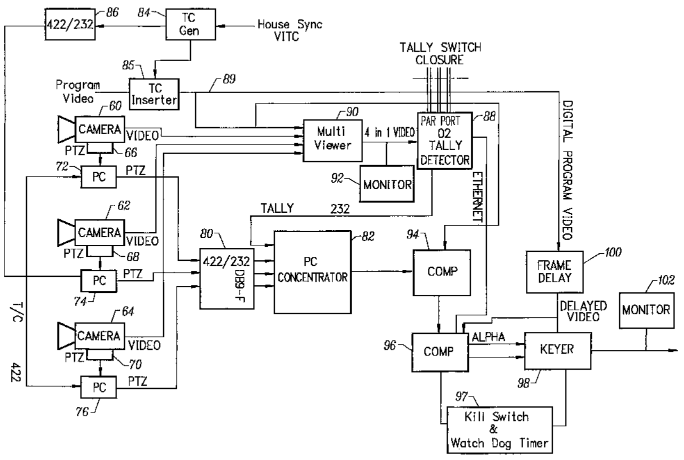
(74) *Attorney, Agent, or Firm*—Vierra Magen Marcus Harmon & DeNiro LLP

(57) **ABSTRACT**

A graphic and video are blended by controlling the relative transparency of corresponding pixels in the graphic and the video through the use of blending coefficients. One example of a blending coefficient is an alpha signal used in conjunction with a keyer. The value of a blending coefficient for a pixel in the graphic is based on the luminance and chrominance characteristics of a neighborhood of pixels in the video. Inclusions and exclusions are set up which define how the neighborhood of pixels is used to create or change a particular blending characteristic.

**50 Claims, 25 Drawing Sheets**



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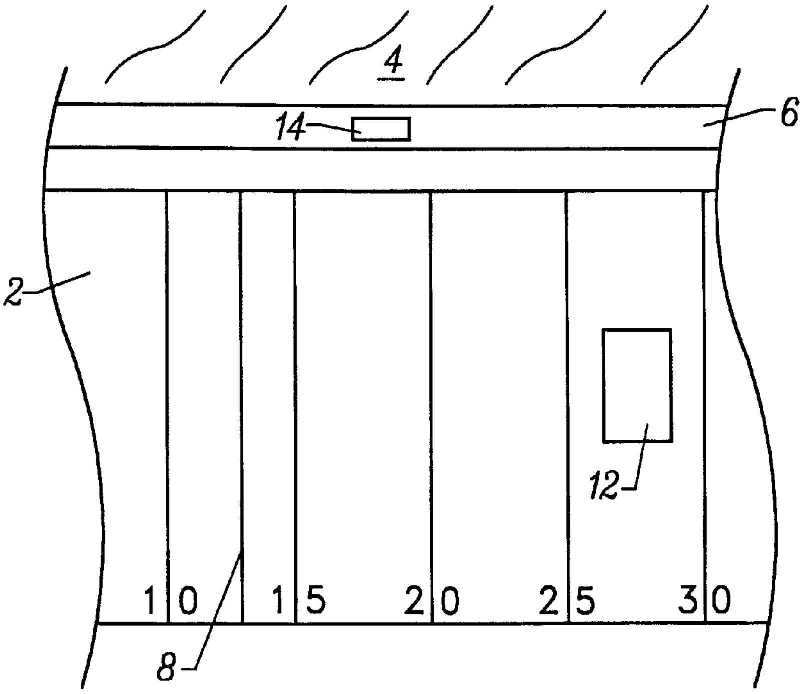


FIG. 1

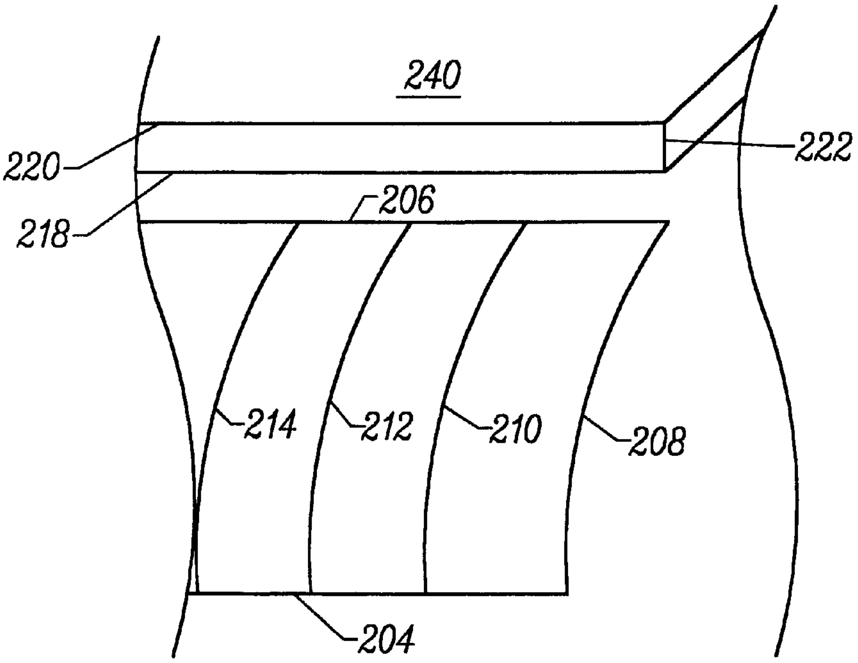
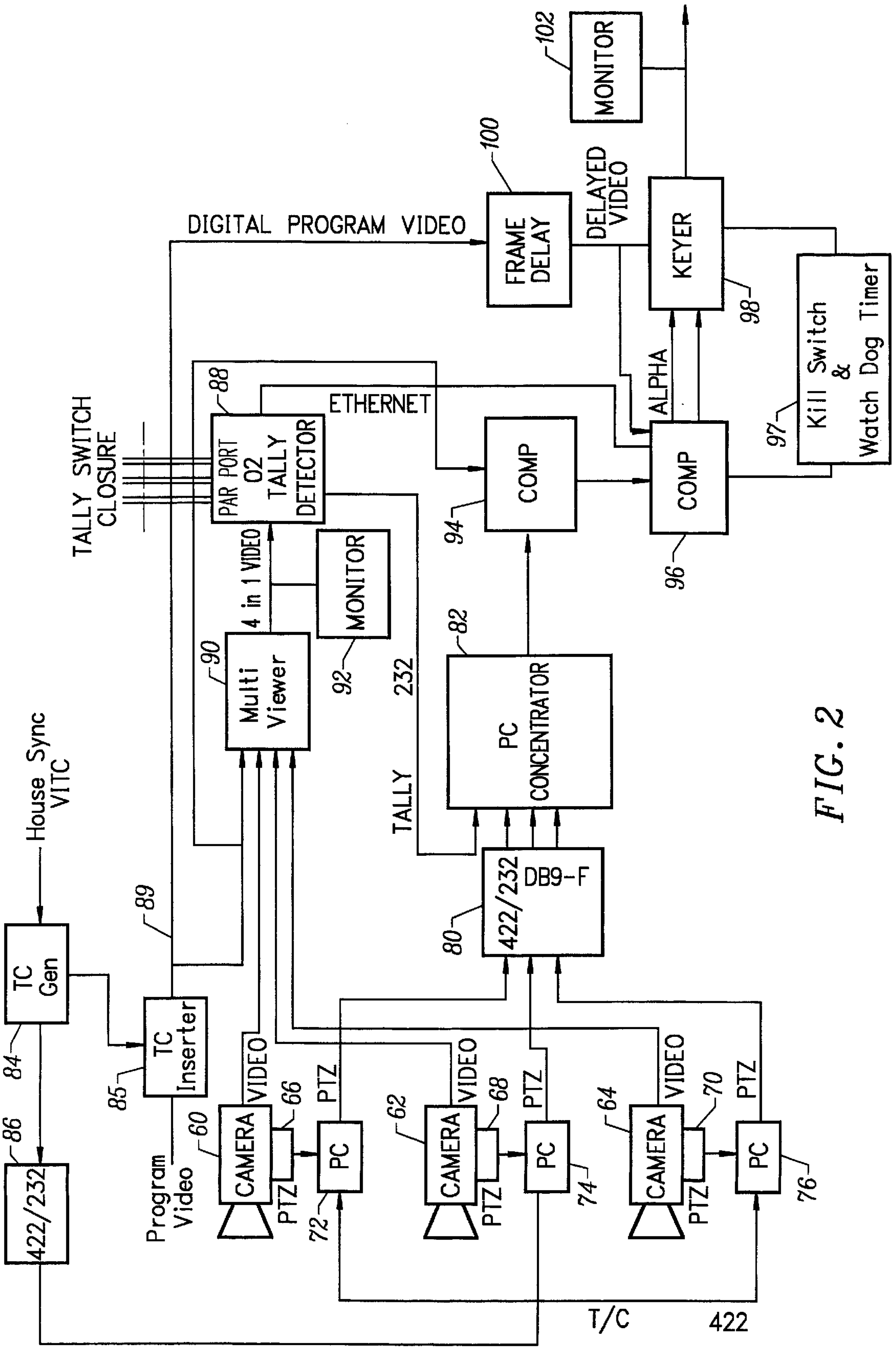


FIG. 5



House Sync
VITC
TC Gen
84
86
422/232
TC Inserter
85
89
Program Video
CAMERA
60
66
PTZ
VIDEO
PC
72
CAMERA
62
68
PTZ
VIDEO
PC
74
CAMERA
64
70
PTZ
VIDEO
PC
76
T/C
422
80
422/232
DB9-F
82
PC CONCENTRATOR
TALLY
232
Multi Viewer
90
4 in 1 VIDEO
MONITOR
92
TALLY SWITCH CLOSURE
88
PAR PORT 02
TALLY DETECTOR
ETHERNET
DIGITAL PROGRAM VIDEO
COMP
94
COMP
96
ALPHA
FRAME DELAY
100
DELAYED VIDEO
KEYER
98
MONITOR
102
Kill Switch & Watch Dog Timer
97

FIG. 2

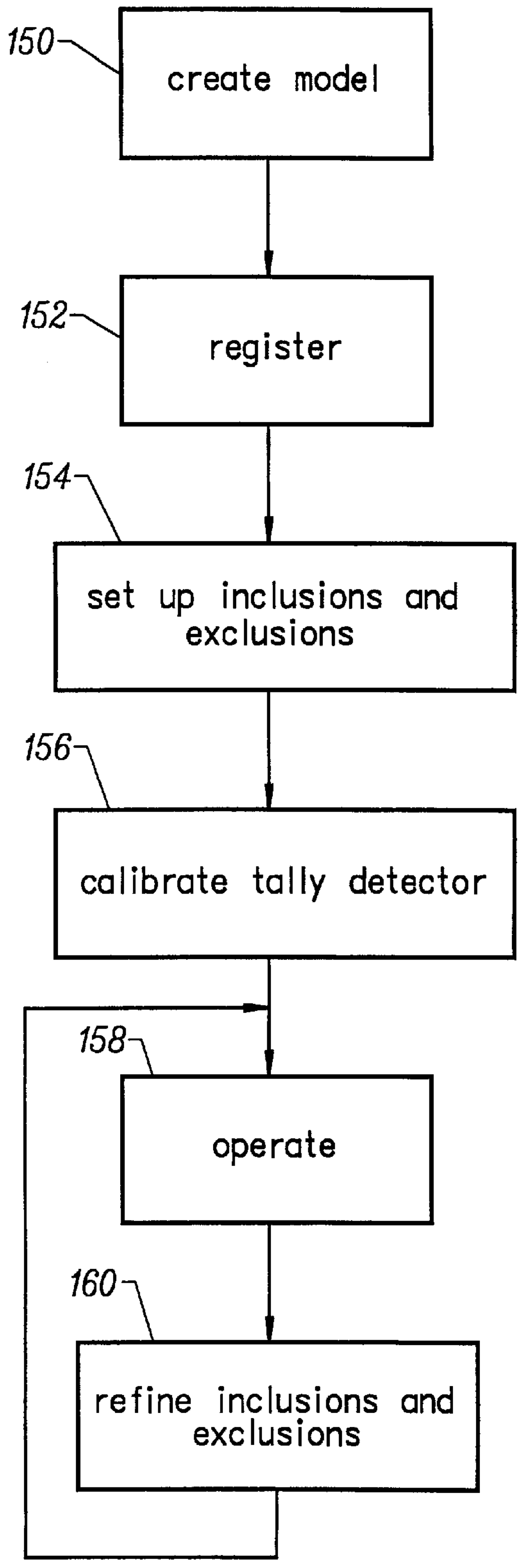

150
create model
152
register
154
set up inclusions and exclusions
156
calibrate tally detector
158
operate
160
refine inclusions and exclusions

FIG. 3

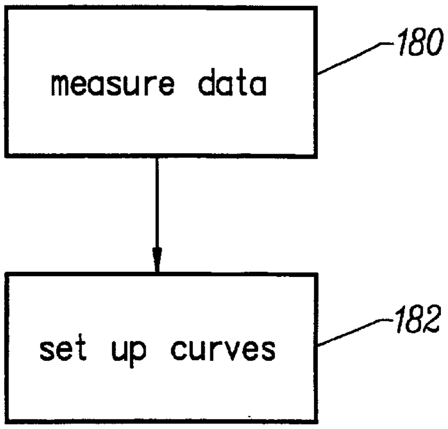

180
measure data
182
set up curves

FIG. 4

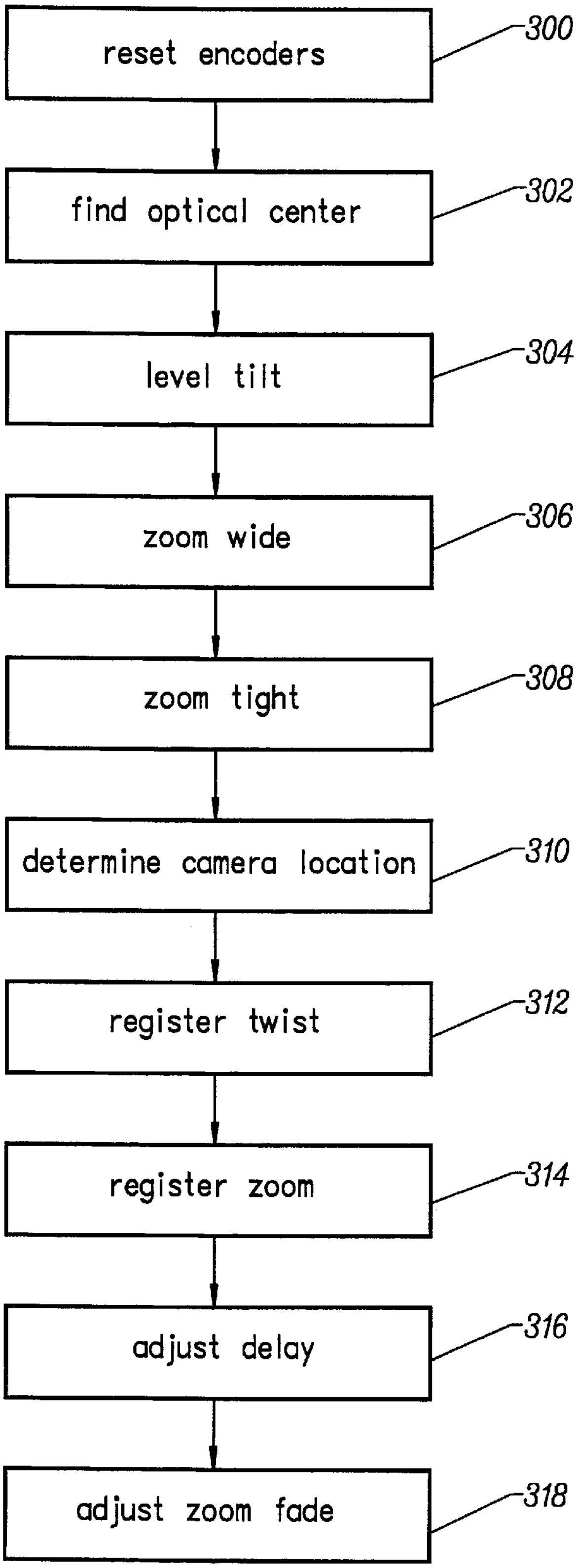

reset encoders
300
find optical center
302
level tilt
304
zoom wide
306
zoom tight
308
determine camera location
310
register twist
312
register zoom
314
adjust delay
316
adjust zoom fade
318

*FIG. 6*

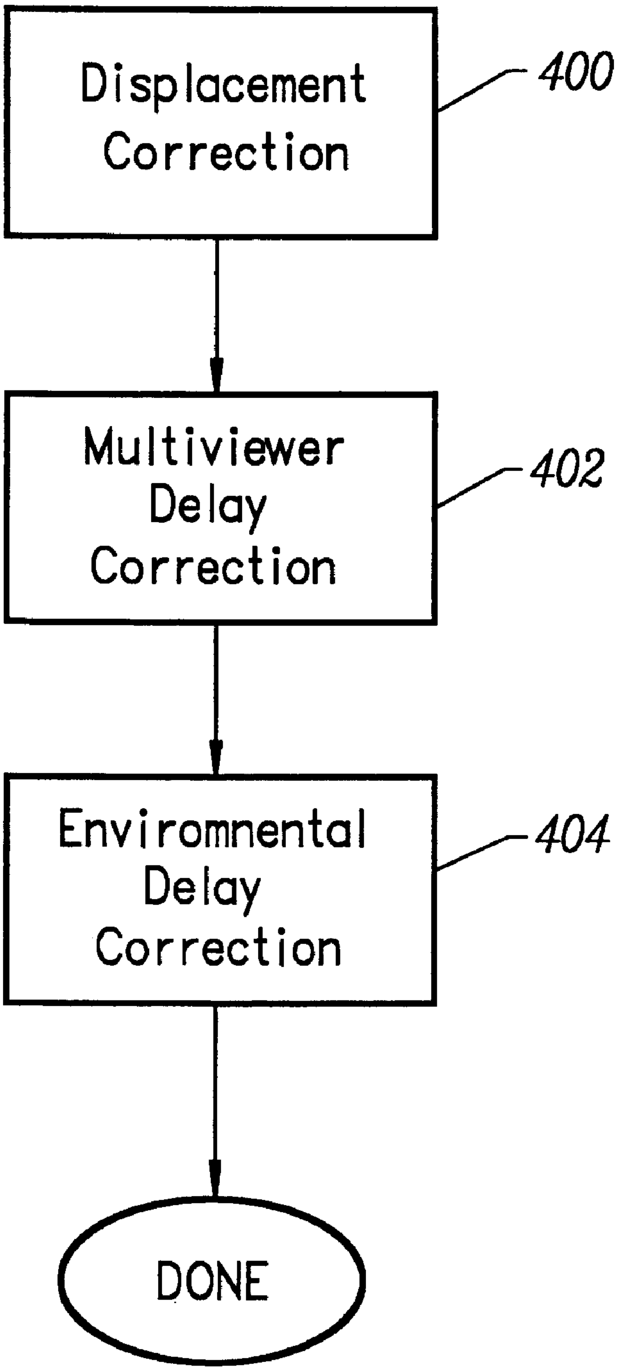

Displacement Correction
400
Multiviewer Delay Correction
402
Enviromnental Delay Correction
404
DONE

FIG. 7

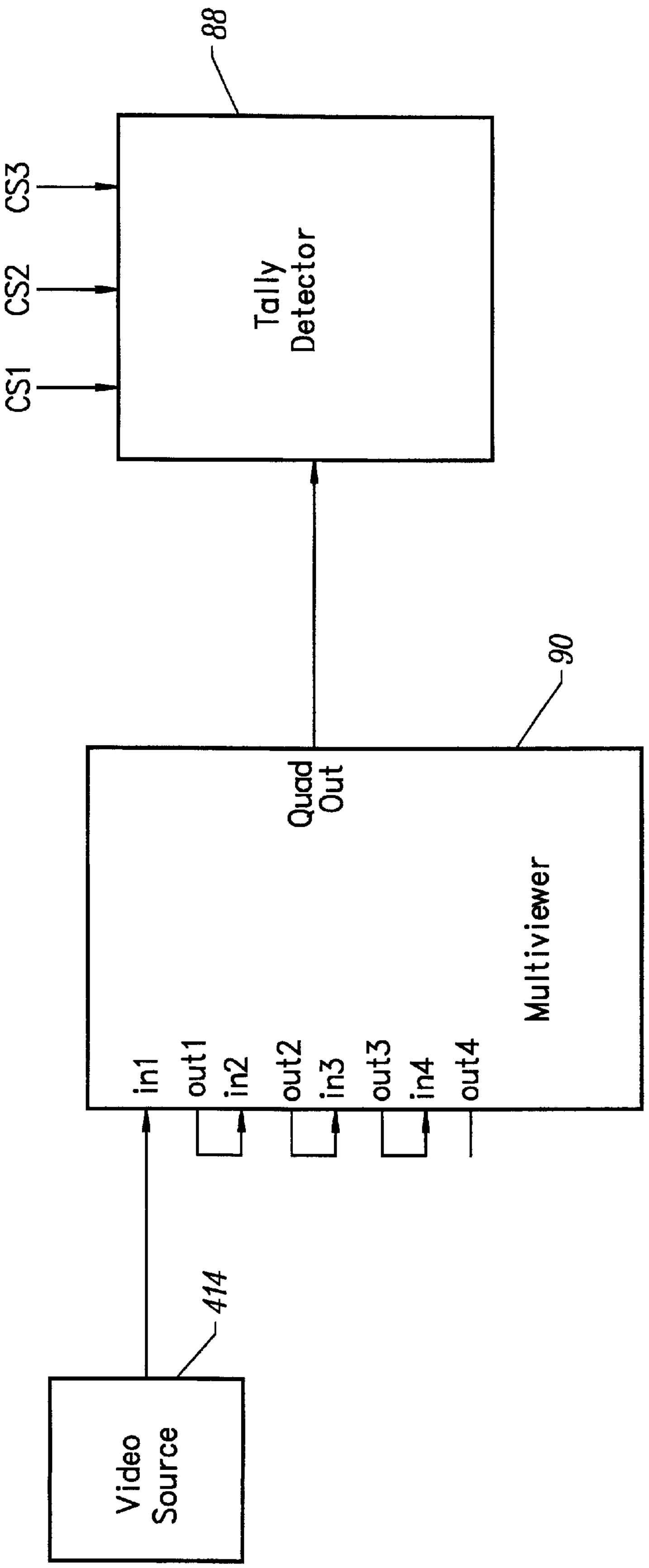

88
Tally Detector
CS1
CS2
CS3
90
Quad Out
Multiviewer
in1
out1
in2
out2
in3
out3
in4
out4
414
Video Source

FIG. 8

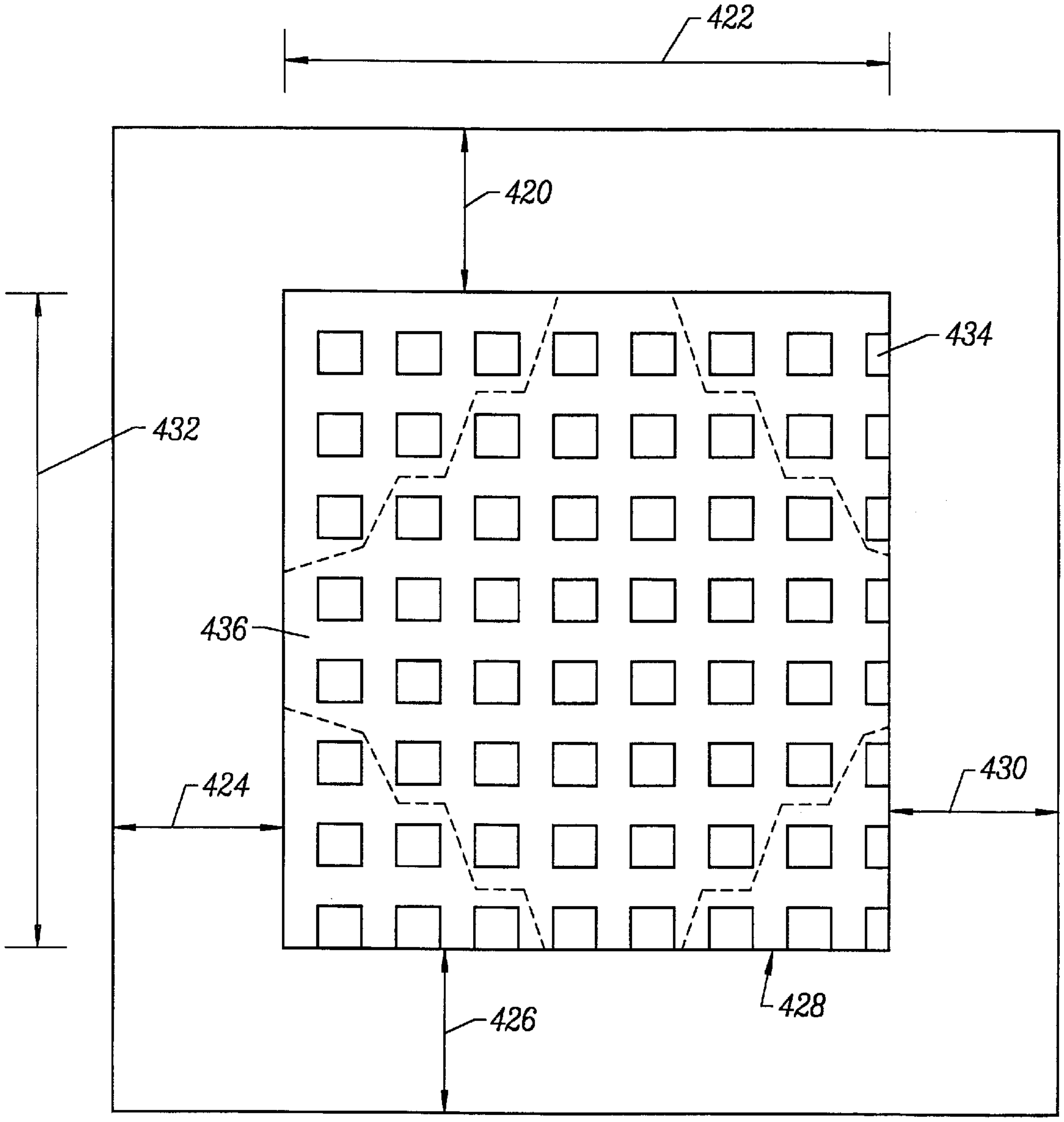


FIG. 9

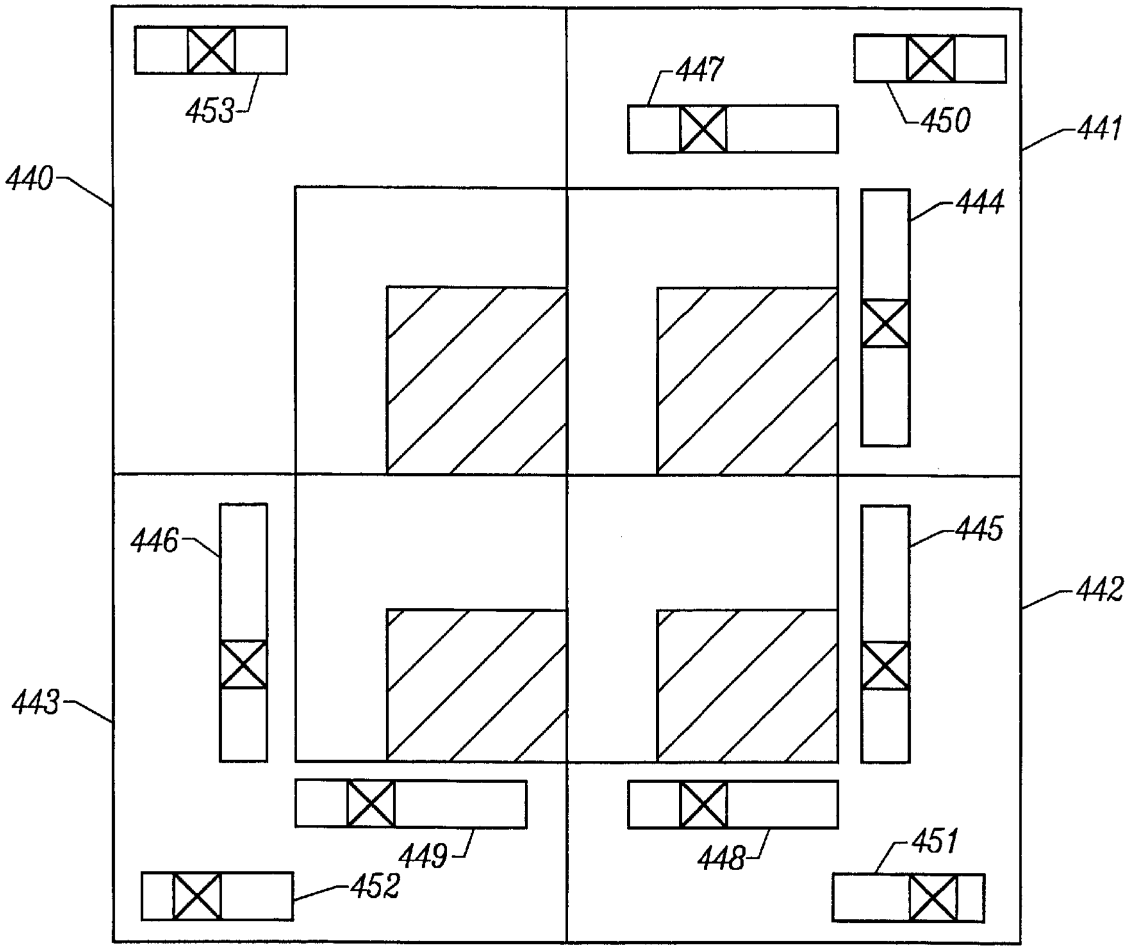


FIG. 10

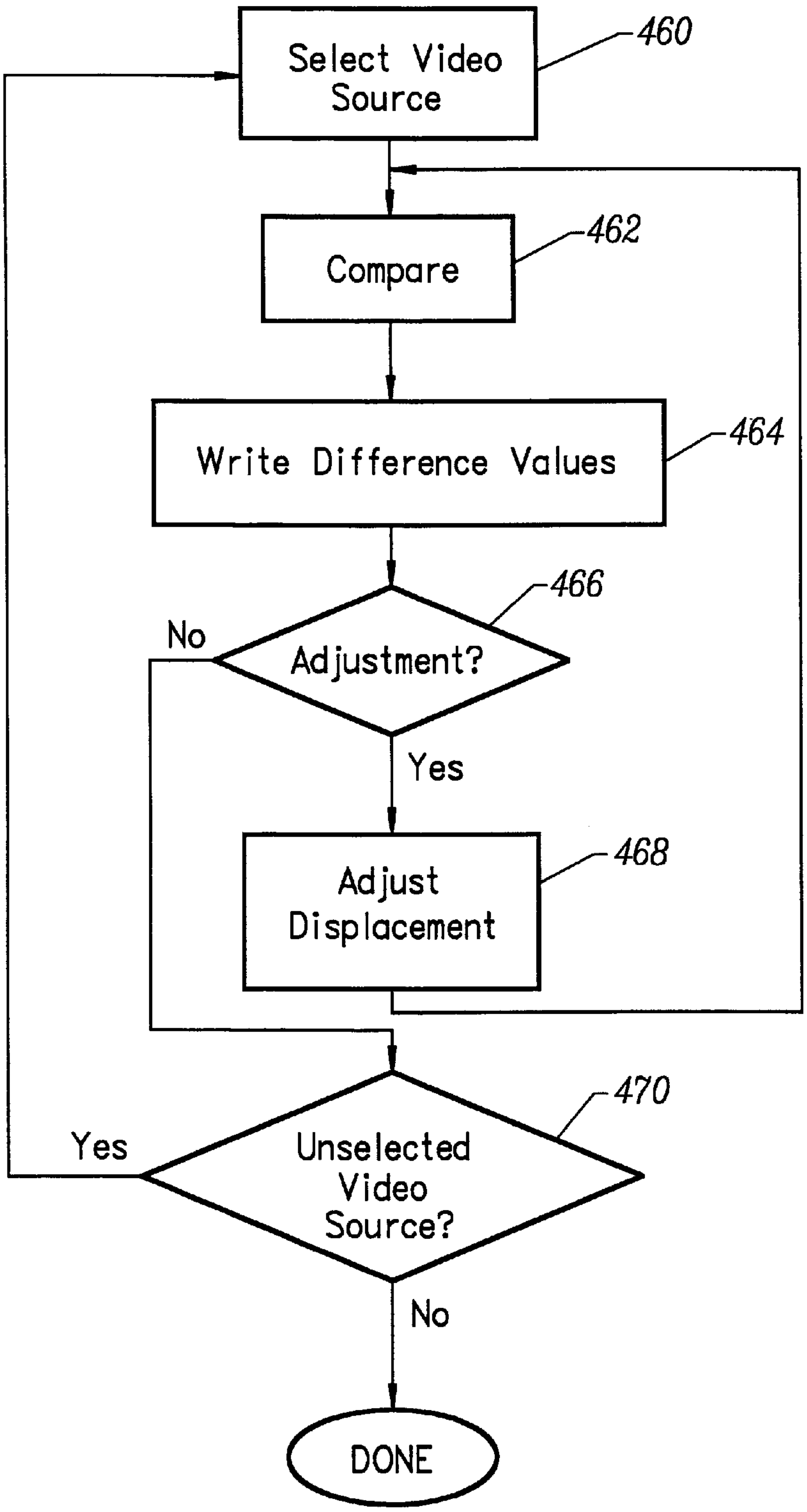

Select Video Source
460
Compare
462
Write Difference Values
464
Adjustment?
466
No
Yes
Adjust Displacement
468
Unselected Video Source?
470
Yes
No
DONE

FIG. 11

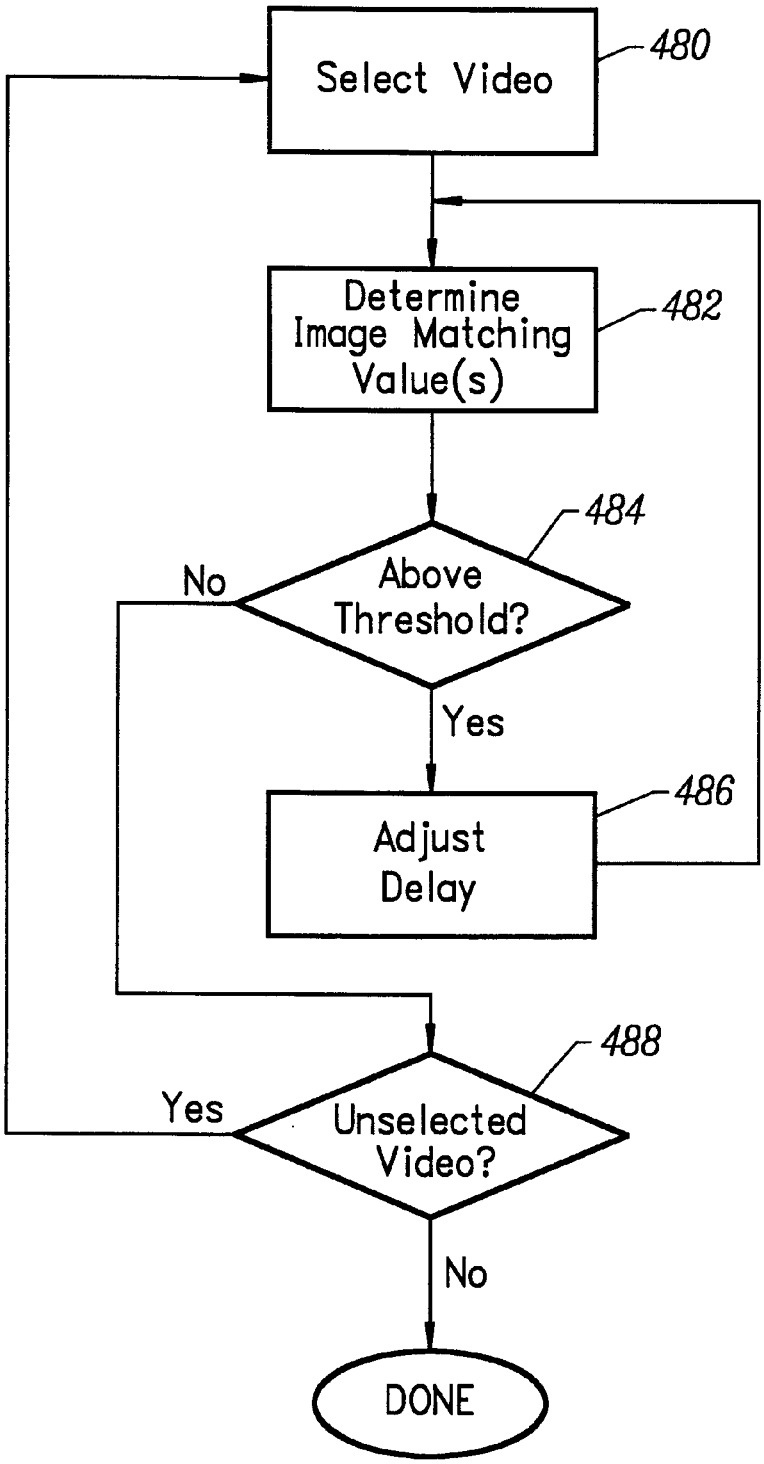

Select Video
480
Determine Image Matching Value(s)
482
484
Above Threshold?
No
Yes
Adjust Delay
486
488
Unselected Video?
Yes
No
DONE

FIG. 12

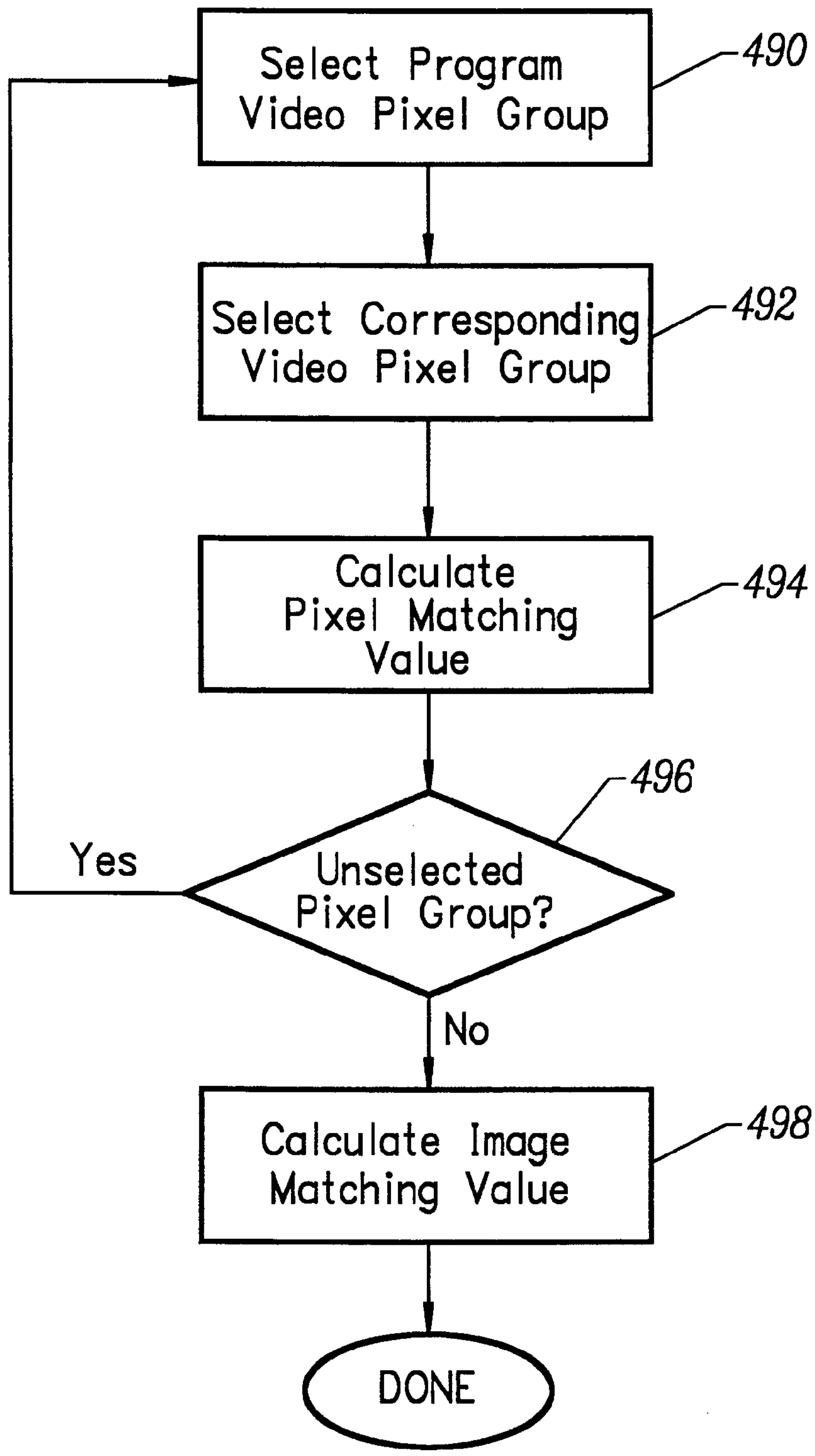

Select Program Video Pixel Group
490
Select Corresponding Video Pixel Group
492
Calculate Pixel Matching Value
494
496
Yes
Unselected Pixel Group?
No
Calculate Image Matching Value
498
DONE

FIG. 13

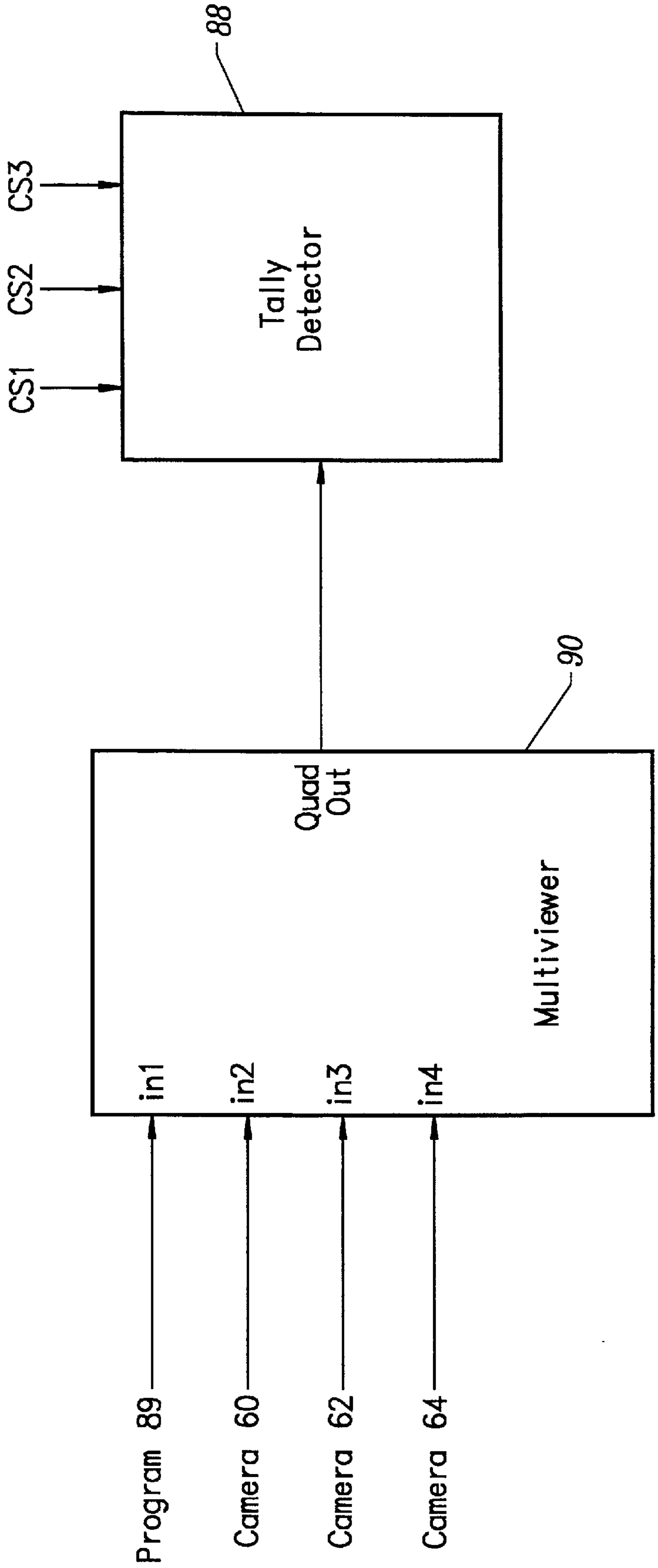

88
CS1
CS2
CS3
Tally Detector
90
Quad Out
Multiviewer
in1
in2
in3
in4
Program 89
Camera 60
Camera 62
Camera 64

FIG. 14

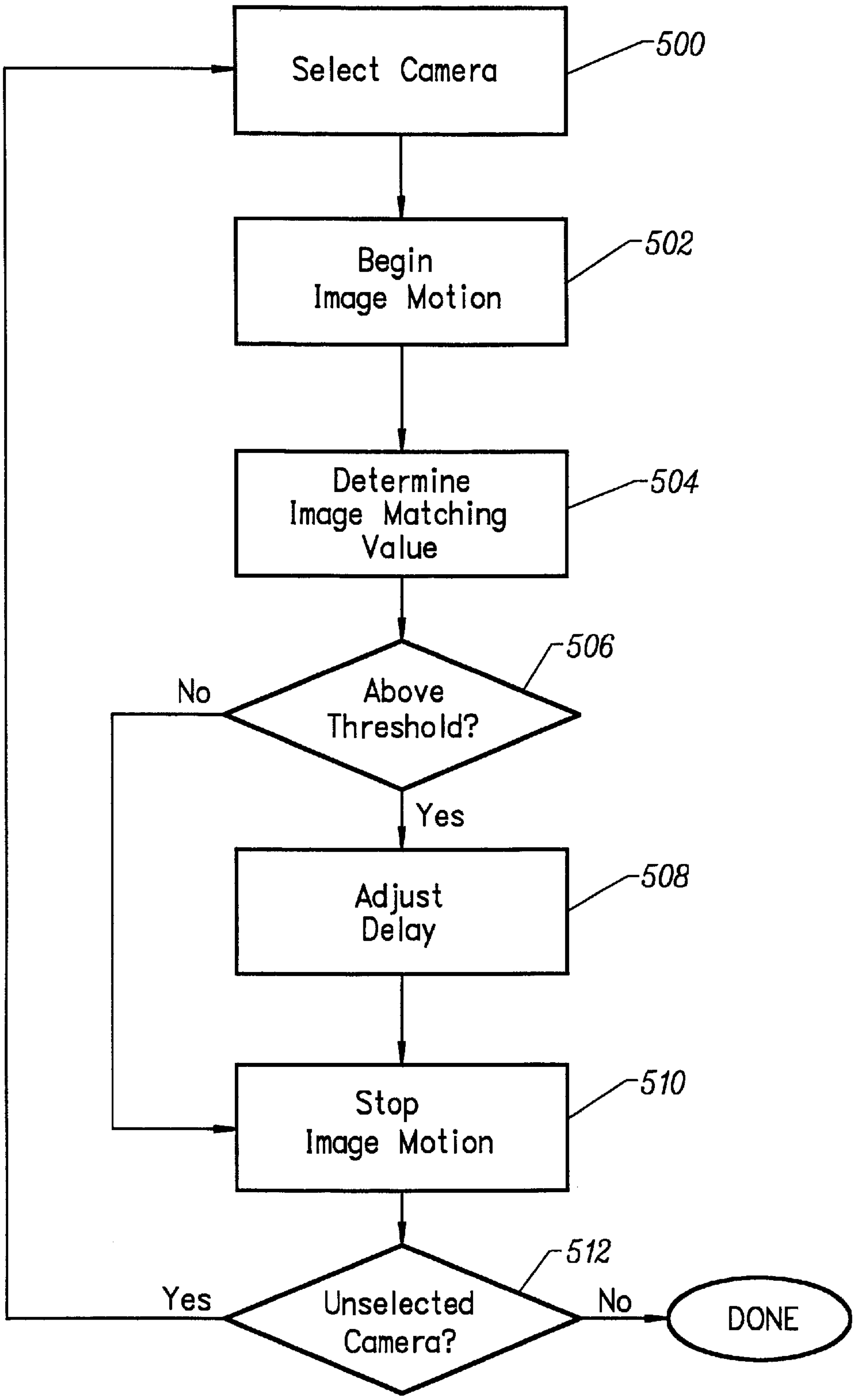

Select Camera
500
Begin Image Motion
502
Determine Image Matching Value
504
Above Threshold?
506
No
Yes
Adjust Delay
508
Stop Image Motion
510
Unselected Camera?
512
Yes
No
DONE

FIG. 15

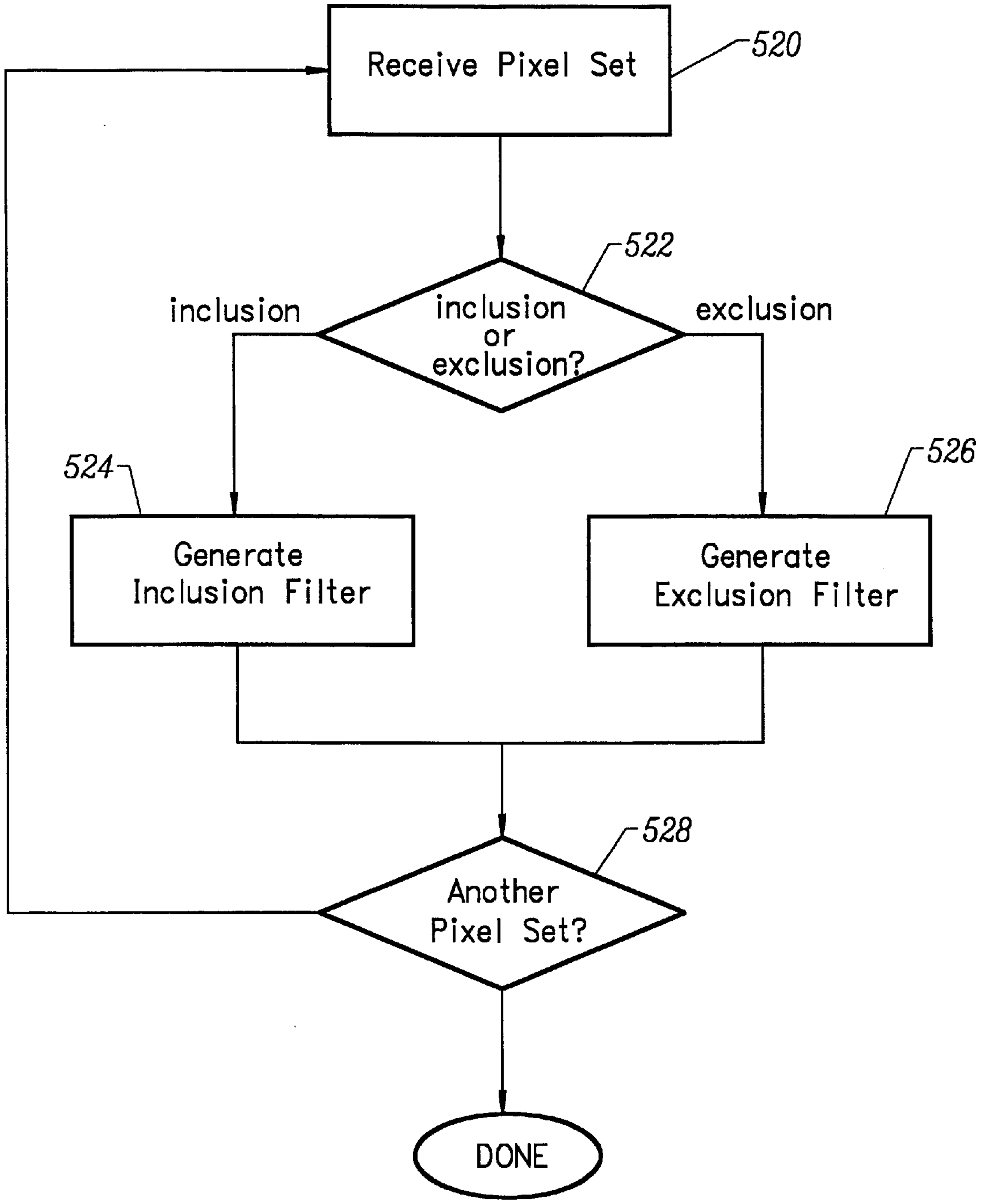

Receive Pixel Set
520
522
inclusion
inclusion or exclusion?
exclusion
524
Generate Inclusion Filter
526
Generate Exclusion Filter
528
Another Pixel Set?
DONE

FIG. 16

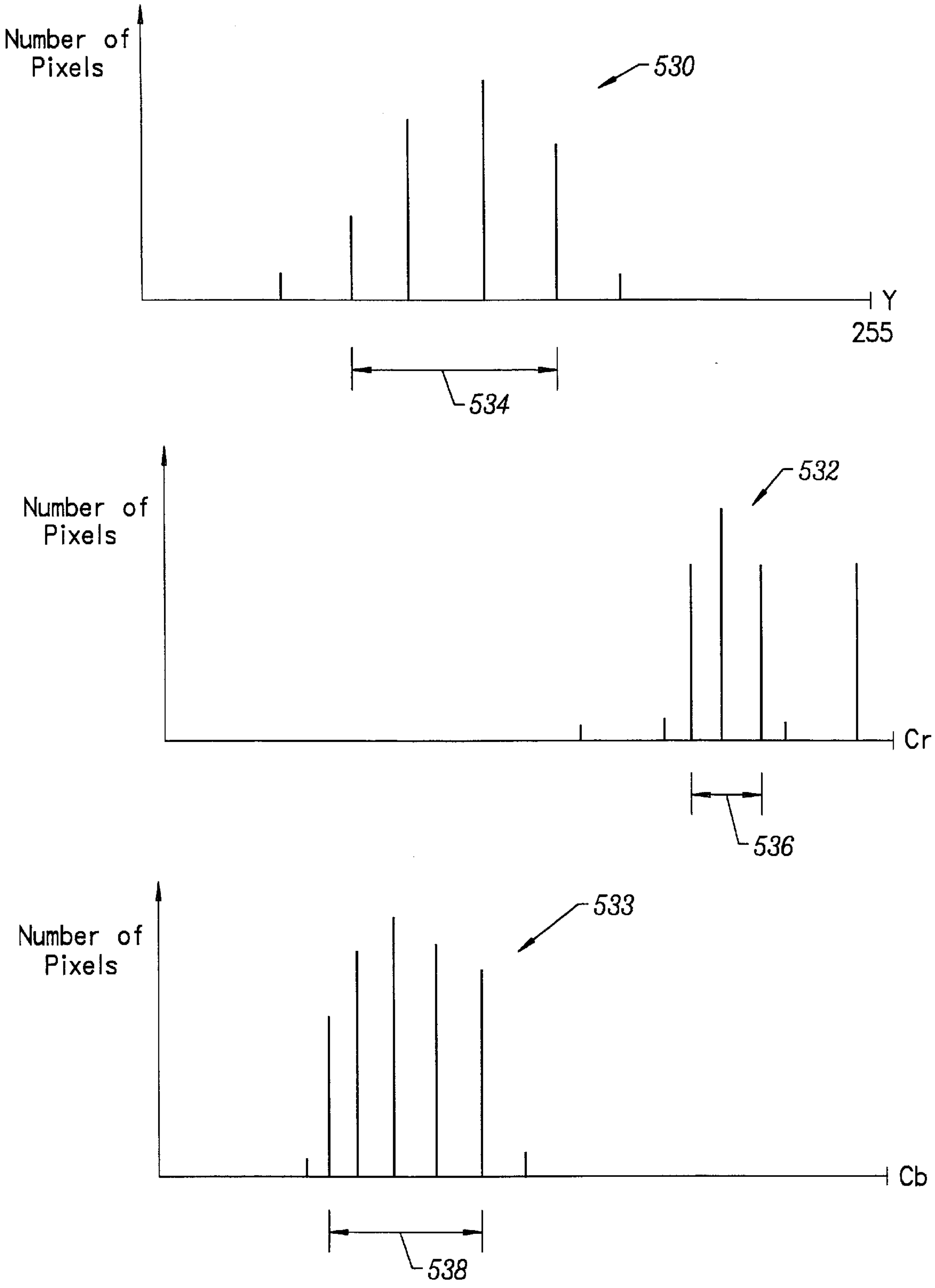

Number of Pixels
530
Y
255
534
Number of Pixels
532
Cr
536
Number of Pixels
533
Cb
538

FIG. 17

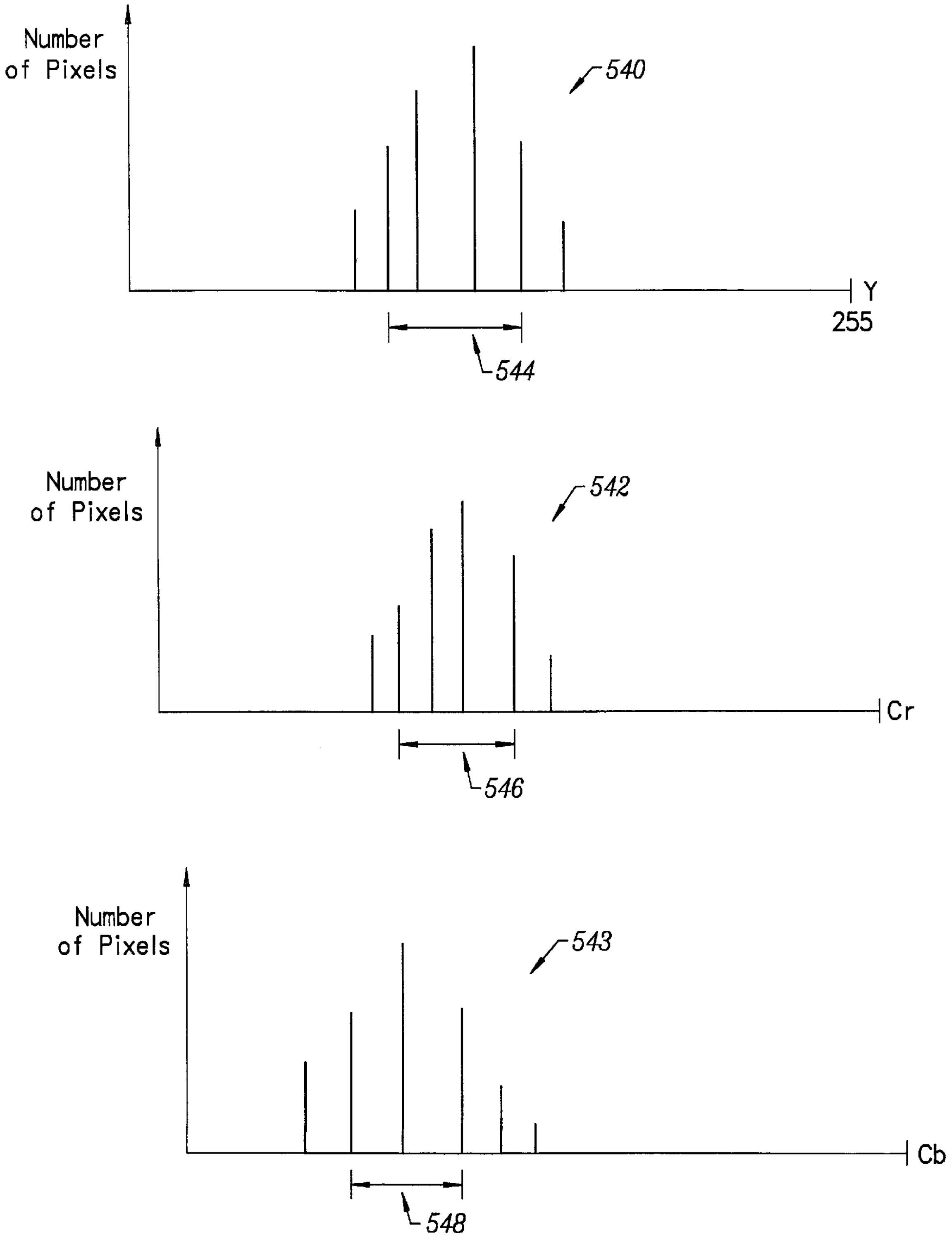

Number of Pixels
540
Y
255
544
Number of Pixels
542
Cr
546
Number of Pixels
543
Cb
548

FIG. 18

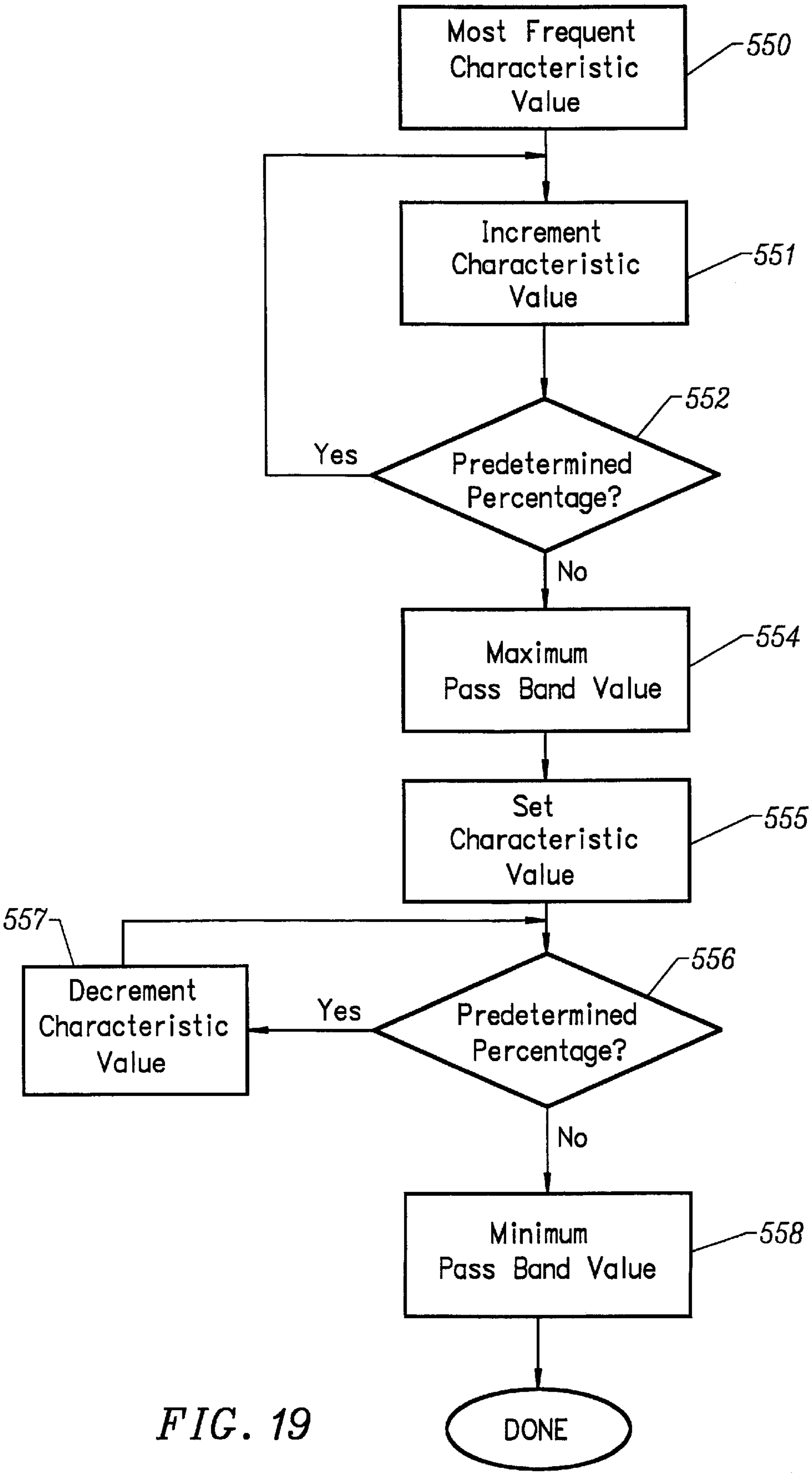

Most Frequent Characteristic Value
550
Increment Characteristic Value
551
552
Yes
Predetermined Percentage?
No
Maximum Pass Band Value
554
Set Characteristic Value
555
557
Decrement Characteristic Value
Yes
556
Predetermined Percentage?
No
Minimum Pass Band Value
558
DONE

FIG. 19

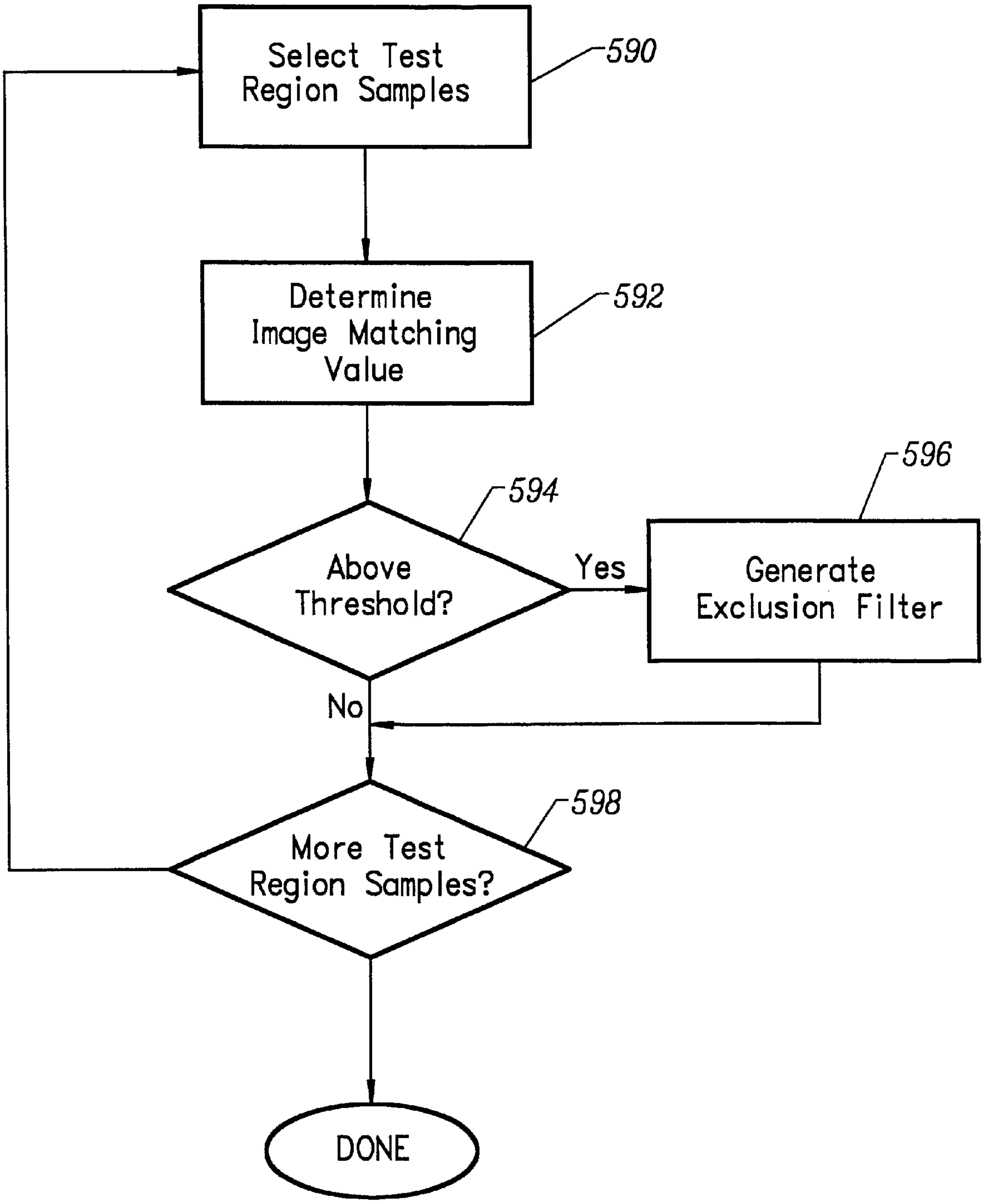

Select Test Region Samples
590
Determine Image Matching Value
592
594
596
Above Threshold?
Yes
Generate Exclusion Filter
No
598
More Test Region Samples?
DONE

FIG. 20

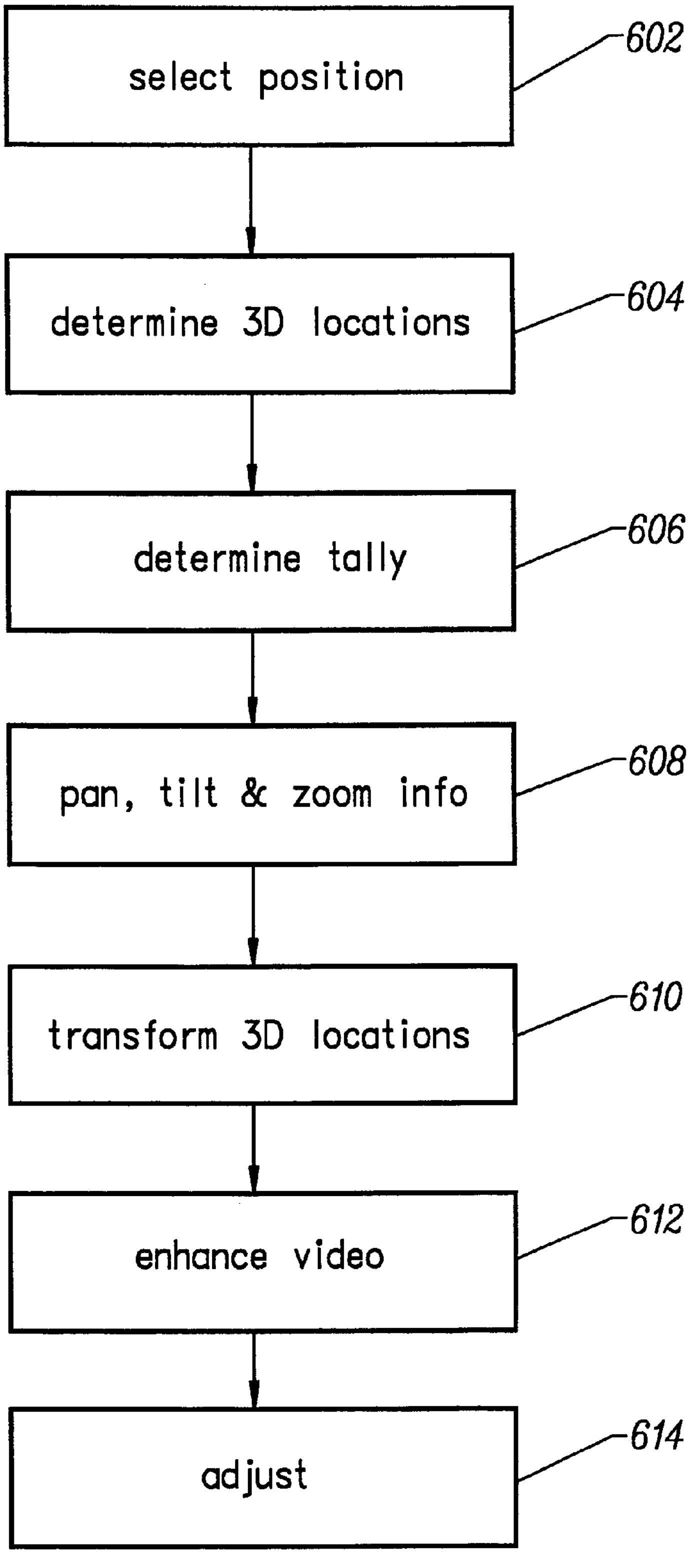

select position
602
determine 3D locations
604
determine tally
606
pan, tilt & zoom info
608
transform 3D locations
610
enhance video
612
adjust
614

FIG. 21

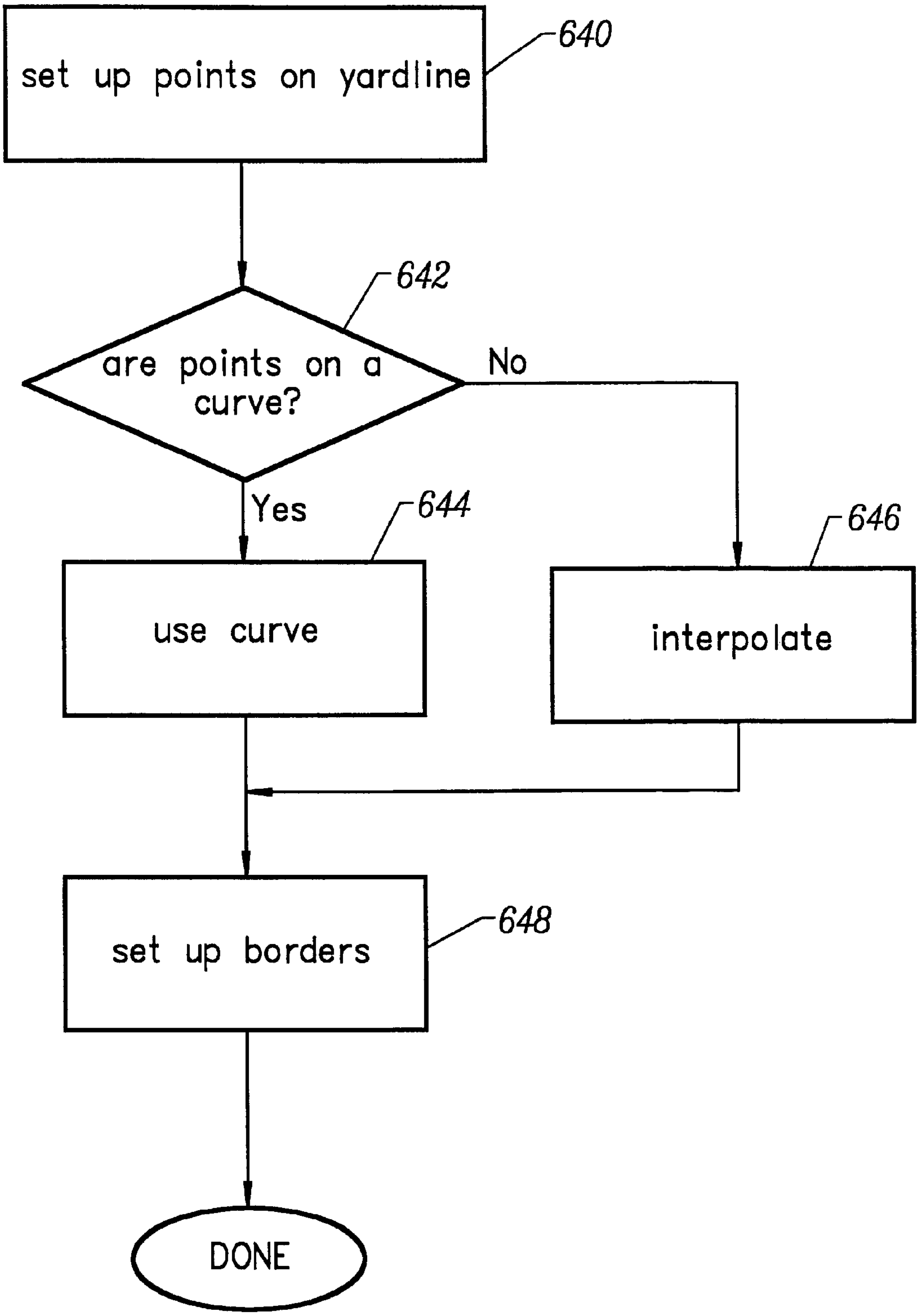

set up points on yardline
640
642
are points on a curve?
No
Yes
644
use curve
646
interpolate
set up borders
648
DONE

FIG. 22A

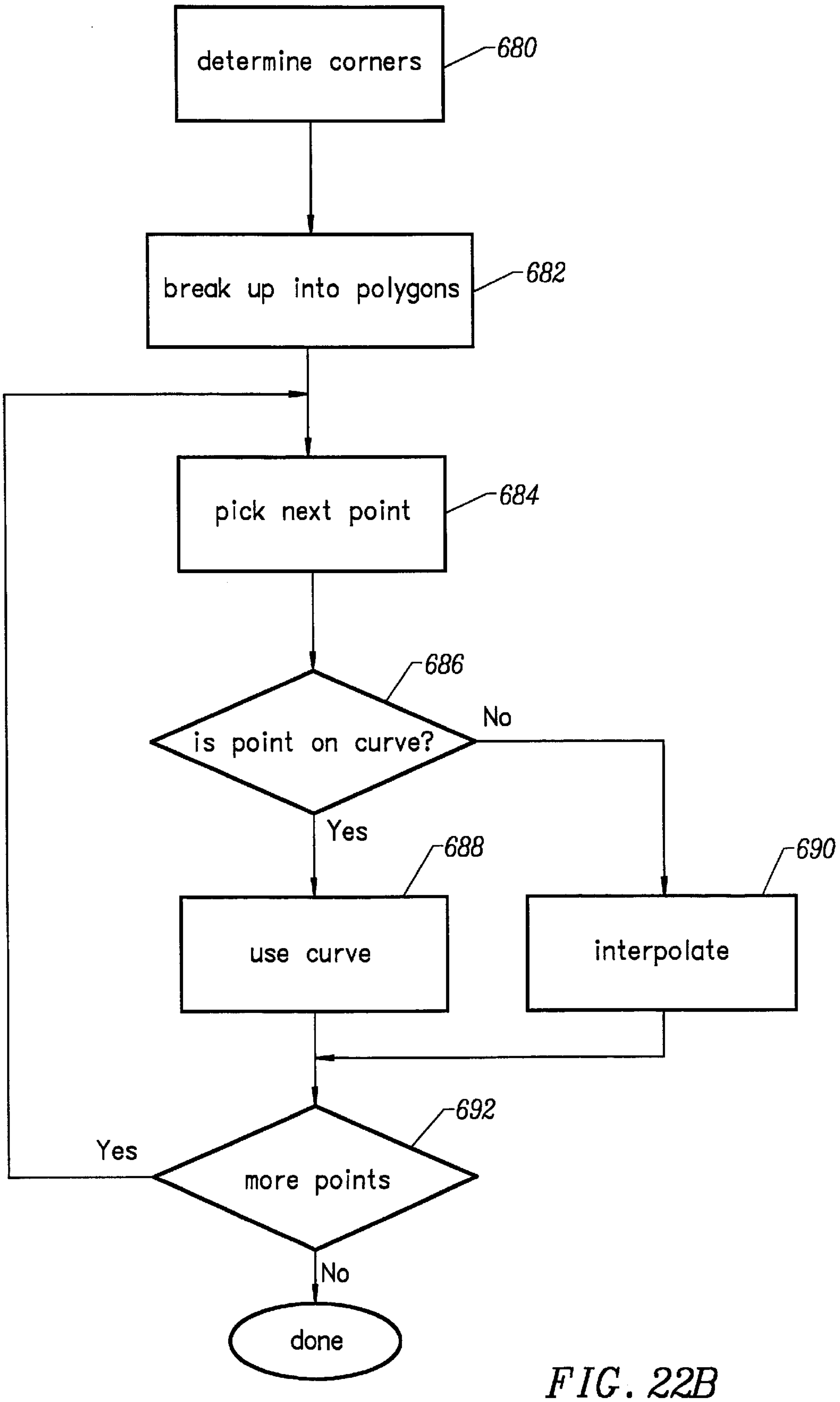

determine corners
680
break up into polygons
682
pick next point
684
is point on curve?
686
No
Yes
use curve
688
interpolate
690
more points
692
Yes
No
done

FIG. 22B

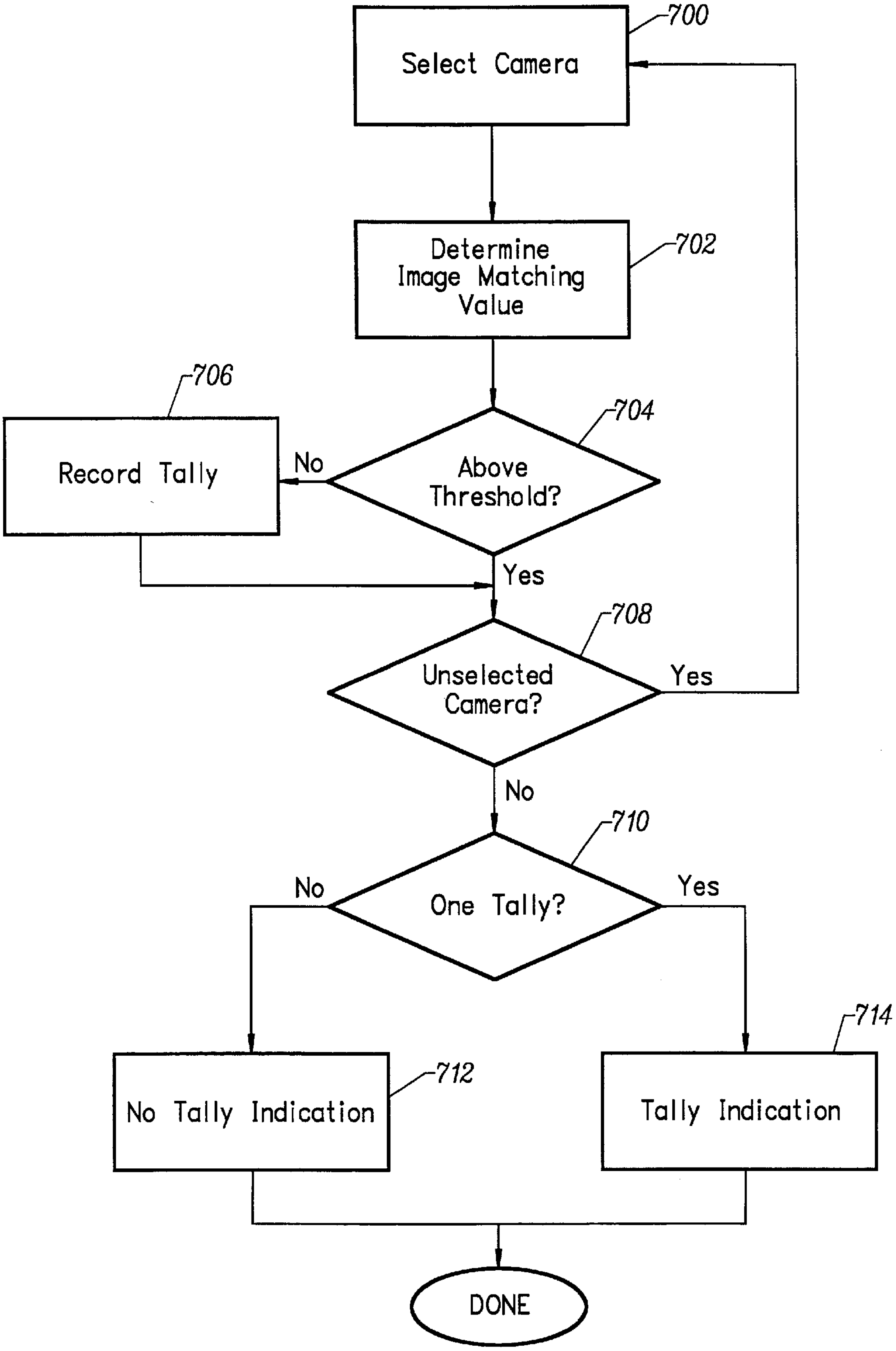

700
Select Camera
702
Determine Image Matching Value
704
Above Threshold?
No
706
Record Tally
Yes
708
Unselected Camera?
Yes
No
710
One Tally?
No
Yes
712
No Tally Indication
714
Tally Indication
DONE

*FIG. 23*

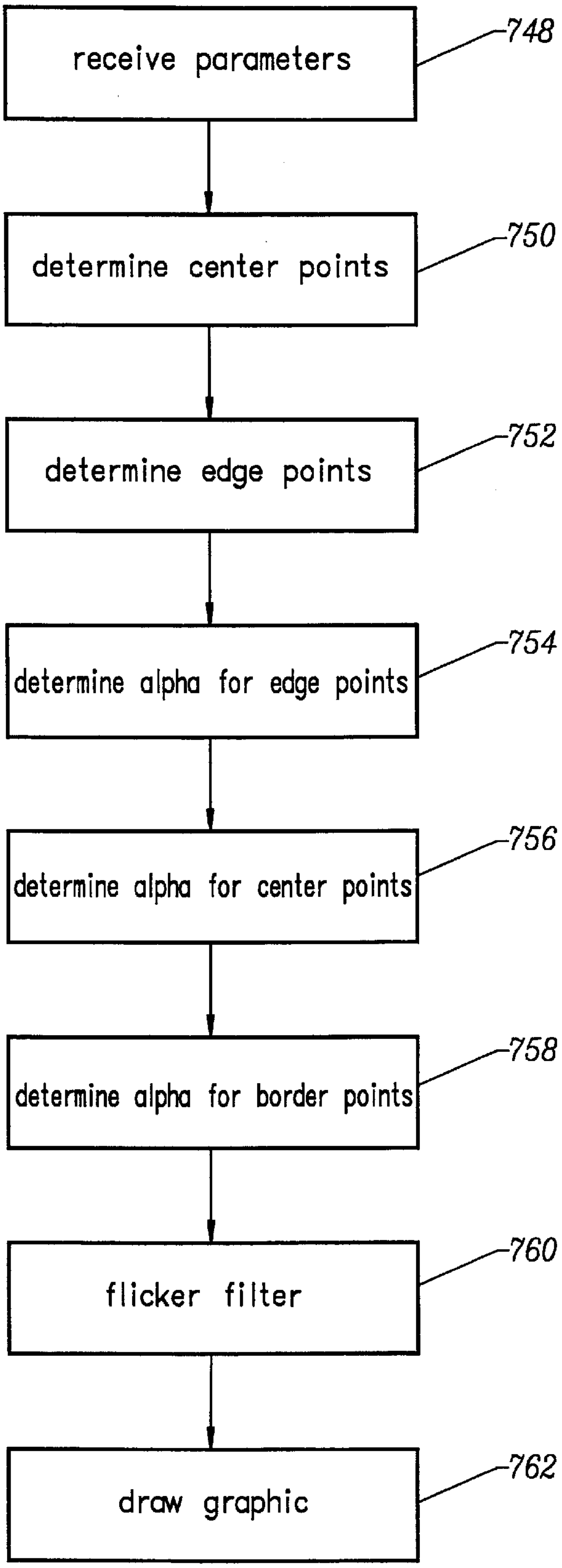

receive parameters
748
determine center points
750
determine edge points
752
determine alpha for edge points
754
determine alpha for center points
756
determine alpha for border points
758
flicker filter
760
draw graphic
762

*FIG. 24*

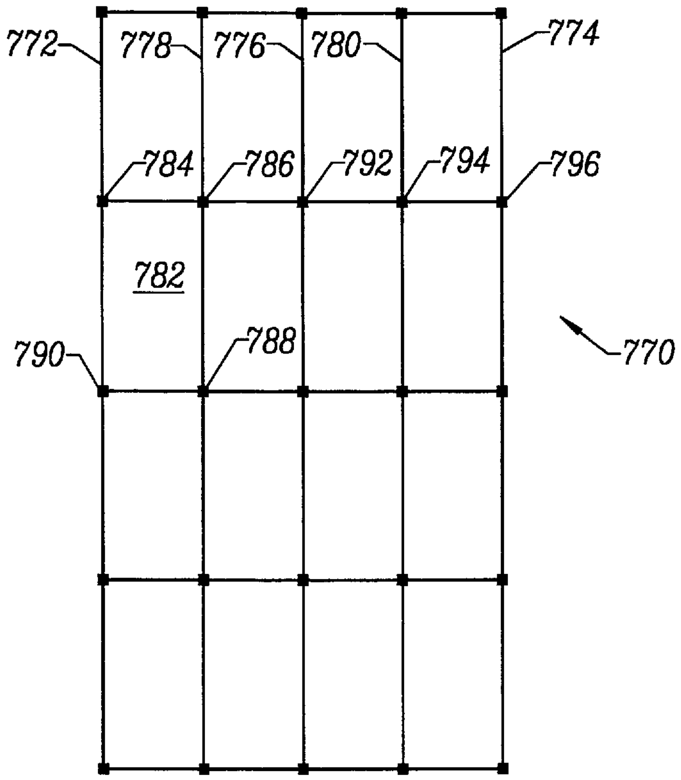

772
778
776
780
774
784
786
792
794
796
782
790
788
770

FIG. 25

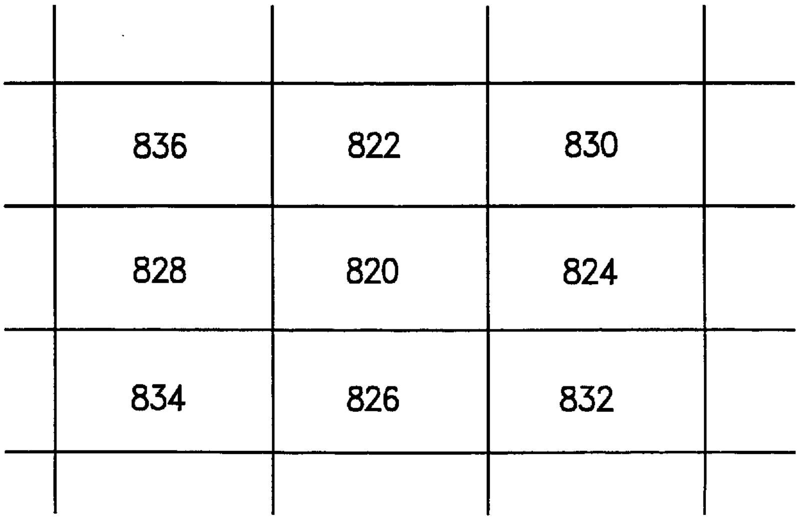

836
822
830
828
820
824
834
826
832

FIG. 27

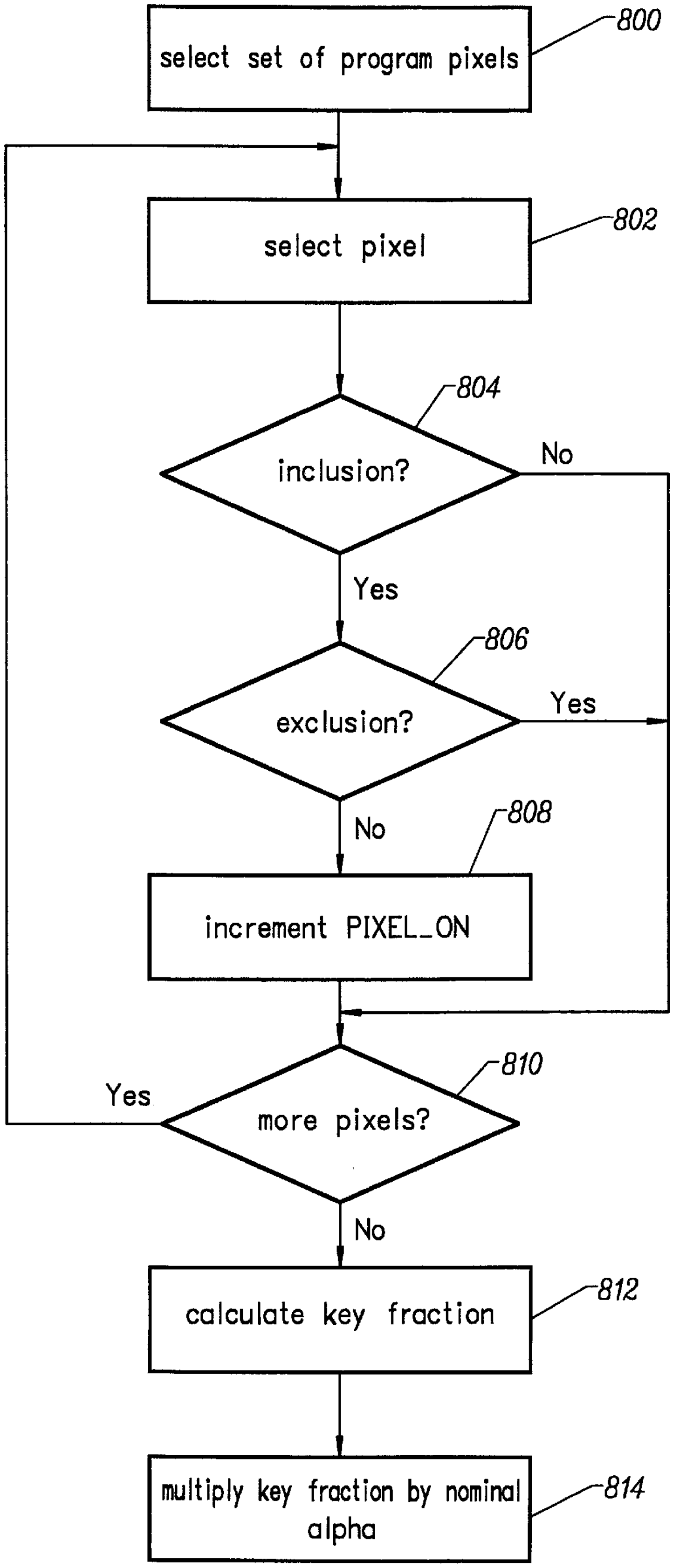

select set of program pixels
800
select pixel
802
inclusion?
804
No
Yes
exclusion?
806
Yes
No
increment PIXEL_ON
808
more pixels?
810
Yes
No
calculate key fraction
812
multiply key fraction by nominal alpha
814

FIG. 26

# BLENDING A GRAPHIC

## CROSS-REFERENCES TO RELATED APPLICATIONS

This Application claims the benefit of U.S. Provisional Application No. 60/099,262, filed on Sep. 4, 1998.

This Application is related to the following Applications:

A System For Enhancing A Video Presentation Of A Live Event, by James R. Gloudemans, Richard H. Cavallaro, Jerry N. Gepner, Stanley K. Honey, Walter Hsiao, Terence J. O'Brien, Marvin S. White, filed the same day as the present application;

Detecting A Tallied Camera, by Marvin S. White, Richard H. Cavallaro, James R. Gloudemans, Stanley K. Honey, filed the same day as the present application;

A Method And Apparatus For Enhancing The Broadcast Of A Live Event, by Stanley K. Honey, Richard H. Cavallaro, Jerry Neil Gepner, Edward Gerald Goren, David Blyth Hill, Ser. No. 08/735,020, filed Oct. 22, 1996.

Each of these related Applications are incorporated herein by reference.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to a system for blending a graphic with another image or video.

2. Description of the Related Art

Television broadcasts of events can be enhanced by providing graphics that are blended with other images or video to convey information to viewers. Such information can be related to the event, people involved in the event, or any other subject that the broadcaster desires. For example, during the broadcast of a football game a graphic can be employed to indicate the field location to which an offensive team must advance in order to obtain a first down. Logos and other graphics can also be blended with a video of an event. In some instances, such as adding a first down line or an advertisement to an image of a playing field, it is desired to blend the graphic with the video such that the graphic appears to be part of the live event, and not superimposed on the video. For example, it may be desired to add a line or logo to a video presentation of a sporting event such that the line or logo appears to be painted on the field.

When blending graphics with a video, broadcasters may want to vary the degree to which the graphic is blended. For example, when blending graphics to appear to be part of the event, it may be desired to vary the amount of blending to account for occlusions. That is, if a person or object is positioned in front of the location where the graphic is to be added, the graphic would look more realistic if the graphic is not drawn over the person or object. A broadcaster may also want to add a graphic to a video representation of a scene such that the graphic shows some of the texture of the underlying scene. A broadcaster may also wish to vary the blending of an image to show hard edges or soft edges. In order to accomplish these results, a blending coefficient can be generated for each pixel in the graphic to indicate the degree of blending between the graphic and the program video. One example of such a blending coefficient is an alpha signal that is used with a keyer for blending a graphic.

Most attempts to generate blending coefficients have utilized chroma-key techniques. Chroma-keying usually entails choosing a color in a video signal to be replaced with a graphic. In most instances, use of the color in the video is controlled and the blending is limited to either replacing or not replacing, without degrees of blending. On the other hand, a broadcast of a live event such as a sporting event may include many different colors and lighting conditions, different hue and brightness conditions, and different color balances that are not controlled by the broadcaster. During the broadcast of a football game, the broadcaster has no control over the color and lighting of either the field or players' uniforms. In addition, changing weather patterns can also affect the appearance of certain colors. For example, a broadcaster may wish to blend a graphic to a video of a sporting event such that the graphic appears to be painted on the field. In such a case, a system should be able to make a distinction between a "green" of a grass field, where blending is to occur, and a "green" of a player's uniform, where no blending is to occur. The standard chroma-key techniques cannot perform all of the above functionality in real time, and cannot make all the necessary fine distinctions between the colors appearing at a live event.

Accordingly, a system is needed for generating a blending coefficient that provides a broadcaster with flexibility in blending a graphic to the video presentation of a live event.

## SUMMARY OF THE INVENTION

The present invention, roughly described, provides for a system for blending a graphic with another image or video. The graphic can be blended with a video representation of a live event such that the graphic appears to be part of the scene captured in the video, rather than superimposed on top of the video. For example, if the graphic is added to a broadcast of a sporting event, the graphic will appear to be part of the field.

The present invention makes use of inclusions and exclusions. An inclusion is a set of characteristics that describe a class of pixels that can be modified in the video. An exclusion is a set of characteristics that describe a set of pixels that are not to be modified in the video. When blending the graphic to a video, the graphic may be blended on a pixel by pixel basis taking into account whether a given pixel in the video is an inclusion or an exclusion. In an alternate embodiment, the video and graphic are blended at a polygon level.

In one embodiment, the creation of an inclusion or an exclusion comprises an identification of luminance and/or chrominance characteristics for pixels. The process of creating inclusions and exclusions includes the steps of choosing an area of a video frame which identifies a set of pixels. An indication is made as to whether the set of pixels will be used to create an inclusion or an exclusion. If the pixels are to be used to generate an inclusion, then a display filter is created which describes the characteristics of the pixels in the set. If the pixels are to be used to create an exclusion, then the system generates a protection filter which describes the characteristics of the pixels in the set.

In one embodiment, a graphic is divided into a number of polygons. One method for dividing the graphic into a number of polygons includes creating border lines and a number of edge lines. In one alternative, all the border lines and edge lines are parallel to each other. Each polygon has its vertices on edge lines and/or border lines. Each of the vertices on the border lines are given a nominal blending coefficient. The vertices on the border lines can also receive nominal blending coefficients or a constant blending coefficient. By adding additional edge lines and changing blending coefficients for the edge lines, the amount of blending of a graphic can be varied throughout the graphic.

In one embodiment, each of the nominal blending coefficients for the vertices on the edge lines are multiplied by edge fractions. An edge fraction for a particular pixel of a graphic is created by a method which includes selecting a set of pixels in the video. The set of pixels includes a first pixel in the video having a position in the video frame corresponding to the position of the pixel in the graphic that is under consideration. The other members of the set may include those neighboring pixels surrounding the first pixel. The set of pixels are examined one pixel at a time to determine what fraction of the pixels are an inclusion and not an exclusion. Other embodiments may use other methods for creating an edge fraction.

Once the blending coefficients are set for each of the vertices of the polygons, blending coefficients can be determined for each pixel in each polygon. Using the blending coefficients, the graphic can be blended with the video.

These and other objects and advantages of the present invention will appear more clearly from the following description in which the preferred embodiment of the present invention has been set forth in conjunction with the drawings.

## BRIEF DESCRIPTIONS OF THE DRAWINGS

FIG. **1** depicts a portion of a football field.

FIG. **2** is a block diagram of one exemplar set of hardware used to implement the present invention.

FIG. **3** is a flow chart describing the overall process of using the current invention.

FIG. **4** is a flow chart describing the step of creating a model.

FIG. **5** is a symbolic representation of a mathematical model.

FIG. **6** is a flow chart describing the step of registering the system.

FIG. **7** is a flow chart describing the step of calibrating a tally detector.

FIG. **8** depicts a wiring configuration for a multiviewer, used during the calibration of the tally detector.

FIG. **9** depicts parameters for an image that is being operated on by the tally detector.

FIG. **10** depicts a graphical user interface used by the tally detector during displacement calibration.

FIG. **11** is a flow chart describing the method of correcting displacement.

FIG. **12** is a flow chart describing the method of correcting for delay.

FIG. **13** is a flow chart describing the method of determining an image matching value.

FIG. **14** depicts a wiring diagram for a multiviewer, used during environmental delay correction of the tally detector.

FIG. **15** is a flow chart describing the method of correcting for environmental delay.

FIG. **16** is a flow chart describing one embodiment of the step of establishing inclusions and/or exclusions.

FIG. **17** depicts inclusion filter histograms.

FIG. **18** depicts exclusion filter histograms.

FIG. **19** is a flow chart describing the setting of a filter pass band.

FIG. **20** is a flow chart describing an alternate embodiment of the step of establishing inclusions and/or exclusions.

FIG. **21** is a flow chart describing the method of operation of the embodiment depicted in FIG. **2**.

FIG. **22**A is a flow chart describing one embodiment of the method of determining three-dimensional locations.

FIG. **22**B is a flow chart describing a second embodiment of the method of determining three-dimensional locations.

FIG. **23** is a flow chart describing the method of determining which camera is tallied.

FIG. **24** is a flow chart that explains one embodiment of the process of enhancing video.

FIG. **25** symbolically represents a portion of a line formed in accordance with the method of FIG. **24**.

FIG. **26** is a flow chart that explains the step of determining alphas for edge points.

FIG. **27** symbolically represents a portion of a frame from the program video.

## DETAILED DESCRIPTION

FIG. **1** is a partial view of a stadium, which includes a football field **2**. The stadium also includes a seating area **4** for fans. At the front of seating area **4** is a retaining wall **6** which separates seating area **4** from field **2**. FIG. **1** depicts field **2** having a number of yard lines, including a ten yard line, fifteen yard line, twenty yard line and twenty-five yard line.

The present invention can be used to enhance a video representation of the football stadium. One exemplar enhancement is the blending of a graphic with the video. Video means an analog or digital signal depicting (or used to produce) moving images. Blending means combining at least a first image or video with at least a second image or video such that the result includes all or part of the first image or video and all or part of the second image or video. One example of how images are blended includes using a keyer to key one video over another video. One example of a graphic that can be blended to the video presentation of a football game is an additional yard line, which is depicted in FIG. **1** with reference numeral **8**. Yard line **8** is not part of the original football field. Rather, the present invention blends the image of yard line **8** with the video so that it would appear to a viewer of the video that the yard line is actually on the field. One example of a suitable use of a "phantom" yard line is to show a line on the field that an offense needs to cross to make a first down.

Another example of a graphic that can be added to the video is a logo. Looking at FIG. **1**, logo **12** can be blended with the video so that logo **12** also appears to be on the field **2**. Logo **12** can be an advertisement, an information box, a team emblem or any other suitable graphic. A logo can also be placed in areas of the stadium other than on the field. For example, logo **14** is added to retaining wall **6**. A logo can also be superimposed above the fans so that it looks like the fans are holding a giant billboard or the fans are holding cards that make up a billboard. Other places to put a logo could include any space above the stadium, space between the goal posts, or other surfaces in the stadium. Yard lines and logos must be added to the video at the right location, and with the right perspective, to look realistic. In one embodiment, a yard line can be thought of as a logo (e.g. a subset of the set of possible logos). When the present invention is used to enhance the video image as discussed above, the spectators and players at the stadium would not see any of these enhancements.

In some embodiments, the blending of a graphic must take into account occlusions. That is, if a player steps on top of the area where the yard line or logo is, the yard line or logo should not be drawn on the player. The player should appear to be stepping on or standing in front of the graphic.

A first down line can be depicted by drawing a line across the field. This fine can be a black or white line, or any other suitable color (e.g. red). The line can be bold, thin, thick, shaded, blinking, dotted, dashed, tapered, etc. In one embodiment, the line or other graphic is displayed to show a certain significance such as having a first down line blink on third down or change color when the offense is near the goal line. The enhancement need not even be a line. The graphic may be another shape or form that is appropriate. In addition to blending two images, the enhancement can be made by editing an image, adding an image, replacing an image with another image, highlighting an image using any appropriate method of highlighting, other suitable graphical enhancements to the video, etc. Furthermore, the enhancements are not restricted to showing first down lines and logos. Any other graphic can be added to or deleted from any suitable surface or portion of the stadium (including the field). For example, a graphic could be added to show more people in the stands.

FIG. **2** is a block diagram of the hardware components that comprise one embodiment of the present invention. FIG. **2** shows three video cameras **60**, **62** and **64**. Alternative embodiments can include more than three cameras or less than three cameras. The present invention will also work with only one camera. Each camera has associated with it one or more camera view sensors. For example, camera **60** includes camera view sensors **66**, camera **62** includes camera view sensors **68** and camera **64** includes camera view sensors **70**. A set of camera view sensors can include one or more of the following: a zoom sensor, a pan sensor and/or a tilt sensor.

Connected to each camera is a 2X Extender, a zoom lens and a means of focusing the camera. A zoom sensor will receive an electrical signal from all three of these devices in order to sense the zoom of the camera, the focal distance of the camera and whether the 2X extender is being used. The analog signal is converted to a digital signal and transmitted to a local computer. Each of the cameras is associated with a local computer. For example, camera **60** is associated with local computer **72**, camera **62** is associated with local computer **74** and camera **64** is associated with local computer **76**. Local computers can be a **486** processor based machine, a Pentium processor based machine, a Macintosh platform, a dedicated microcontroller or another type of computer/processor. In one alternative, the zoom sensor would include a digital output and, thus, there would be no need for an analog to digital converter. In one embodiment, a camera may also include one or more inclinometers (measures tilt) or one or more rate gyro (measures tilt rate).

Each of the cameras also include a pan/tilt head that enables the camera to pan and tilt. Attached to the pan/tilt head is a pan sensor and a tilt sensor. In one embodiment, the pan/tilt head is part of the camera. In another embodiment, the pan/tilt heads is part of a tripod. One embodiment uses separate pan and tilt heads. The local computers (**72**, **74** and **76**) include a pan and tilt electronics board for receiving electrical signals from the pan and tilt sensors. These boards can convert the signals into a usable signal for the processor inside the local computers. Additionally, each of the local computers may also include memory, hard drives and appropriate input/output devices. In one embodiment, a particular camera may not have either a pan head, a tilt head or a zoom lens. If one of these options are missing, there is no need for the corresponding sensor.

In one embodiment, the pan sensor and the tilt sensor are optical encoders that output a signal, measured as a number of counts (or pulses), indicating the rotation of a shaft. Forty thousand (40,000) counts represent a full 360° rotation. Thus, a processor can divide the number of measured counts by 40,000 and multiply by 360 to determine the pan or tilt angle in degrees. The pan and tilt sensors use standard technology known in the art and can be replaced by other suitable pan and tilt sensors known by those skilled in the relevant art. The pan and tilt electronics board inside the local computer receives the output from the pan and tilt sensors, converts the output to a digital signal, stores the results and transmits a digital signal of suitable format to the processor in the local computer. The pan, tilt and zoom sensors are used to determine the corresponding camera's view. Thus, one or more of the pan, tilt or zoom sensors can be labeled as a camera view sensor(s). For example, if a camera cannot zoom or tilt, the camera view sensor would only include a pan sensor. The "camera view" is defined as that which is viewed by the camera. With some cameras, the camera view can be determined by looking in the camera's view finder.

The output signals of local computers **72**, **74** and **76** are sent in RS-422 format to an RS-422-to-RS-232 converter **80** for purposes of converting the format of the signal to RS-232. The information sent by local computers **72**, **74** and **76** includes the pan, tilt and zoom data measured for cameras **60**, **62** and **64**, respectively. After converting the signals to RS-232, converter **80** sends all three signals to PC concentrator **82**. PC concentrator **82** also receives a signal from tally detector **88**. All the signals received by PC concentrator **82** are combined into one serial signal and sent to main computer **94**. One embodiment includes sending all the signals directly to computer **94** and eliminates the need for PC concentrator **82**. In one alternative, the signals from the local computer can be transmitted via the microphone channel of the video signals from the camera.

The video outputs of cameras **60**, **62** and **64** are sent to multiviewer **90**. In addition, the video outputs are also sent to a production truck used to produce the video presentation of the live event. The production truck may receive signals from many different video cameras. The producer chooses which video signal to broadcast. The video signal being broadcast is called the "program signal" or "program video." The program signal is also sent to multiviewer **90**. In one embodiment, the cameras output an analog video signal. In another embodiment, the cameras output a digital video signal. In another embodiment, the cameras output analog signals which are converted to digital signals. The system can work with analog signals or digital signals, as long as the appropriate multiviewer is chosen. For example, a multiviewer that can accept digital inputs includes the Video Gainsie CVX64Q. An example of a multiviewer that can accept analog inputs includes the Panasonic WJ-420 quad unit or FOR-A MB-40E. Using digital signals may improve the accuracy of tally detector **88**. Multiviewer **90** combines the four input video signals into one signal which is sent to tally detector **88** and monitor **92**. A suitable multiviewer can be used with less than four or more than four signals. Alternatively, if the tally detector can receive more than one input, there may not be a need for the multiviewer. Monitor **92** (optional) is used by an operator to monitor the video signals being sent to tally detector **88**.

Tally detector **88** determines which (if any) of the three cameras **60**, **62** or **64** is tallied. A camera is said to be tallied if it is the primary source of the video chosen by the producer to be broadcast. With respect to the system of FIG. **1**, a camera is tallied if it is the primary source of the video being sent on signal **89**. Tally detector **88** sends to PC concentrator **82** an indication of which (if any) of the three cameras is tallied. In a system which has only one camera, there is no need for a tally detector. In a system that has more than three cameras, the tally detector can be designed to determine which of the many cameras is tallied.

The system also receives a house time code or house sync **83** used by the broadcaster. Time code generator **84** accepts signal **83**, interprets the VITC/LTC signal and converts that signal to an RS-232 signal which is sent to converter **86** and time code inserter **85**. Converter **86** accepts the RS-232 signal and converts it to RS-422. The output of converter **86** is sent to local computers **72**, **74** and **76**. The local computers append time codes to the field of view data. In an alternative embodiment, the output of generator **84** is transmitted to PC concentrator **82**. Time code inserter **85** receives the RS-232 signal from generator **84** and also receives the program video signal. Time code inserter **85** inserts time codes into the program video and sends the program video with time code, signal **89**, to multiviewer **90**, computer **94** and frame delay **100**. The time code is used to match the field of view data with the correct frame of video. The time code is also used to synchronize the timing between computers **94** and **96**.

PC concentrator **82** sends the camera view data from all three cameras and the tally indication to computer **94**. In one embodiment, PC concentrator **82** is a computer that also provides the user interface for the operator to choose the location to enhance. In another embodiment, the operator uses computer **94** to select the location to enhance. Using a model, computer **94** determines the three-dimensional coordinates of the selected location. Using the camera view data received from the local computers **72**, **74** and **76**, main computer **94** also determines the position of the selected location in the video signal from the camera that has been tallied. That information can be used to blend a graphic with the video signal at or near the determined position. Computer **94** and computer **96** work together to create the graphic and a set of associated alpha signals. Both the graphic and alpha signals are sent to keyer **98**. An alpha signal that is sent to keyer **98** is also called a key signal. Each pixel has its own key or alpha value. The graphic signal can be sent as a YUV signal, RGB signal, YCbCr signal or other appropriate signal according to the specifications of the keyer. Keyer **98** also receives a video signal from frame delay **100**. Frame delay **100** receives video signal **89** and delays video signal **89** to account for the processing time of computers **94** and **96**, collection of data, as well as other delays from the production. In one alternative, a computer can be used to blend the graphic instead of using a keyer. For example, either computer **94** or computer **96** can be used, or an additional computer can be used.

The graphic sent from computer **96** to keyer **98** is called foreground and the signal from frame delay **100** is called background. Based on the level of the alpha or key from computer **96**, keyer **98** determines how much foreground and background to blend on a pixel by pixel basis. Keyer **98** can blend from 100% foreground and 0% background to 0% foreground and 100% background. In one embodiment, the key or alpha for a pixel can range from 0%–100% (or 0–1, or another similar range as per the specification of the keyer). The output of keyer **98** can be broadcast, recorded or both. This output of keyer **98** is also sent to a monitor **102** for reviewing by the operator of the system.

Kill Switch/Watch Dog Time **97**, which is in communication with computer **96** (via signal WDT) and keyer **98**, can be used by an operator to enable or disable the keying of the graphic. Additionally, the Watch Dog Timer automatically disables the keying of the graphic if the WDT signal from computer **96** stops sending a periodic signal. In one example, the WDT signal is a pulse sent for each frame or for each field. The Watch Dog Timer may disable the keying if the pulses stop for a predefined amount of time, frames or fields. For example, the Watch Dog Timer may disable the keying if the pulses stop for two frames.

As an option, the system could also include a data inserter for inserting non-video data into a television signal. Non-video data is information other than traditional data used by a television to draw the normal scan lines on a television display. An example of non-video data is data transmitted during the vertical blanking interval, which can be closed-caption data, statistics regarding the game, interactive queries or Internet addresses. The optional data inserter can receive the television signal from keyer **98** and insert the non-video data into the vertical blanking interval of the television signal. The output of the data inserter would be broadcast, recorded or both. In one embodiment, a data inserter can insert into the video signal instructions for a computer to enhance the video. At the viewer's home will be a set-top box which can read the instructions from the received signal and pass the information to a computer. The computer can receive the information from the set-top box and receive the video. The computer can use the instructions to blend the graphic with the video. Thus, a viewer can customize and control the enhancements using the viewer's personal computer. Alternatively, the set-top box will be capable of applying the enhancement.

In one embodiment, computer **94** and tally detector **88** are O2 workstations from Silicon Graphics, and computer **96** is an Indigo 2 Impact from Silicon Graphics. In other embodiments, other suitable computers can be used. It is noted that these computers typically include processors, memory, disk drives, monitors, input devices, output devices, network interfaces, etc. In one embodiment, an Ethernet is set up between computer **94**, computer **96** and tally detector **88**. The Ethernet is used for maintenance purposes and communication from computer **94** to computer **96**.

FIG. **3** describes the basic operation of the system described in FIG. **2**. In step **150**, the user of the system creates a mathematical model of the environment whose video image will be enhanced with the graphic. If the system is being used to add a yard line to a football field, then the environment would only include the football field and step **150** would include creating a model of the football field. If the user intends to add a graphic to other portions of the stadium, then the environment must include those other portions of the stadium as well. The model created is a three-dimensional model of the environment. For example, if the environment to be modeled is a football field, the model would include a description of the surface of the football field. Most football fields are not flat surfaces, and include crown for drainage purposes. Additionally, many fields include other variations in the height (and possibly length and width) of the field due to errors and other abnormalities. Thus, the model will serve as a three-dimensional representation of the surface of the field. If the environment includes portions of the stadium, then the model will include the relevant contours of the stadium such as any retainer walls, the top of the stands and any other surface the user may want to add a graphic to.

In step **152**, the operator of the system registers the system. The step of registering will be discussed in more detail below. In step **154**, the operator will set up inclusions and exclusions. In one embodiment of the present invention, the graphic can simply be added to the video without taking into account the contents of the video signal. There will be no accounting for occlusions; for example, a player or object in front of the enhancement. In another embodiment, the system can include inclusions and/or exclusions. An inclusion is a color range for a pixel that can be enhanced using the present invention. An exclusion is a color range for a pixel that should not be enhanced using the present invention. During operation, the operator can set up one or more inclusions and/or one or more exclusions. For example, the operator may decide that a yard line can be drawn over white (the original yard lines), green (grass) and brown (dirt). Additionally, the operator may want to set up an exclusion so that a line is not drawn over a specific color (e.g. team's uniforms). In an alternate embodiment of the present invention, exclusions also include video frame pixel locations that are not to be enhanced. In step **156**, tally detector **88** is calibrated. In step **158**, the system is operated during the live event. In step **160**, the inclusion and exclusion zones can be modified or deleted, or new inclusion and/or exclusion zones can be created. Step **160** is an optional step that can be performed while the system is being operated (step **158**) or before the system is operated. Thus, the inclusion zones and exclusion zones can be created and modified during a live event while the system is being operated.

FIG. **4** is a flow chart explaining this method of creating the model (step **150** in FIG. **3**). In step **180**, an operator will measure data from different points in the environment. In one embodiment, each data point includes x, y and z values. Any method can be used to obtain these x, y and z values. One example of a suitable method is to use a laser plane for z values and a laser range finder for x and y values, or other surveying devices. Suppose that the environment being modeled is the football field of FIG. **1**. The first step is to create a coordinate system. For simplicity, assume the origin is at the near corner of the left end zone, the y-axis is along the width of the field (e.g. the back of the end zone), the x-axis is along the length of the field (e.g. the side line) and the z-axis extends vertically from the field. The operator can measure or use the yard markings on the field to determine the x and y coordinates for most points of interest on the field. The laser plane can be used to measure the corresponding z coordinate. The laser plane is utilized by placing the laser plane at the origin (or another point) and reading the laser image off a pole that is positioned at the point of interest. In one embodiment, data samples are taken for the back of both end zones, both goal lines, both 20 yard lines and both 40 yard lines. For each yard line measured, measurements should at least be taken at each side line and in one or more points between the side lines, including the middle of the field. Additional data points can also be taken. If the environment includes parts of the stadium, the laser plane, a measuring tape or another measuring device can be used (as well as simple geometry) to determine data for other points in the environment.

In one embodiment, the data points measured in step **180** can be used to simply create the model. That is, data points can be plotted and connected (symbolically). In another embodiment, a set of curves are created (step **182**) using the measured data. That is, if the data is taken for a number of points along a line (e.g. 20 yard line, 40 yard line, edge of a wall, etc.) then that line can be modeled by fitting the data into a curve of the form $A+By+Cy^2=z$. Thus, any point on a yard line can be found using that equation because it is assumed that every point on the yard line has the same x value. As the y value changes, the z value will also change. Similar curves can be used to represent other lines. For example, a side line (as opposed to a yard line) can be modeled with the equation of the form $A+Bx+Cx^2=z$. Other lines in the environment can use either one of these two equations or different equations. If the system wants to find the z value for a point between two curves, the system can use linear interpolation.

After step **182** is complete, the system has a set of curves. This set of curves constitutes the model. FIG. **5** is a symbolic (or graphical or schematic) representation of such a model. Curves **204** and **206** represent the side lines and curve **208** represents the back of the end zone. Curves **210**, **212** and **214** represent yard lines. Curves **218**, **220** and **222** represent the contours of the wall surrounding the stands. In one embodiment, a plane **240** can be defined to represent the fans. In one embodiment, the model is stored as a database and can be drawn by any of the computers discussed above. Thus, the model can exist as a database and can be rendered as an image.

FIG. **6** is a flow chart which explains the method for registering the system (step **152** of FIG. **3**). In step **300**, the operator will reset the encoders for all of the pan and tilt sensors. That includes moving the cameras through the range of motion to pass the zero count index reference point for each of the encoders. In step **302**, the optical center (or optical axis) is found for each camera and each extender setting. To do so, the camera's cursor (e.g. cross hair) is positioned in the center of the camera's viewfinder and the camera is zoomed in to the tightest zoom. The camera is positioned (panned and tilted) so that the cursor is centered on a fixed location. At that point, the camera is zoomed out to the widest zoom. If the cursor is still centered on the fixed location, the cursor is located on the optical axis. If the cursor is not centered on the fixed location, (while the camera is still zoomed out) the cursor is moved, without moving the camera, so that the cursor is now centered on the fixed location in the viewfinder. The camera is then zoomed in to the tightest zoom. If the cursor is still centered on the fixed location, then the cursor is located on the optical axis. Otherwise, the camera is moved such that the cursor is centered on the fixed location. This process will continue until the cursor remains on the fixed location while the camera is zoomed in and out. This process will be repeated both for the 1X setting and the 2X setting of the 2X Extender.

In step **304**, the level tilt reading is found. Level tilt is the tilt of the camera when the optical axis is perpendicular to the force of gravity. Level tilt is found by setting the laser plane next to the camera at the level of the camera's lens. A stick or other object that can be used to view the marking from the laser plane should be placed across the stadium at a height to receive the beam. By pointing the optical center of the camera on the point illuminated on the stick by the laser plane across the stadium, the camera is brought to level tilt. The tilt registration parameter, which is referred below, is the encoder reading in degrees (or radians) at level tilt. Prior to determining level tilt, a digital level is placed on the camera and the camera is panned to ensure that the pan axis is vertical. If it is not, suitable adjustments are made. In an alternative, a pan axis that is not vertical can be modeled (rather than corrected). In another embodiment, one or more inclinometers can be connected to the base of the pan and tilt heads, in order to more accurately measure and, perhaps, model the attitude of the pan axis. This allows for toleration of shifts in camera attitude. Radio frequencies sometimes cause noise in the pan and tilt sensors. To compensate, the zero count mark is moved so that it is in the typical center of the camera's view.

In step **306**, the zoom lens is opened to its widest angle and its output voltage is recorded. In step **308**, the zoom lens is zoomed to the tightest zoom and its output voltage is recorded. Steps **306** and **308** are used to determine the range of the zoom voltages. In one embodiment, the zoom sensor includes adding a wire to read an output voltage from a zoom lens. Alternatively, a zoom lens can output a digital signal that describes the state of the zoom lens.

In step **310**, the system determines the location (x, y and z coordinates) of the cameras. To determine the x and y coordinates of a particular camera, a camera's optical center is pointed to three or more (e.g. 8) known fiducials. A known fiducial is a marking or location whose coordinates are known by accurately measuring the coordinates in relation to the origin. The coordinates of a fiducial can be measured using a laser plane, tape measure, and/or other suitable methods. While pointing the camera at the known fiducials, the system counts the pan sensor counts between the fiducials. Each count represents 0.009 degrees of pan. Geometry can be used to form triangles connecting the camera to all the fiducials, determining the angles between the different lines using the number of pan sensor counts and solving (using numerical solver software) for the x and y coordinates of the one point that can best satisfy all the data. One caveat is that all of the fiducials must not be on the same straight line.

To get the z coordinate of a camera, a camera is pointed to a known fiducial (once the x, y position is known). By pointing to, it is meant that the camera is panned and tilted so that the optical center is placed on the known fiducial in the camera's viewfinder. The system can detect the number of counts on the tilt sensor from the level tilt position. These counts can be used to compute an angle θ. Using geometry, a right triangle can be drawn where one vertex is the fiducial, a second vertex is the camera and the third vertex is the point directly beneath the camera (at the z coordinate of the fiducial) necessary to make the right triangle. One of the angles in the triangle will be θ and the other angle will be 90-θ. The system knows the x and y coordinates for all three vertices, thus the bottom of the triangle's length is already known. Thus, the height of the triangle, which is the z coordinate of the camera's location, can be determined using known trigonometry. This can be repeated for multiple fiducials and the result can be averaged for a more accurate solution.

To determine the pan registration parameter (discussed below), a camera's optical center is pointed to a fiducial. The pan encoder reading in degrees (θ) is noted. The x, y coordinates of the fiducial ($x_1$, $y_1$) are noted. The x, y coordinates of the camera are noted ($x_2$, $y_2$). An angle Φis determined as:

$$\Phi = \tan^{-1}\left(\frac{y_1 - y_2}{x_1 - x_2}\right)$$

The pan registration parameter is computed as

$$\text{Pan Reg}=180^\circ-\theta-\Phi$$

In step **312**, a twist parameter is determined for each camera. A camera is pointed to the field (or other portion of an environment) and the output of the camera is sent to computer **94**. The image from the camera is superimposed over a transformed image of the model of the environment. A slider on a graphical user interface (GUI) is used to alter the twist of the camera image so that it completely aligns with the image of the model. The degree of alignment correction is recorded as the twist registration parameter. Note that the transformation of the image of the model is performed with the best parameters known at the time.

In step **314**, the system registers zoom for each camera. The video from the camera is sent to computer **94** and is superimposed on top of a transformed image of the model. First, the camera will be zoomed to its widest position and a second slider on the GUI will be moved until the image from the camera is aligned (expand or shrink) with the image of the model. At this point, the system will store the zoom voltage, the focus voltage and a zoom factor to be used to align the image to the model. The system will record data points at at least five (could also be six or twelve or another number) different zoom measurements with the Extender at 1X and four zoom measurements with the Extender at 2X. The data will be used to create two curves that map zoom voltage to zoom factor: one curve for the extender at 1X position and one curve for the extender at 2X position. In an alternative embodiment, four curves can be generated: near focus and 1X, near focus and 2X, far focus and 1X and far focus and 2X. Interpolation will be used for points between the curves.

In step **316**, the system attempts to create a compensation factor for the delay of pan, tilt and zoom data with respect to the video signals from the cameras. To do this the pan, tilt and zoom data is used to superimpose a graphic on the video from a camera. The camera is panned back and forth. Using a slider on a GUI, delay is added to the graphic rendering so that the motion of the graphic in relation to the original video is eliminated. This delay factor is used to correlate pan, tilt and zoom data to video.

In step **318**, the system adjusts zoom fade and zoom cut off. That is, in some embodiments it may be desirable that the graphic is not added to the video if the camera is zoomed in beyond a threshold. Thus, an operator can set a first zoom threshold, at which point any graphic being added to a video will start to fade. The operator can also choose a cut-off zoom threshold. When the camera zooms passed the cut-off threshold the graphic is completely faded out. The amount the line has faded depends on how far zoomed the camera is between the first zoom threshold and the cut-off threshold.

FIG. **7** is a flow chart describing the method for calibrating the tally detector (step **156** in FIG. **3**). Tally detector **88** determines whether a camera is tallied to provide a broadcast image by comparing portions of the program video (the tallied video signal) to portions of video being provided by the camera. The camera under test is determined to be providing the program video if the result of the comparison meets or falls below a predetermined threshold. In one embodiment of the present invention, tally detector **88** is implemented with a computer and software stored on a processor readable storage medium (e.g. memory, disk, etc.). Alternatively, tally detector **88** can be implemented completely in hardware.

Multiviewer **90** provides to tally detector **88** a video output that enables a single display screen to simultaneously display all of the images being input to multiviewer **90**. In alternate embodiments of the present invention, the tally detector **88** is configured to receive multiple independent video inputs, thereby eliminating the need for the multiviewer **90**. Tally detector **88** can also be coupled to receive the closure switch signals (CS**1**, CS**2**, and CS**3**) of the cameras **60**, **62**, **64** undergoing tally detection.

In order to ensure that accurate image comparisons are made during the operation of tally detector **88**, tally detector **88** is calibrated to minimize misalignments between images that are being compared. As shown in FIG. **7**, a displacement correction is performed in step **400** to reduce the horizontal and vertical misalignment caused by multiviewer **90** and other components of the system shown in FIG. **2**. Next, a multiviewer delay correction is performed in step **402** to minimize the delay misalignment caused by multiviewer **90** and other components in the system shown in FIG. **2**. Once these misalignments are addressed, an environmental delay correction is performed in step **404** to reduce the delay misalignment caused by environmental factors, such as varying delays caused by production equipment.

When performing the displacement correction **400** and multiviewer delay correction **402**, multiviewer **90** is configured as shown in FIG. **8**. A first input of multiviewer **90** is configured to receive a video input from a video source **414**. In one embodiment of the present invention, the video source **414** can be a videotape player or a computer. The first video output of multiviewer **90**, which carries the video provided to the first input, is coupled to a second input to multiviewer **90**. A second video output, which carries the video provided to the second video input, is coupled to a third video input on multiviewer **90**. A third video output, which carries the video provided to the third video input, is provided to a fourth input of multiviewer **90**. As a result of this set-up, the video provided by the video source **414** is displayed in the four quadrants of the tally detector's display.

In order to perform the calibration, a set of parameters is defined for each video view that is displayed by tally detector **88**. FIG. **9** illustrates these parameters, which include a top margin **420**, right margin **430**, bottom margin **426**, left margin **424**, height **432**, and width **422**. Also defined is a sample size for samples **434** that appear within the view, wherein each sample **434** is made up of a set of adjacent pixels. The margins **420**, **430**, **426**, and **424** define a test region **428** for the image view within which video comparisons are performed. The height **432** determines the number of samples **434** that are to extend from the top margin **420** to the bottom margin **426**. The width **422** determines the number of samples **434** that are to extend from the left margin **424** to the right margin **430**. Given the height **432** and width **422**, tally detector **88** spaces the samples **434** evenly between the margins **420**, **424**, **426**, and **430**. In one embodiment of the present invention, each of the margins **420**, **424**, **426**, **430** is defined as being **32** pixels; each of the samples **434** is defined as being a set of 16 pixels configured in a square with 4 pixels on each side; the height **432** is defined to be 12 samples; and the width **422** is defined to be 16 samples.

Once the above-described image parameters are set, tally detector **88** completes the parameter definition by selecting a set **436** of samples **434** in the test region **428** that will be employed when performing delay comparisons. In one embodiment of the present invention, the selected set **436** of samples **428** form a diamond that extends outward from the center of the test region **428** to the margin **420**, **424**, **426**, **430** boundaries. In alternate embodiments of the present invention, the selected set **436** of samples **434** can form a different shape or no particular shape at all. The selected set **436** of samples shown in FIG. **9** are the samples within the dotted line in the test region **428**.

During the calibration set-up, additional variables can also be set, such as the baud rate of the incoming image data and an identifier indicating the format of the video data that is being received.

Once multiviewer **90** is configured and the parameters are set, the calibration process, as shown in FIG. **7**, can commence. In performing the displacement correction **400**, the operator determines whether the video from the second, third, and fourth video inputs of multiviewer **90** are vertically and horizontally aligned with the video provided from the first video input on multiviewer **90**. Video source **414** provides a static image without any changing pixels to the first video input on multiviewer **90**, so that the displacement correction **400** can be made.

FIG. **10** depicts the GUI provided by tally detector **88**. In FIG. **8**, the GUI is displaying a static image provided by video source **414** in the four quadrants. The video in the upper left hand quadrant **440** is the video received at the first video input of multiviewer **90**; the video in the upper right hand quadrant **441** is the video received at the second video input of multiviewer **90**; the video in the lower right hand quadrant **442** is the video received at the third video input of multiviewer **90**; and the video in the lower left hand quadrant **443** is the video received at the fourth video input of multiviewer **90**. In alternate embodiments of the present invention, video inputs on multiviewer **90** can be routed to different tally detector **88** display quadrants than set forth above.

As can be seen in FIG. **10**, the images are not all vertically and horizontally aligned. This is illustrated by the bottom portions of the static video being truncated at the bottom of the displays in the lower quadrants **442** and **443**. During displacement correction **400**, tally detector **88** clearly illustrates the horizontal and vertical misalignments by determining the difference between pixel values for pixels in the test region of the first quadrant **440** and pixel values for corresponding pixels in the other quadrants **441**, **442**, and **442**. Each difference is then written to the respective pixel location in the appropriate (**441**, **442** or **443**) quadrant. As a result, pixels that have values matching a corresponding pixel in the upper left hand quadrant **440** are set to a predetermined color, such as black. When a quadrant video is vertically and horizontally aligned with the video in the upper left hand quadrant **440**, all the corresponding pixels in the quadrant image will be set to the predetermined color.

During the displacement correction **400** (FIG. **7**), the vertical and horizontal alignment of each image with respect to the video in quadrant **440** can be adjusted. In the embodiment shown in FIG. **10**, this adjustment is achieved by moving the vertical displacement sliders **444**, **445**, and **446** and horizontal displacement sliders **447**, **448**, and **449** positioned along the horizontal and vertical axes of each quadrant **441**, **442**, and **443** on the tally detector's GUI. Once an adjustment is made, another set of differences can be determined and written to see if the vertical and horizontal alignment is acceptable. In an alternate embodiment of the present invention, tally detector **88** evaluates the result of the pixel value differences to determine whether a sufficient number of the pixels are properly aligned. In yet another embodiment of the present invention, tally detector **88** self adjusts the horizontal and vertical alignments.

FIG. **11** illustrates a sequence of operations that are performed to carry out the displacement correction shown in FIG. **7**. First, a video for comparison is selected in step **460** from one of quadrants **441**, **442**, and **443** on tally detector **88**. Next, test region **428** of the video in quadrant **440** is compared to the selected quadrant video to determine pixel value differences in step **462**. After the comparison in step **462**, the pixel value differences are written to corresponding pixels in the selected quadrant **441**, **442**, or **443** in step **464**.

In one embodiment of the present invention, pixel value differences are determined for each pair of pixels because the video image is being presented in a 4:2:2 YCbCr format. In such a format every two horizontally adjacent pixels are defined by one set of Cb and Cr characteristics and each pixel has a Y characteristic. The Y characteristic defines the luminance for a pixel, and the Cb and Cr characteristics combine to define the pixel color. The Y characteristic can have a value in a range of 16 to 180. The Cb and Cr characteristics can each have a value in a range of 16 to 240. A pixel is black when Y equals 16 and Cb and Cr each equal 180. In such an embodiment, the pixel value differences are determined in step **462** according to the following equations:

$$Y1PD=(Y1P-Y1C)$$

$$Y2PD=(Y2P-Y2C)$$

$$CrPD=(CrP-CrC)$$

$$CbPD=(CbP-CrC)$$

wherein:

Y1PD is the Y pixel difference value for a first pixel;

Y2PD is the Y pixel difference value for a second pixel;

CrPD is the Cr pixel difference value;

CbPD is the Cb pixel difference value;

Y1P is the Y value for the first pixel in the pixel pair from the quadrant **440** video;

Y1C is the Y value for the first pixel in the pixel pair from the selected quadrant video;

Y2P is the Y value for the second pixel in the pixel pair from the quadrant **440** program video;

Y2C is the Y value for the second pixel in the pixel pair from the selected quadrant video;

CrP is the Cr value for the pixel pair from the quadrant **440** video;

CrC is the Cr value for the pixel pair from the selected quadrant video;

CbP is the Cb value for the pixel pair from the quadrant **440** video; and

CbC is the Cb value for the pixel pair from the selected quadrant video.

Next, a determination of whether a suitable displacement adjustment has been reached is made in step **466** (FIG. **11**). An adjustment is suitable if difference values are less than a selected threshold. One example of a typical threshold is 10,000. In one embodiment of the present invention, such a determination is made by a user making a visual evaluation of whether a sufficient number of pixels in the selected quadrant image are black. In an alternate embodiment of the present invention, tally detector **88** evaluates each of the pixel differences to ensure that a sufficient number of them are less than a predetermined maximum value. Such a maximum value may be the pixel value that results in a pixel being black. Alternatively, such a maximum value may be the threshold mentioned above.

If it is determined that a suitable adjustment has not been rendered in step **466**, then a horizontal, vertical, or horizontal and vertical adjustment is made in step **468**. The adjustment results in tally detector **88** recording that each pixel in the quadrant **440** video corresponds to a pixel in the selected quadrant video that is offset from the quadrant **440** pixel by an adjustment number of pixels in either the horizontal, vertical, or both horizontal and vertical directions. After the adjustment offset is set in step **468**, the pixel value difference comparison in step **462** is repeated, as described above.

The adjustment offset, in one embodiment of the present invention, is set by a user manipulating the horizontal and vertical sliders **447**-**448** and **444**-**446** described above with respect to FIG. **10**. In an alternate embodiment of the present invention, the adjustment offset can be determined by tally detector **88** performing an iterative process in which it supplies different adjustment offsets until it is determined that the displacement adjustment is suitable in step **466**.

If it is determined that the displacement adjustment is suitable in step **466** for the selected quadrant video, then it is determined whether any of the quadrant videos to be compared have not yet been selected in step **470**. If it is determined that any of the videos have not yet been selected, then a new video is selected in step **460** and the process in FIG. **11** is repeated for the newly selected video, as described above. If it is determined that there are no unselected quadrant videos in step **470**, then the displacement correction (step **400**, FIG. **7**) is completed.

As shown in FIG. **7**, the displacement correction **400** is followed by the multiviewer delay correction step **402**. Prior to performing the multiviewer delay correction **402**, the video source **414** (FIG. **8**) is adjusted to begin providing a moving image to multiviewer **90**. FIG. **12** illustrates a sequence of operations for performing the multiviewer delay correction **402**. First, a quadrant **441**, **442**, or **443** video is selected in step **480** to be compared with the quadrant **440** video. Next, an image matching value or set of values is determined in step **482**. The image matching value indicates the magnitude of the delay misalignment between a frame in the quadrant **440** video and a frame in the selected quadrant video. An explanation of the image matching value is found below in the discussion with respect to FIG. **13**.

The image matching value (or values) is then compared using a threshold in step **484**. The threshold is a maximum allowable image difference value. In one embodiment of the present invention, the threshold determination **484** is made by a user comparing a displayed image matching value on the tally detector **88** GUI with the threshold image difference value. In such an embodiment, multiple image matching values can be determined by tally detector **88** for successive incoming video frames prior to a threshold determination **484** being made. The values would be displayed to a user who can decide whether the threshold is met. In an alternate embodiment, tally detector **88** makes the threshold comparison. A range of suitable thresholds is from 10,000 to 20,000. One exemplar method of computing a suitable threshold is to calculate 32 multiplied by the number of pixels employed in determining the image matching value (discussed below).

If it is determined that the image matching value is above the threshold in step **484**, then the delay alignment between the quadrant **440** video and selected quadrant video is adjusted in step **486**. Once the delay adjustment is made, a new image matching value is determined in step **482**. In one embodiment of the present invention, an adjustment in the delay causes tally detector **88** to either increase or decrease the delay of the selected quadrant video. Such an adjustment is made in one embodiment of the present invention by adjusting one or more of the delay sliders **450**, **451**, **452** or **453** for the selected quadrant image on tally detector **88** GUI. Sliders **450**, **451** and **452** adjust the delays for the videos in quadrants **441**, **442** and **443**. Delay slider **453** adjusts the delay for the program video. The program video can be delayed one or two frames. Delay slide **453** permits simultaneous adjustments of the three cameras and avoids negative delays for the cameras. In an alternate embodiment of the present invention, the adjustment can be made by tally detector **88** automatically.

Once the image matching value is determined to be equal to or less than the threshold (image difference value) in step **484**, it is determined whether any of the quadrant **441**, **442**, and **443** videos have not yet been selected in step **488**. If any of the quadrant **441**, **442**, **443** videos have not yet been selected, then a new quadrant video is selected in step **480**.

If all the quadrant videos have been selected, then the multiviewer delay correction is complete.

FIG. **13** illustrates a sequence of operations for determining an image matching value (step **482** of FIG. **12**) in accordance with the present invention. First, a group of pixels in the quadrant **440** video is selected in step **490**. Next, a group of corresponding pixels in the selected quadrant **441**, **442**, or **443** video are selected in step **492**. In one embodiment of the present invention using 4:2:2 YCbCr format, selecting groups of pixels for both the first quadrant **440** video and selected quadrant video in one embodiment of the present invention includes selecting a pair of pixels for each video.

Once the pixel groups have been selected, a pixel matching value is determined in step **494**. The pixel matching value is determined by calculating the difference between pixel group characteristics for the quadrant **440** video pixel group and the selected quadrant video pixel group. In one embodiment of the present invention, the pixel matching value is calculated according to the following equation:

$$PM=|(Y\mathbf{1}P-Y\mathbf{1}C+Y\mathbf{2}P-Y\mathbf{1}P)*LW+(CrP-CrC+CbP-CbC)*CW|$$

wherein:

PM is the pixel matching value;

Y1P is the Y value for a first pixel in the quadrant **440** video group of pixels;

Y1C is a Y value for a first pixel in the selected quadrant video pixel group;

Y2P is a Y value for a second pixel in the quadrant **440** video pixel group;

Y2C is a Y value for a second pixel in the selected quadrant video pixel group;

LW is a luminance weighting value, which can be set during the calibration set-up;

CrP is a Cr value for the quadrant **440** video pixel group;

CrC is a Cr value for the selected quadrant video pixel group;

CbP is a Cb value for the quadrant **440** video pixel group;

CbC is a Cb value for the selected quadrant video pixel group; and

CW is a color weighting value, which can be set during the calibration set-up.

In one embodiment of the present invention, LW is set to equal 1, and CW is set to equal 2. LW and CW can be set to equalize the effective differences observed in luma and chroma for a test video input.

Once the pixel matching value is determined in step **494**, it is determined in step **496** whether any other pixel groups are to be evaluated. In one embodiment of the present invention, all of the pixel groups that are included within samples **434** (FIG. **9**) in the quadrant **440** image test region **428** (FIG. **9**) are used to calculate pixel matching values. If it is determined that more pixel matching values are to be calculated for pixel groups, then new pixel groups are selected in steps **490** and **492** and a new pixel matching value is determined in step **494**, as described above.

If it is determined that no more pixel groups are to be evaluated in step **496**, then an image matching value is calculated in step **498**, based on the pixel matching values. In one embodiment of the present invention, the image matching value is calculated according to the following equation:

$$IM=(IMP*(TC-\mathbf{1})/TC)+(\Sigma PM/TC)$$

wherein:

IM is the image matching value;

IMP is the last calculated image matching value for the selected quadrant image;

TC is a time constant, which can be set during the calibration set-up;

ΣPM is a summation of a set of the pixel matching values calculated in step **494**.

The use of the time constant and prior image matching value causes the image matching value to be the output of a single pole infinite impulse response filter. This reduces the effect of brief, for example, one frame changes, in one of the video streams. Such change may occur from noise or signal processing in multiviewer **90**. In one embodiment of the present invention the time constant is set to be equal to 8 frame samples.

The set of pixel matching values that are selected to be summed (ΣPM) in determining the image matching value, in one embodiment of the present invention, are pixel matching values that are calculated for pixel groups that fall within the selected set **436** of samples in the test region **428**, as described above with reference to FIG. **9**. The selected set **436** of samples is employed, because most of the activity and change in the image will typically take place in this region and because titles and other graphics typically do not occur in that region. In further embodiments of the present invention, pixel matching values for pixels in addition to those pixels in the selected set **436** of samples can be employed to determine the image matching value.

FIG. **7** shows displacement correction **400** followed by multiviewer delay correction **402**. In alternate embodiments, displacement correction **400** and multiviewer delay correction **402** do not follow in sequential order. In such embodiments, displacement correction **400** and multiviewer delay correction **402** can be performed simultaneously. In further embodiments of the present invention, the displacement correction is performed and then the multiviewer delay correction **402** and environmental delay correction **404** are simultaneously performed. In this embodiment, the configuration of FIG. **14** is used.

Once displacement correction **400** and multiviewer delay correction **402** are complete, environmental delay correction **404** (FIG. **7**) is performed. During environmental delay correction **404** and during normal operation, multiviewer **90** is configured as shown in FIG. **14**. The video inputs of multiviewer **90** are configured to receive a program video **89** and video outputs from the set of cameras **60**, **62**, and **64** that are to undergo tally detection.

The first video input of multiviewer **90** is coupled to receive program signal **89**, the video to be broadcast. The second video input of multiviewer **90** receives the output of camera **60**; the third video input of multiviewer **90** receives the output of camera **62**; and the fourth video input of multiviewer **90** receives the output of camera **64**. The multiviewers quad output, as described above, provides a video output to tally detector **88** that provides for simultaneously displaying all of the videos being received by multiviewer **90** on tally detector **88** display. As a result, the upper left hand quadrant **440** of the tally detector **88** display will show program video **89**; the upper right hand quadrant **441** will show the video from camera **60**; the lower right hand quadrant **442** will show the video from camera **62**; and the lower left hand quadrant **443** will show the video from camera **64**. In alternate embodiments of the present invention, the program signal **89** and camera **60**, **62**, and **64** video outputs are coupled to different multiviewer **90** inputs than described above. As a result, the video from program signal **89** can appear in a different quadrant than **440**.

Once multiviewer **90** is configured, the environmental delay correction step **404** corrects delay alignments that exist between the program video and the videos from each of cameras **60**, **62**, and **64**. Such delays are typically introduced by environmental factors such as frame synchronization.

FIG. **15** illustrates a sequence of operations performed in the environmental delay correction **404** in one embodiment of the present invention. First, a camera **60**, **62**, or **64** is selected in step **500**. In selecting the camera, the camera is tallied so that its output is provided as program signal **89**. The selected camera is then operated so that it provides rapidly changing video images in step **502**. This can be achieved by continuously panning and tilting the selected camera. While the rapidly changing video images are being provided, an image matching value is determined in step **504** between the program image and the selected camera image. The image matching value is calculated as described above with respect to the image matching value determination step **482** (FIG. **12**) in the multiviewer delay correction (step **402** in FIG. **7**).

After an image matching value is determined, it is determined in step **506** whether the image matching value is within a desired threshold, such as being equal to or less than a maximum possible value (e.g. use the threshold example described above or determine a new one based on trial and error). If it is determined that the image matching value is above a desired threshold, then the delay alignment between the camera image and program image can be adjusted by adjusting the camera image delay in step **508**. After the delay is adjusted, a new image matching value is calculated in step **504**. The threshold comparison **506** and delay adjustment **508** can be performed as described above with respect to the threshold determination step **484** and adjustment step **486** (FIG. **12**) in the multiviewer delay correction (step **402** in FIG. **7**).

Once it is determined in step **506** that the image matching value is not above a delay threshold, the selected camera stops providing rapidly changing video images in step **510**. After the rapidly changing video images are no longer provided, it is determined whether any of the cameras **60**, **62**, and **64** have not yet been selected in step **512**. If it is determined that any of the cameras **60**, **62**, and **64** have not been selected, then one of the unselected cameras is selected in step **500** and the environmental delay correction **404** is continued as described above with respect to FIG. **15**. If it is determined that all the cameras **60**, **62**, and **64** have been selected, then the environmental delay correction **404** is done. In alternate embodiments of the present invention, the environmental delay correction **404** is only performed for a single camera. This is done when it is believed that the delay for each of the cameras with respect to the program image is the same.

In one embodiment of the present invention, the multiviewer displacement correction **400** is performed using the same configuration as for environmental delay correction **404**. In such an embodiment, the program signal **89** provides a static video frame instead of rapidly changing video. In such an embodiment, the multiviewer delay correction **402** is not performed, since it is achieved by doing the environmental delay correction **404**.

Looking back at FIG. **3**, step **154** includes the establishment of inclusions and exclusions. In one embodiment, the creation of an inclusion comprises the identification of luminance and/or colors for pixels that can be modified (inclusions) and the creation of an exclusion comprises the identification of luminance and/or colors for pixels that are not to be modified (exclusions). In a further embodiment, the creation of an exclusion includes the identification of pixel locations that are not to be modified (exclusions).

The establishment of inclusions and exclusions in embodiments of the present invention provides for making fine distinctions between luminance and color values that are very close, where it is critical to modify pixels with one luminance-color combination and not modify pixels with another combination. Such circumstances arise during the rendering of a first down line, as described above, when the appearance of a player's uniform is very similar to the field. For example, an inclusion may describe the green color of grass while an exclusion might describe a different shade of green used on a player's uniform. A traditional chroma key system lacks the ability to make such distinctions, since it merely provides for replacing a predetermined color.

When operating the system of FIG. **2** to provide a first down line, step **154** includes having an output from a camera being sent to main computer **94**. The camera will be panned and tilted to point to the different areas of the stadium. The operator can view the output of the camera on a monitor and using a pointing device (e.g. a mouse), select areas for inclusion (create an inclusion filter) or exclusion (create a exclusion filter). For example, the operator could choose the shady grass, sunny grass, chalk and dirt for inclusions. The operator may choose the players' uniforms, shoes, football and referees as exclusions.

FIG. **16** illustrates a sequence of operations that are performed to establish a set of luminance and color criteria for use in determining inclusions and exclusions, in one embodiment of the present invention. The process of FIG. **16** can be repeated for each set of criteria. First, main computer **94** receives a set of pixels in step **520**. In one embodiment of the present invention, the pixel set received is from the output of one of the cameras **60**, **62** or **64**. For example, when the system is employed for displaying a first down line (or other type of marker) on a football game, a pixel set can include selected pixels from an image of the playing field, selected pixels from an image of one of the teams' uniforms, or other images. In another embodiment, the pixel set can be received from a stored image.

Once the pixel set is received, the operator of main computer **94** determines whether the pixel set is to be used for identifying exclusion pixels or identifying inclusion pixels in step **522**. An exclusion pixel is a pixel in the captured video that is not to be modified. An inclusion pixel is a pixel in the captured video that can be modified to blend with a graphic (as long as it is not also an exclusion pixel). For example, when the graphic is a first down marker in a football game, a exclusion pixel in the broadcast program image might be a pixel having the luminance-color combination of one of the teams' uniforms. An inclusion pixel in such an example, might be a pixel in the broadcast program image that has the luminance-color combination of the grass on the playing field.

If it is determined in step **522** that the pixel set has been received for establishing criteria for exclusion pixels (also called exclusion criteria), then main computer **94** generates an exclusion filter (step **526**). If it is determined in step **522** that the pixel set has been received to establish criteria for inclusion pixels (also called inclusion criteria), then main computer **94** generates an inclusion filter (step **524**). An exclusion filter defines an exclusion by providing criteria that can be employed to determine whether a pixel is an exclusion pixel. An inclusion filter defines an inclusion by providing criteria that can be employed in determining whether a pixel is an inclusion pixel. In one embodiment, if a pixel passes both an inclusion filter and an exclusion filter, the pixel will be treated as part of an exclusion.

After generating either an inclusion filter in step **524** or an exclusion filter in step **526**, a determination of whether another pixel set is to be received is made in step **528**. If another pixel set is to be received, then the new pixel set is received in step **520** and the above-described process is repeated. Otherwise, the process for establishing luminance and color criteria is done. As can be seen, multiple inclusion filters and exclusion filters can be generated.

The process of FIG. **16** can be performed at various times throughout the operation of the system of FIG. **2**. This may be necessary, for example, when a first down marker is to be shown on a playing field that is made up of all green grass prior to the start of a football game. During the football game, areas of the grass may become torn up, thereby exposing brown dirt that was not present before the game. The first down marker will need to be drawn over the dirt appearing on the playing surface. Accordingly, the luminance-color criteria process in FIG. **16** will be reinitiated, so an inclusion filter can be generated for the dirt. Other factors that can necessitate a reinitiation of the process of FIG. **16** include, but are not limited to, sunsets, moving clouds, changes in zoom and changes in camera color correction controls.

In one embodiment of the present invention, main computer **94** generates inclusion filters and exclusion filters by generating a set of histograms characterizing the received sets of pixels. FIG. **17** shows a set of histograms **530**, **532**, and **533** that have been created for an inclusion filter in one embodiment of the present invention. In such an embodiment, the pixels have pixel characteristic sets that conform to a YCbCr format, as described above. The filter includes a histogram for each of the YCbCr characteristics.

The Y characteristic histogram **530** has a horizontal axis representing luminance values and a vertical axis representing the number of pixels in the received pixel set that corresponds to each of the luminance values. The Cr characteristic histogram **532** has a horizontal axis representing Cr values and a vertical axis representing the number of pixels in the received pixel set that corresponds to each of the Cr values. The Cb characteristic histogram **533** has a horizontal axis representing Cb values and a vertical axis representing the number of pixels in the received pixel set that corresponds to each of the Cb values. Each histogram **530**, **532**, and **533** has a respective pass band **534**, **536**, and **538** that defines the Y, Cr, or Cb characteristics that a pixel must have to be an inclusion pixel. Accordingly, a pixel will be designated as an inclusion pixel when the filter shown in FIG. **17** is applied and the pixel has a Y characteristic value within pass band **534**, a Cr characteristic value within pass band **536**, and a Cb characteristic value within pass band **538**.

FIG. **18** shows a set of histograms **540**, **542**, **543** that have been created for an exclusion filter in one embodiment of the present invention, based on a received pixel set conforming to the YCbCr pixel characteristic set format. The filter includes a histogram **540**, **542**, and **543** for each of the YCbCr characteristics.

The Y characteristic histogram **540** has a horizontal axis representing luminance values and a vertical axis representing the number of pixels in the received pixel set that corresponds to each of the luminance values. The Cr characteristic histogram **542** has a horizontal axis representing Cr values and a vertical axis representing the number of pixels in the received pixel set that corresponds to each of the Cr values. The Cb characteristic histogram **543** has a horizontal axis representing Cb values and a vertical axis representing the number of pixels in the received pixel set that corresponds to each of the Cb values. Each histogram **540**, **542**, and **543** has a respective pass band **544**, **546**, and **548** that defines the Y, Cr, or Cb characteristic value that a pixel must have to be an exclusion pixel. Accordingly, a pixel will be designated as an exclusion pixel when the filter shown in FIG. **18** is applied and the pixel has a Y characteristic value within pass band **544**, a Cr characteristic value within pass band **546**, and a Cb characteristic value within pass band **548**.

FIG. **19** illustrates a sequence of operation performed by main computer **94** to determine a pass band for an inclusion filter histogram or an exclusion filter histogram. In the embodiment using YCbCr, the steps of FIG. **19** are performed for each of the three histograms. First, main computer **94** identifies the most frequently occurring value for the characteristic (Y, Cr, or Cb) represented by the histogram in step **550**. Next, the characteristic value is incremented in step **551**. It is then determined whether the number of pixels having the resulting characteristic value is within a predetermined percentage of the number of pixels having the most frequently occurring characteristic value in step **552**. In one embodiment of the present invention, the predetermined percentage employed in step **552** is 10 percent for an inclusion filter and 50 percent for an exclusion filter.

If it is determined that the number of pixels with the characteristic value is within the predetermined percentage, then the characteristic value is incremented in step **551** and a new comparison is performed. If it is determined that the number of pixels with the characteristic value is not within the predetermined percentage, then the maximum characteristic value for the pass band is set in step **554**. In step **554**, the maximum pass band value is set to equal the last characteristic value that was determined to be represented by a number of pixels within the predetermined percentage of the number of pixels representing the most frequently occurring characteristic value.

Once the maximum pass band characteristic value is set, the characteristic value is set to be equal to the characteristic value just below the most frequently occurring characteristic value in step **555**. It is then determined whether the number of pixels having the resulting characteristic value is within a predetermined percentage of the number of pixels having the most frequently occurring characteristic value in step **556**. In one embodiment of the present invention, the predetermined percentage employed in step **556** is 1 percent for an inclusion filter and 25 percent for an exclusion filter. In another embodiment of the present invention, the predetermined percentage employed in step **556** is 10 percent for an inclusion filter and 50 percent for an exclusion filter.

If it is determined that the number of pixels with the characteristic value is within the predetermined percentage, then the characteristic value is decremented in step **557** and a new comparison is performed. If it is determined that the number of pixels with the characteristic value is not within the predetermined percentage, then the minimum characteristic value for the pass band is set in step **558**. In step **558**, the minimum pass band value is set to equal the last characteristic value that was determined to be represented by a number of pixels within the predetermined percentage of the number of pixels representing the most frequently occurring characteristic value.

Although the generation of an inclusion filter and exclusion filter has been described with respect to forming a histogram, one of ordinary skill in the art will recognize that it is not necessary to actually form a graphical image of a histogram. Main computer **94** could also maintain a table of data that reflects the Y, Cr, and Cb pixel occurrences for a set of pixel values and derive the same filter. It will also be recognized that 1 percent and 25 percent (and 10% and 50%) are not the only percentages that may be employed. Any number of percentages may be employed, depending upon the resolution that is desirable for the filter. One with ordinary skill in the art will further recognize that other methods can be employed for generating inclusion filters and exclusion filters. For example, a color region or set of color regions can be selected for inclusion or exclusion using a chromacity diagram.

FIG. **20** illustrates a sequence of operations performed by tally detector **88** for generating a different type of exclusion filter that identifies exclusions based on pixel locations. In such an embodiment, the exclusion filter identifies pixel locations in a program video that are to be excluded, instead of identifying exclusion pixel luminance-color combinations. Such an exclusion filter is useful to account for graphics added to the program video, such as game clocks, scores and other graphics.

First, a set of the samples **434** in the program video are selected in step **590**. In one embodiment of the present invention, the set of the samples selected in step **590** represent pixel locations where a constant image (constant location in frame), such as a game clock, is expected to be located. For example, the constant image in one embodiment may be located in any one of the four corners of a frame of the program video. Thus, it may be advantageous to first choose samples in one corner of the frame.

Once the set of samples is selected, an image matching value is determined in step **592** between the selected samples in the program video and corresponding samples in the video directly provided by a camera supplying the program video. As described above, the image matching value indicates the degree of similarity between the selected samples in the program video and the tallied camera's video. The image matching value is then compared to a matching threshold in step **594**.

If the image matching value is above the threshold, then the low degree of similarity is taken as an indication that the program video contains a constant image, such as a game clock, that is not in the tallied camera video. As a result, the pixel location in the program video that are bounded by the samples selected in step **590** are listed in an exclusion filter in step **596**. After the exclusion filter is generated in step **596**, a determination is made in step **598** of whether more samples in the program video are to be evaluated. If so, the system loops back to step **590** and selects new samples.

If the image matching value is not determined to be above the threshold in step **594**, then the high degree of similarity is taken as an indication that the program video does not contain a constant image at the location of the samples. Next, it is determined in step **598** whether more samples in the program video are to be evaluated. Once it is determined that no more program samples are to be evaluated, the process is done.

In one embodiment of the present invention, the above described process is repeated, until the relevant boundaries for all constant images in the program video are identified. It may be advantageous to select a corner of the frame in step **590**. If it is determined that the corner includes a constant image, the entire corner can be used to define an exclusion. Smaller samples can be used in future iterations of the method of FIG. **20** to find the exact position of the image. After processing on one corner (or other region) is exhausted, subsequent iterations of the method of FIG. **20** will operate on other corners or regions.

In one embodiment, the exclusion filter contains pixel locations that identify the boundaries of the constant image. For example, the exclusion filter can indicate that all pixel locations to the left of (or to the right of, or below, above, etc.) a particular line of pixel locations are not to be modified.

FIG. **21** is a flow chart describing the operation (step **158** of FIG. **3**) of the system during a live event. In step **602**, a position in the environment is selected for placement of the graphic. If the graphic is a yard line representing the first down, an operator can select the location to add the yardline using a pointer or keyboard. For example, the operator can type in a yard line number such as "27.3." If the graphic is a logo, advertisement or other graphic, the operator can point to or type in the location of one or more vertices of a rectangle bounding the logo. Any logo can be represented as a rectangle by filling portions of the rectangle with a clear image, as necessary. In one alternative, the position of the graphic could be entered automatically from a sensor system, other computer, etc. In step **604**, computer **94** uses the model created in step **150** to determine the three-dimensional coordinates of the position selected in step **602**. In step **606**, tally detector **88** determines which camera is tallied. In step **608**, main computer **94** receives camera view data (pan, tilt and/or zoom or other information) from the various local computers **72**, **74** and **76**. Main computer **94** will make use of the camera view data for the tallied camera.

In step **610**, computer **94** transforms the three-dimensional locations (determined in step **604**) to a set of two-dimensional positions in the frame of video from the tallied camera. The step of transforming could be accomplished by using any suitable means for converting a location in the three-dimensional real space to the corresponding two-dimensional point within the camera's view. One exemplar suitable means is using transformation matrices. Other means known in the art can also be used. The terms "transform" and "converting" are not limited to the use of transformation matrices.

A point in three-dimensional space is represented by a 4 element row vector: (x, y, z, 1.0). The 1.0 (sometimes called w) allows for translation. In camera space, the point (0,0,0, 1.0) is at the origin. A camera is represented mathematically by a 4×4 matrix (K) which includes details of position and orientation. The three-dimensional point is transformed into a two-dimensional normalized frame position by multiplying the point by the camera matrix (K). The camera matrix (K) is a combination of rotation, translation, and perspective elements, all of which are represented by 4×4 matrices. In reality, the motion of the camera point of view (POV) is much more complicated with offsets caused by the kinematics of the tripod head and the motion of the optical POV along the camera's optical axis due to lens characteristics. All these effects can be modeled as more complex linkages (additional matrices) between the fixed camera base and the resulting POV of the camera as the camera is moved through its range of motion. These techniques are well-known in the art.

In the disclosed embodiment, cameras **60**, **62** and **64** are each modeled as a 4×4 matrix which includes two parts—a fixed transformation (X) which represents the position of the camera in the stadium and its orientation, and a variable transformation (V) which varies with changes in pan angle, tilt angle and the zoom:

$$K=XV$$

The fixed transformation matrix (X) models x, y, z position as well as fixed yaw, pitch and roll representing the camera's mount orientation:

$$X=TYPR$$

where,

$$T=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -x & -y & -z & 1 \end{bmatrix}$$

$$Y=\begin{bmatrix} \cos yaw & -\sin yaw & 0 & 0 \\ \sin yaw & \cos yaw & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$P=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos pitch & -\sin pitch & 0 \\ 0 & \sin pitch & \cos pitch & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R=\begin{bmatrix} \cos roll & 0 & \sin roll & 0 \\ 0 & 1 & 0 & 0 \\ -\sin roll & 0 & \cos roll & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The parameter of the matrices T, Y, P & R are determined during registration. the x, y and z variables of matrix (T) are the x, y and z coordinates determined in step **310**. The yaw variable of matrix (Y) is the pan parameter determined in step **310**. The pitch variable in matrix (P) is the tilt parameter determined in step **304**. The roll variable of matrix (R) is the twist parameter determined in step **312**.

For a camera used with a Vinton Vector **70** camera head and a Canon J55 Super lens, the variable transformation is modeled in four parts (matrices):

$$V=ADFG$$

$$A=\begin{bmatrix} \cos pan & -\sin pan & 0 & 0 \\ \sin pan & \cos pan & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$D=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos tilt & -\sin tilt & 0 \\ 0 & \sin tilt & \cos tilt & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$F=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -povdist & 0 & 1 \end{bmatrix}$$

$$G=\begin{bmatrix} f_h & 0 & 0 & 0 \\ 0 & f_v & 0 & 0 \\ 0 & 0 & -(f+n)/(f-n) & -1 \\ 0 & 0 & -2fn/(f-n) & 0 \end{bmatrix}$$

Matrix (A) models the camera's pan on its fixed base. Matrix (D) models the camera's tilt angle. Pan and tilt angles are measured with the pan and tilt sensors. Matrix (F) models the lens moving fore and aft along the optical axis of the lens as a function of zoom. The variable povdist (or First Principal Point, or Front Nodal Point) is the position of the camera's virtual point of view measured as a distance forward of the tilt axis when the camera is in the horizontal position. This information can be measured on an optical bench and a lookup table built as a function of zoom position, focus, and 2X Extender setting. The information for the lookup table is measured by placing two targets in the view of the camera, off-center, one farther away than the other, so they appear in line through the viewfinder. Where a line extended through those targets intersects the optical axis of the camera is the position of the virtual point of view. Matrix (G) models the effective focal length of the lens as a function of zoom, focus, and 2X Extender settings. The variables n and f are the distances to the mathematical near and far clipping planes; which are only important in assigning a useful range for z-buffered graphics drawing; therefore, nominal values are used of n=1 meter and f=100 meters. The variable $f_h$ is the effective horizontal focal length of the lens. The variable $f_v$ is the effective vertical focal length of the lens. The aspect ratio, which is constant, is $f_h/f_v$. A software routine is used to convert the appropriate zoom factor and aspect ratio to $f_h$ and $f_v$.

After using the transformation matrices, the system takes into account lens distortion. That is, each two-dimensional pixel position is evaluated in order to determine if the two-dimensional position should change due to lens distortion. For a given two-dimensional pixel position, the magnitude of a radius from the optical center to the two-dimensional pixel position is determined. Lens distortion is accounted for by moving the pixel's position along that radius by an amount ΔR:

$$\Delta R=K(R)^2$$

where

R=pixel distance from optical center to two-dimensional position

K=distortion factor.

At a fixed focus, the distortion factor is measured at a number of zoom values using a GUI slider to align the model to the video. These values are used to generate a distortion curve. During operation, the distortion factor at the current zoom is interpolated from the curve and applied to all transformed two-dimensional pixel positions points. The distortion data can also be obtained from the lens manufacturer or can measured by someone skilled in the art.

After the system transforms the coordinates of the three-dimensional location representing the place in the environment where the graphic is to be added to a two-dimensional position in the frame of video, the system enhances the video accordingly in step **612**. Because the system uses the model in conjunction with camera view data, there is no need to use pattern recognition to find images in the video. The steps of enhancing the video includes blending the graphic with the video. In one embodiment, step **612** includes keying the graphic over the video. In other embodiments, step **612** could include the step of a computer editing the actual video to add the graphic, replacing a portion of the video with the graphic, adding a highlight at or near the graphic, etc. In one alternative, the system also accounts for occlusions. A more detailed discussion of step **612** is provided below. An operator can view the enhanced video on monitor **112**. If the two-dimensional position determined in step **610** is not within the frame of the tallied camera, then the system does not enhance the video in step **612**.

It is possible that after the system enhances the video the operator is unhappy with the actual placement of the graphic. Therefore, PC concentrator **82** can include a GUI that will allow the operator to manually adjust the placement of the graphic in step **614**. That is, the operator can use a slider or a keyboard to move the graphic or, in one alternative, the operator can drag the graphic. For example, consider the system where a first down line is being added to a video of a football field. If the video from a camera shows a marker on the side of the field that indicates the official first down location, the operator can adjust the position of the graphic of the line to exactly coincide the official first down marker. In one embodiment, the system can use the technology described above to perform the steps in reverse and determine the numerical yard line for the first down based on the step **614** of adjusting the yard line.

FIG. **22**A describes one embodiment for the method of determining three-dimensional locations using the model (step **604** of FIG. **21**). Steps of FIG. **22**A are used in the case where the graphic is a yard line to be placed on an image of a football field; however, the steps can be modified or used without modification to add other graphics to a video. In step **640**, computer **94** sets up a set of points on the line. Previously in step **602** of FIG. **21**, a position was selected. If the graphic is a yard line, step **640** includes accessing the yard line position in the model that corresponds to the selected position. The yard line position represents the x coordinate of the yard line. Main computer **94** will represent the yard line as a number of points. In one embodiment, the yard line is represented by 151 equally spaced points with the first point at the near side line and the last point at the far side line. Thus, in step **640** main computer **94** determines the x and y coordinates for all 151 points. In step **642**, main computer **94** determines whether the yard line is on a preexisting curve in the model. If it is, then in step **644**, the equation for that curve is used to determine the z coordinate for each of the 151 points. If it is not on a curve, then in step **646** main computer **94** interpolates between the two nearest curves (using linear interpolation) to determine z coordinates for each of the 151 points. In one alternative, rather than interpolate between two curves, main computer **94** can create a new curve. The new curve will have a similar form to the equations discussed above. The coefficients of the equations are obtained by interpolating between the coefficients of the two nearest curves. In other embodiments, more or fewer than 151 points can be used. In one such embodiment, 101 points are employed on each border.

In step **648**, main computer **94** sets up two border lines, each having 151 points. A yard line can be thought of as a line segment with no width. However, to make the yard line visible on a monitor the yard line is depicted as being one yard wide. Other widths (such as a ¼ of a yard) can also be used. In one embodiment of the present invention, the width is selected by a user of the system shown in FIG. **2**, using the system's GUI. Because the yard line has a width, the system models the graphic as the space between two borders. Each border will be represented by 151 points, each point corresponding to a point on the center yard line. The x coordinate for each point on the borders will be the x coordinate of the selected portion plus or minus a half yard (or other appropriate value if the line is not one yard wide). Each point of the borders will have z and y coordinates equal to a corresponding point on the yard line.

At this point, main computer **94** has a set of 302 three-dimensional points, where 151 points represent a first border and 151 points represent a second border. Each point on the first border has a corresponding point (with the same y coordinate) on the second border. In one embodiment, these points represent the maximum boundary of the graphic to be added. In alternative embodiments, these points can represent vertices or other reference points for the graphic, rather than maximum boundaries.

FIG. 22B describes a method for an alternative embodiment of step **604** of FIG. **21**. This method may be more suitable for adding logos. In step **680**, main computer **94** determines the four corners of a rectangle bounding the logo or other graphic. That is, if the operator entered one or more vertices of the logo in step **602** and main computer **94** knows the size of the rectangle, then computer **94** can determine the location on the model of the four corners of the rectangle in step **680**. In step **682**, the rectangle bounding the logo is broken up into a plurality of rectangles. Each of these rectangles has four vertices. Each of these vertices represents a point for which a three-dimensional location is needed. Because the system knows the x and y coordinates of the four vertices and also knows how big the polygons are, the system can determine the x and y coordinates of each vertex. In step **684**, main computer **94** takes the next point to be considered from the set of vertices. In step **686**, main computer **94** determines whether this point is on a preexisting curve. If it is, that curve is used to determine the z coordinate for the point in step **688**. If it is not on a curve, then the system interpolates between the two nearest curves in step **690** in order to determine the z coordinate. After steps **688** or **690**, the system determines whether there are any more points to be considered (step **692**). If not, the method of FIG. 22B is done. If there are more points to consider, then main computer **94** loops back to step **684**. At the conclusion of the method of FIG. 22B, main computer **94** has a set of three-dimensional locations for the vertices of the rectangles making up the larger rectangle that bounds the graphic.

In an alternative embodiment, a logo can be added by simply using the four corners of the rectangle that bounds the logo. Only these four corners would be operated on in steps **684**–**692**. Thus, at the end of the method of FIG. **22**B, the system would have three-dimensional locations for the four corners of the bounding rectangle. These four corners would be transformed to two-dimensional positions and the graphic can be built by inserting the rectangle at the transformed two-dimensional positions. A simple method for rendering the graphic into the four two-dimensional coordinates is to use the Open GL functions provided with a Silicon Graphic O2 workstation.

In one embodiment when adding logos, it may be useful to defocus the logo for a more realistic image. Alternatively, the logo can appear completely focused at certain zoom levels and slightly unfocused at other zoom levels. In another alternative, the logo can be placed over the field to be slightly transparent (the alpha for keyer being slightly less than 100% foreground). This method will allow some of the texture of the background to appear in the video.

FIG. **23** illustrates a sequence of operations performed by tally detector **88** when making the determination of which camera (if any) in the set of cameras **60**, **62**, and **64** is tallied (step **606** of FIG. **21**). First, a camera is selected in step **700**. Once a camera is selected, an image matching value is determined based on the program signal **89** and the selected camera's video in step **702**. The image matching value is determined as described above. As described above with respect to FIG. **13**, only a selected set **436** of samples **434** from a test region **428** are employed for calculating the image matching value. This is beneficial during the operation of tally detector **88**, because in some instances graphics are added to program video in the non-selected test region **428** areas. An example of such a graphic is a game clock in the upper right hand corner of the program video. This graphic is added to the broadcast program video prior to the calculation of an image matching value and will not appear in the selected camera's video. Accordingly, an image matching value that is determined using the entire test region of the broadcast program video will most likely indicate an image mismatch, even though the selected camera may be providing the broadcast program video. Employing only the selected set **436** of samples **434** avoids this problem.

After an image matching value is determined, tally detector **88** determines whether the image matching value is within a predefined threshold in step **704**. The predefined threshold in one embodiment of the present invention is a maximum image matching value that must not be exceeded by the calculated image matching value. In one embodiment of the present invention, the predefined threshold is equal to 32 times the number of pixels that are employed in determining the image matching value.

If the image matching value is equal to or below the predefined threshold, tally detector **88** records that the selected camera is tallied in step **706**. Once the recording (**706**) is made or it is determined that the image matching value is above a predefined threshold (**704**), a determination is made of whether any of the cameras **60**, **62**, and **64** have not yet been selected in step **708**. If any of the cameras have not yet been selected, then a new camera is selected in step **700** and an image matching value is determined and evaluated as described above. If all of the cameras have been selected, then it is determined whether there is only a single camera that has been recorded as being tallied in step **710**.

If only a single camera has been recorded as being tallied, then tally detector **88** provides an indication that the tallied camera is providing the program video in step **714**. However, if it is determined that either multiple or none of the selected cameras are tallied, then tally detector **88** provides an indication that there is no tallied camera in step **712**. In an alternate embodiment, if a first camera has continuously been identified as tallied to provide broadcast program video and a second camera briefly becomes recorded as tallied in step **706**, then tally detector **88** will continue to indicate that the first camera is tallied and ignore the brief tally on the second camera. After either identifying that there is no tallied camera (**712**) or identifying a tallied camera (**714**), the process of detecting a tallied camera is done.

When multiple cameras have been recorded as tallied, tally detector **88** provides an indication that no camera is tallied because it is unclear which camera's view information must be used to enhance the program video. Thus, when tally detector **88** provides an indication that no camera is tallied, step **612** of FIG. **21**—enhance video—is not performed.

In alternate embodiments of the present invention, the determination of which camera **60**, **62**, and **64** is tallied can be made by employing the closure switch signals (CS**1**, CS**2**, and CS**3**) that are received by tally detector **88**. In one embodiment, a camera is only recorded as being tallied (step **706** in FIG. **22**) when the image matching value is within a predefined threshold and the selected camera's closure switch signal indicates that the camera is "On Air." In alternate embodiments of the present invention, the closure switch signals could be used to identify the tallied camera, if the sequence of operations shown in FIG. **23** became unexpectedly disabled or are inconclusive, or if the closure switch signals for all cameras used for the event are coupled to tally detector **88**. In further embodiments of the present invention, the tally detector GUI includes a manual switch that can be asserted for any one of the camera images to cause the chosen camera to be identified as tallied for broadcast. In one embodiment, if tally detector **88** determines in step **710** that there was more or less than one tally indicated, rather than output no tally (step **712**), tally detector **88** can send the identity of the camera that is indicated by the closure switch signals or the camera identified manually by the operator.

FIG. **24** illustrates a sequence of operations performed in one embodiment of the present invention for enhancing the video. First, a set of parameters are obtained in step **748** for use in building the graphic. The parameters include edge fraction, nominal center point alpha, nominal edge point alpha, and border point alpha. These parameters will be explained in greater detail as they are introduced below. Once the parameters are obtained, a set of center points for the graphic is determined in step **750**. The center points are pixel locations in the graphic that are positioned between the graphic's border points. As explained above with reference to FIGS. **21**, **22**A, and **22**B, a set of three dimensional border points for the graphic is determined is step **604** (FIG. **21**) and converted into a set of two-dimensional border points in step **610** (FIG. **21**). In determining the center points, interpolation is employed in one embodiment to place a center point between a pair of border points.

FIG. **25** is a symbolic representation of a portion of an exemplar line **770**, which is one possible embodiment of a graphic. A symbolic center line **776** is depicted which connects the set of center points determined in step **750**. Also depicted are border lines **772** and **774**, which symbolically connect the border points. Each center point is located between two border points. In one embodiment of the present invention, each center point lies midway between its two associated border points, while in an alternate embodiment center points can be located in positions other than midway between its two associated border points.

Once a set of center points has been established, edge points are determined in step **752**. In one embodiment, the edge points are pixel locations that reside between a center point and a border point. In such an embodiment, the location of each edge point is based on a desired edge fraction. The edge fraction defines the distance between the edge point and a corresponding center point as a percentage of the distance between the center point and the border point that the edge point lies between. In other embodiments of the present invention, the location of each edge point can be determined by alternate means, such as interpolating, receiving the location from a system user, or assigning a predefined value. In further embodiments, the edge points are located in places other than between a center point and a border point.

FIG. **25** shows edge lines **778** and **780**. Each edge line symbolically connects its respective set of edge points. The edge lines, border lines and center lines are drawn in FIG. **25** for illustration purposes. In one embodiment, the number of edge points along an edge line is equal to the number of center points. Each edge point lies between a border point and a center point. For example, edge point **786** lies between border point **784** and center point **792**. The edge fraction is equal to the distance between edge point **786** and center point **792** divided by the distance between center point **792** and border point **784**. In alternate embodiments of the present invention different edge fractions may be employed. For example, the edge fraction can be the percentage of the distance between the two borders.

Once the edge points have been determined, alphas are determined for each of the edge points in step **754**. In one embodiment, an edge alpha is the product of a key fraction value multiplied by a nominal edge point alpha. FIG. **26** shows a sequence of operations for determining an alpha for an edge point in one embodiment of the present invention. First, a corresponding set of pixels in the program video is selected in step **800**. FIG. **27** illustrates nine pixels that are part of a frame from the program video. Pixel **820** represents a pixel in the program video that has the same position as the edge point for which an alpha is being calculated. Pixel **820** along with a set of the pixels surrounding pixel **820** are selected in step **800** for use in determining the key fraction for the selected edge point. In one embodiment of the present invention, the set of pixels includes pixels **820**, **822**, **824** **826** and **828**. In an alternate embodiment, the set of pixels includes pixels **820**, **822**, **824**, **826**, **828**, **830**, **832**, **834** and **836**. In yet another embodiment, the set of pixels only includes pixel **820**. Step **800** also includes initializing a PIXEL$_{13}$ ON counter to zero.

Once the set of pixels is selected, one of the pixels in the set is selected in step **802**. It is then determined in step **804** whether the selected pixel is an inclusion pixel. In one embodiment, this determination is made by determining whether the selected pixel has a pixel characteristic set that falls within a pass band of any of the inclusion filters. For example, when the YCbCr format is employed, it is determined whether the selected pixel has a Y characteristic, Cb characteristic, and Cr characteristic that each fall within the Y characteristic pass band, Cb characteristic pass band, and Cr characteristic pass band for any one of the inclusion filters. If it is determined that the selected pixel is not an inclusion pixel, then it is determined in step **810** whether there are more pixels in the set of program pixels to be considered.

If it is determined that the selected pixel is an inclusion pixel, then the determination is made in step **806** of whether the selected pixel is an exclusion pixel. In one embodiment, this determination is made by determining whether the selected pixel has a pixel characteristic set that falls within the pass bands of an exclusion filter. In an alternate embodiment, additional criteria other than a pixel characteristic set are employed to determine whether the selected pixel is an exclusion pixel. One such example is the use of an exclusion filter designating excluded screen locations, as described above with reference to FIG. **20**.

If, in step **806**, the pixel is determined not to be an exclusion pixel, then a PIXEL_ON value is incremented in step **808**. Once the PIXEL_ON value is incremented, the determination is made in step **810** of whether there are more pixels to be selected from the selected set of pixels. If it is determined that the pixel is an exclusion pixel, then a determination is made in step **810** of whether there are any more pixels to be considered (step **810**). If there are more program pixels to be considered, then a new pixel from the set is selected in step **802**. Otherwise, a key fraction is calculated in step **812**. In one embodiment of the present invention, the key fraction is calculated by dividing the PIXEL_ON value by the total number of pixels in the selected set of program pixels. For example, if the set of program pixels includes pixels **820**, **822**, **824**, **826** and **828**; and pixels **820**, **822**, **824** and **828** are inclusions (and not exclusions) then the key fraction is ⅘. It is contemplated that other means can be employed to determine the key fraction.

Once the key fraction is calculated, the alpha value for the edge point (called the edge point alpha) is determined in step **814**. In one embodiment, the edge point alpha is determined by multiplying the nominal alpha for the edge point by the key fraction for the edge point. The above described process is repeated for each of the edge points in the graphic.

After alphas have been determined for each of the edge points, alphas are determined for each of the center points in step **756**. In determining an alpha for each center point, a key fraction is determined for the center point and multiplied by a nominal alpha value for the center point. In one embodiment of the present invention, the key fraction for each center point is determined based on the key fractions for the edge points that bound the center point. For example, as shown in FIG. **25**, the key fraction for center point **792** is based on the key fractions for edge points **786** and **794**. In one embodiment, the key fraction for each center point is equal to the average of the key fractions for the edge points that bound the center point. In an alternate embodiment of the present invention, the key fraction for each center point is equal to the lowest of the key fractions for the edge points that bound the center point. In yet another embodiment of the present invention, the key fraction for each center point is determined as described above with respect to the edge points. In yet another embodiment, the key fraction for the center point is provided in step **748** or it can be based on another pixel's key fraction or value. Once a key fraction is determined for a center point, the key fraction is multiplied by the center point's nominal alpha to obtain the alpha for the center point.

Once an alpha has been obtained for each center point, an alpha is determined for each of the border points in step **758**. In one embodiment of the present invention, the alpha for each border points is set to a predetermined value. In one embodiment, the predetermined value is zero. By setting the border points to zero, aliasing at the edges of the graphic can be avoided. In another embodiment, the predetermined value of the border point alphas can be defined as a parameter in step **748** by a user of the system in FIG. **2** using the system's GUI. In other alternate embodiments of the present invention, the alpha for each border point is determined as described above with respect to the edge points in step **754**. The border points can be determined using the steps of FIG. **26**, when the graphic is a logo in which anti-aliasing at the borders of the graphic has already been provided for through the use of an alpha mask.

After alphas have been determined for the boundary points, in one embodiment of the present invention, a flicker filter operation is performed in step **760**. The flicker filter is employed to reduce flickering in the appearance of the graphic. The flicker filter averages a newly calculated alpha for the pixel with past and future alphas for the same pixel to generate a filtered alpha. In one embodiment of the present invention, the flicker filter operation is performed according to the following equation:

$$\alpha_F = \frac{\left(\sum \alpha_{FP} + \alpha + \sum \alpha_U\right)}{N}$$

wherein

$\alpha_F$ is the filtered alpha;

$\Sigma\alpha_{FP}$ is a summation of filtered alphas for the selected pixel in prior video frames;

$\alpha$ is the unfiltered alpha of the selected pixel for the current video frame;

$\Sigma\alpha_U$ is a summation of unfiltered alphas for the selected pixel for future video frames; and

N is a number of values being averaged.

It is possible to obtain filtered alphas for pixels using future alpha values, because delays in the system shown in FIG. **2** provide for the calculation of alphas several frames in advance of their use. In one embodiment, $\Sigma\alpha_{FP}$is the sum of the selected pixel's filtered alphas for the two video frames preceding the current video frame; $\Sigma\alpha_U$ is the sum of the selected pixel's filtered alphas for the two video frames following the present video frames; and N is equal to 5. In an alternate embodiment, the summation of filtered alphas for the selected pixel in prior video frames ($\Sigma\alpha_{FP}$) is replaced by a summation of unfiltered alphas for the selected pixel in prior video frames. In one embodiment of the present invention, the flicker filter operation is applied to the alphas of the center points, border points and edge points. In alternate embodiments, the flicker filter is applied to only a subset of the alphas of the center points, border points, and edge points. In yet another embodiment, the flicker filter is applied to each pixel to be blended. In further embodiments, the flicker filter operation is not employed. In still further embodiments, values of alphas from different times can be weighted differently.

Once the flicker filter operation is completed, or all of the unfiltered alphas have been obtained in an embodiment in which the flicker filter is not employed, the graphic is drawn in step **762**. In drawing the graphic, a frame that includes the graphic is rendered and alphas are determined for each graphic pixel in the frame. When rendering the graphic, each pixel's location and fill characteristics are determined. The fill characteristics and alpha are then sent to the keyer **98** for blending with the program video.

One embodiment of the present invention includes dividing the graphic into regions with each region being defined by a set of vertices, in which each vertex is either an edge point, a center point or a boundary point. For example, as shown in FIG. **25**, when line **770** is drawn, it is divided into regions that are defined by either a pair of edge points and a pair of border points, or a pair of center points and a pair of edge points. For example, region **782** is defined by border point **784**, border point **790**, edge point **788**, and edge point **786**.

For each region, the fill characteristics and alpha of each of vertex of the region is employed to establish the fill characteristic and alpha for each pixel within the region. For example, line **770** shown in FIG. **25** can be rendered with all pixels having the same fill characteristics and varying alphas. In such an embodiment, the fill characteristics for the vertices (**784**, **786**, **788**, **790**) defining region **782** are the same. These fill characteristics are then applied to each of the pixels within region **782**. The alpha for each of the pixels in region **782** is determined by using interpolation based on the alphas for each vertex (**784**, **786**, **788**, **790**) defining region **782**.

In one embodiment of the present invention, a computer generates and supplies the line **770**, by executing instructions from a program stored in memory. In one embodiment, the computer uses the Open GL language and generates a set of polygons using a g1Begin, g1End command in conjunction with a GL_QUADS instruction. The GL_QUADS instruction provides sets of vertices to the g1Begin, g1End command for drawing quadrilaterals. Also provided are the alphas and fill characteristics for each vertex. A quadrilateral is generated by the g1Begin, g1End command for each set of four vertices that is provided.

In an alternate embodiment to the present invention, graphics can be provided with regions that have more or fewer than four vertices and/or different fill characteristics for each of the vertex pixels. When a different number than four vertices are employed, the segments that are rendered will be a shape other than a quadrilateral. When different fill characteristics are provided for each vertex pixel, in one embodiment of the present invention, bilinear interpolation is employed to determine the fill characteristics for each of the pixels in the region based on the fill characteristics for the region's vertex pixels.

For line **770**, FIG. **25** depicts only two edge lines **778** and **780**. In alternate embodiments of the present invention, there can be more than two edge lines. By using multiple edge lines and different nominal alphas for the different edge lines, different effects can be achieved for drawing the graphic.

In one embodiment for using a logo, there are two border lines, no center lines and nine equally spaced apart edge lines, thereby forming 100 equally sized polygons representing the graphic. In such an embodiment, the alpha for each of the border points and edge points are determined as described above in step **754** with respect to edge points.

In one embodiment of the present invention, computer **94** is used to perform all of the steps described in FIG. **24**. In an alternate embodiment of the present invention, the process steps described in FIG. **24** are shared between computer **94** and computer **96**. In one such embodiment, the steps of drawing a graphic **762** and employing the flicker filter operation **760** are performed by computer **96**, while the other steps are performed by computer **94**. Computer **94** provides computer **96** with locations for each of the center points and boundary points, the alphas for each of the boundary points, center points, and edge points, and the edge fraction. Computer **96** then determines the location of the edge points based on the edge fraction as described above with respect to step **752** in FIG. **24**. In yet another embodiment of the present invention, the flicker filter **760** is employed by computer **94**, so that computer **96** receives filtered alpha values for the center points, border points, and edge points.

In further embodiments of the present invention, each pixel in the graphic can be analyzed individually to determine its alpha. In one such embodiment, the above described process for determining the alpha for an edge point (**754** in FIG. **24**) is employed for each of the pixels in the graphic.

An alpha signal is one example of a blending coefficient. A blending coefficient is a value used to indicate how to blend one image or video with a second image or video. The above discussion describes a means for determining alphas for various pixels and using the determined alphas for blending a graphic using a keyer or a computer. It is contemplated that other technologies can be used to blend the graphic and that these other technologies may use different blending coefficients than an alpha signal.

The foregoing detailed description of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teaching. The described embodiments were chosen in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. The invention is, thus, intended to be used with many different types of live events including various sporting events and non-sporting events. It is intended that the scope of the invention be defined by the claims appended hereto.

What is claimed is:

**1**. A method for blending images, comprising the steps of:

selecting a first portion of a first image, said first portion of said first image includes different color values;

storing information about said different color values;

receiving a first video image after said step of selecting;

accessing color data for said first video image;

comparing said color data to said stored information about said different color values; and blending a second image with said first video image at least partially based on said step of comparing.

**2**. A method according to claim **1**, wherein:

said step of accessing includes accessing color data for at least a subset of a portion of said first video image; and

said step of blending includes blending said second image with said portion of said first video image.

**3**. A method according to claim **2**, wherein:

said first portion of said first image does not depict said portion of said first video image.

**4**. A method according to claim **1**, wherein:

said step of blending includes blending said second image with a target area in said first video image; and

said first portion of said first image is different than said target area.

**5**. A method according to claim **1**, wherein:

said first image is a second video image of an event; and

said first video image depicts said event.

**6**. A method according to claim **1**, wherein:

said second image is a second video image.

**7**. A method according to claim **1**, wherein:

said first video image is live and said step of blending includes broadcasting said blended first video image.

**8**. A method according to claim **1**, wherein:

said step of selecting a portion of a first image includes selecting a set of adjacent pixels.

**9**. A method according to claim **1**, wherein:

said step of accessing color data for said first video image includes accessing color data for a subset of pixels for a portion of said first video image; and

said step of blending includes blending said second image with said portion of said first video image.

**10**. A method according to claim **1**, wherein:

said different color values pertain to visibly distinct colors.

**11**. A method according to claim **1**, wherein:

said color data pertains to visibly distinct colors.

**12**. A method according to claim **1**, wherein:

said first video image depicts a live event;

said step of receiving said first video image is performed during said live event; and

said step of blending is performed during said live event.

**13**. A method according to claim **12**, wherein:

said first image is a second video image depicting a scene prior to said live event.

**14**. A method according to claim **12**, wherein:

said first image is a second video image depicting said live event.

**15**. A method according to claim **12**, further comprising the steps of:

selecting a new portion of a new video image during said live event;

storing new information about new color values in said new portion;

receiving a second video image during said live event;

accessing new color data for said second video image;

comparing said new color data to said stored new information; and

blending a third image with said second video image at least partially based on said step of comparing said new color data.

**16**. A method according to claim **1**, further including the step of:

creating an inclusion based on said first portion of said first image, said step of storing includes storing said inclusion.

**17**. A method according to claim **16**, wherein:

said inclusion includes data identifying a range of colors.

**18**. A method according to claim **16**, further including the steps of:

selecting a second portion of said first image or another image; and

creating an exclusion based on said second portion.

**19**. A method according to claim **18**, wherein:

said step of blending includes blending a pixel if said pixel is in said inclusion and not in said exclusion; and

said inclusion and exclusion include overlapping colors.

**20**. A method according to claim **18**, wherein:

said step of blending includes blending a particular pixel according to a ratio of pixels in one or more inclusions to pixels in one or more exclusions, said pixels in said one or more inclusions and said pixels in said one or more exclusions include said particular pixel and neighboring pixels.

**21**. A method according to claim **1**, wherein:

said second image comprises a plurality of polygons; and

said step of blending includes assigning blending coefficients to said polygons based on said stored information about said different color values.

**22**. A method according to claim **21**, wherein:

a particular blending coefficient is determined according to a ratio of neighboring pixels in one or more inclusions to neighboring pixels in one or more exclusions.

**23**. A method according to claim **22**, further comprising the step of:

determining edge points for said polygons, said blending coefficients pertain to said edge points.

**24**. A method according to claim **21**, wherein:

a particular blending coefficients is determined by comparing whether a color associated with said polygon is in an inclusion and not in an exclusion.

**25**. A method according to claim **21**, further comprising the steps of:

determining edge points for said second image, said step of assigning blending coefficients to said polygons includes determining blending coefficients for said edge points;

determining center points for said second image, said step of assigning blending coefficients to said polygons includes determining blending coefficients for said center points; and

determining border points for said second image, said step of assigning blending coefficients to said polygons includes determining blending coefficients for said border points.

**26**. A method according to claim **25**, further comprising the steps of:

flicker filtering at least a subset of said blending coefficients.

**27**. One or more processor readable storage devices having processor readable code embodied on said one or more processor readable storage devices, said processor readable code for programming one or more processors to perform a method comprising the steps of:

receiving a selection of a first portion of a first image, said first portion of said first image includes different color values;

storing information about said different color values;

receiving a first video image after said step of selecting, said first video image includes color data;

comparing said color data to said stored information about said different color values; and

blending a second image with said first video image at least partially based on said step of comparing.

**28**. One or more processor readable storage devices according to claim **27**, wherein:

said step of blending includes blending said second image with a target area in said first video image; and

said first portion of said first image is different than said target area.

**29**. One or more processor readable storage devices according to claim **28**, wherein:

said first image and said second image are video images;

said first video image is live video depicting a live event;

said step of blending is performed during said live event; and

said different color values pertain to visibly distinct colors.

**30**. One or more processor readable storage devices according to claim **27**, wherein:

said different color values pertain to visibly distinct colors.

**31**. One or more processor readable storage devices according to claim **27**, wherein:

said first video image depicts a live event;

said step of receiving a first video image is performed during said live event;

said step of blending is performed during said live event; and

said first image is a second video image depicting said live event.

**32**. One or more processor readable storage devices according to claim **27**, wherein said method further includes the step of:

creating an inclusion based on said first portion of said first image, said inclusion includes data identifying a range of colors.

**33**. One or more processor readable storage devices according to claim **32**, wherein said method further includes the steps of:

receiving a selection of a second portion of said first image or another image; and

creating an exclusion based on said second portion.

**34**. One or more processor readable storage devices according to claim **33**, wherein:

said step of blending includes blending a pixel if said pixel is in said inclusion and not in said exclusion; and

said inclusion and said exclusion include overlapping colors.

**35**. One or more processor readable storage devices according to claim **33**, wherein:

said step of blending includes blending a particular pixel according to a ratio of pixels in one or more inclusions to pixels in one or more exclusions, said pixels in said one or more inclusions and said pixels in said one or more exclusions include said particular pixel and neighboring pixels.

**36**. One or more processor readable storage devices according to claim **27**, wherein:

said second image comprises a plurality of polygons; and

said step of blending includes assigning blending coefficients to said polygons based on said stored information about said different color values.

**37**. One or more processor readable storage devices according to claim **36**, wherein said method further comprises the steps of:

determining edge points for said second image, said step of assigning blending coefficients to said polygons includes determining blending coefficients for said edge points; and

determining border points for said second image, said step of assigning blending coefficients to said polygons includes determining blending coefficients for said border points.

**38**. An apparatus, comprising:

one or more processors;

an input device in communication with said one or more processors;

an output device in communication with said one or more processors;

a storage device in communication with said one or more processors, said processor programmed to preform a method comprising the steps of:

receiving a selection of a first portion of a first image, said first portion of said first image includes different color values,

storing information about said different color values,

receiving a first video image after said step of selecting, said first video image includes color data,

comparing said color data to said stored information about said different color values, and

blending a second image with said first video image at least partially based on said step of comparing.

**39**. An apparatus according to claim **38**, wherein:

said step of blending includes blending said second image with a target area in said first video image; and

said first portion of said first image is different than said target area.

**40**. An apparatus according to claim **39**, wherein:

said first image is a video image of an event;

said first video image depicts said event; and

said first video image is live.

**41**. An apparatus according to claim **38**, wherein:

said step of receiving a selection of a portion of a first image includes selecting a set of adjacent pixels;

said color data pertains to a portion of said first video image; and

said step of blending includes blending said second image with said portion of said first video image.

**42**. An apparatus according to claim **38**, wherein:

said different color values pertain to visibly distinct colors.

**43**. An apparatus according to claim **38**, wherein:

said first video image depicts a live event;

said step of receiving said first video image is performed during said live event; and

said step of blending is performed during said live event.

**44**. An apparatus according to claim **38**, wherein said method further includes the step of:

creating an inclusion based on said first portion of said first image, said inclusion includes data identifying a range of colors.

**45**. An apparatus according to claim **44**, wherein said method further includes the steps of:

selecting a second portion of said first image or another image

creating an exclusion based on said second portion.

**46**. An apparatus according to claim **45**, wherein:

said step of blending includes the step of blending a pixel if said pixel is in said inclusion and not in said exclusion; and

said inclusion and said exclusion include overlapping colors.

**47**. An apparatus according to claim **45**, wherein:

said step of blending includes the step of blending a particular pixel according to a ratio of pixels in one or more inclusions to pixels in one or more exclusions, said pixels in said one or more inclusions and said pixels in said one or more exclusions include said particular pixel and neighboring pixels.

**48**. An apparatus according to claim **38**, wherein:

said second image comprises a plurality of polygons; and

said step of blending includes assigning blending coefficients to said polygons based on said stored information about said different color values.

**49**. An apparatus according to claim **48**, wherein said method further comprises the steps of:

determining edge points for said second image, said step of assigning blending coefficients to said polygons includes determining blending coefficients for said edge points; and

determining border points for said second image, said step of assigning blending coefficients to said polygons includes determining blending coefficients for said border points.

**50**. A method for blending images, comprising the steps of:

receiving video of an environment;

selecting a first region in said video, said first region includes a first set of different color values;

creating inclusion criteria describing said first set of different color values;

selecting a second region in said video, said second region includes a second set of one or more color values;

creating exclusion criteria describing said second set of one or more color values, said first set of color values overlap with said second set of color values;

identifying a target area in said video after said steps of creating inclusion criteria and creating exclusion criteria;

comparing said color data for said target area to said inclusion criteria and said exclusion criteria; and

blending a graphic with said target area at least partially based on said inclusion criteria and said exclusion criteria.

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