Description

The present invention relates to image recorders and, in particular, image recorders providing an automatically aligned and adjusted image on a film plane from a CRT image. It also relates to methods of adjusting an image in such an image recorder.

Previous image recorders providing film copies of CRT images require precise mechanical, optical and electronic adjustments to provide the optimum reproduction image quality. (e.g. DE-A-1134287). Furthermore, the adjustments, having been made, require constant attention and readjustment to maintain the performance of the image recorder apparatus. The individual adjustment parameters of the image recorder may either be adjusted independently or if necessary, adjusted in combination due to the interaction of the various signals in the image recorder apparatus. Moreover, the adjustment is further complicated by the two-dimensional nature of the image recorder, requiring the adjustments to be provided in both dimension. In spite of the extremely complex nature of the alignment apparatus and processes, a practical image recorder must maintain the alignment and provide for realignment with minimal interruption with the use of the image recorder.

For various reasons, it is inappropriate to do all images at highest resolution. But, for pictures done with differing resolutions, e.g., 4000 and 2000 lines, the resulting color renditions do not match. Thus exact color matching of different resolutions is important.

SUMMARY OF THE INVENTION

The image recorder according to the present invention provides complete automatic alignment of the various parameters controlling the creation of an image on the plane of the film and precise color control and matching for images of different pixel densities. The apparatus and process according to the present invention provides the adjustment and alignment preceding use of the image recorder. Thereafter, the image recorder is available for use, having the parameters optimally adjusted.

The CRT beam in the image recorder of the present invention is controlled by an array of numeric values. The entries in the array correspond to beam position, focus and intensity level. One difficulty in determining the exact value for each entry in the array is that the array entries only indirectly control the beam characteristics. In between the array of numbers or "mesh" and the CRT plane are system components which perform interpolations, filtering, and delay operations on the values. A "prototype" mesh is generated for an idealized system which models the image recorder characteristics.

No model is perfect and there are errors and inaccuracies in the model used for the generation of the mesh. In addition, there will be manufacturing variations and tolerances. Because of these factors, it is necessary to "tune" the mesh for each individual image recorder.

The present invention comprises a process of automatically adjusting the values of the "prototype" mesh to meet the acceptance criteria and limitations of the produced film image and will be referred to as mesh alignment.

The apparatus according to the present invention can also modify the mesh values to "predistort" the resulting image in a controlled manner to obtain images which will be correct after projection. For instance, if a projector is angled upward at the screen, the image is distorted into a "keystone." The present invention permits the film image to be predistorted so that the projected image is rectilinear. Further, the modifications to the mesh can also create selected special effects.

The modifications to the prototype mesh are generated by a set of measurements which characterize the specific image recorder. These measurements contain the information necessary to supply the parameters for all of the required operations on the prototype mesh. The apparatus according to the present invention performs the necessary measurements, and the corresponding mathematical operations in order to produce a corrected prototype mesh which meets the acceptance criteria.

Thus, according to the present invention, the prototype mesh is stored in Read Only Memory (ROM) in the image recorder. The measurements and/or parameters may be stored in nonvolatile read/write memory. At power-up the alignment operations on the prototype mesh are computed and the resulting mesh used for imaging.

BRIEF DESCRIPTION OF THE DRAWING

These and other features according to the present invention will be better understood by reading the following detailed description, taken together with the drawing, wherein :

Fig. 1 is a block diagram of one embodiment of the image recorder automatic alignment system according to the present invention ;

Fig. 1A shows an alternate embodiment of the alignment of the optical elements of the system of Fig. 1 ;

Fig. 2 is a drawing showing the film plane coordinates and an example of 35 mm slide coordinates ;
Fig. 3 is a drawing showing one embodiment of the mask according to the present invention ;
Fig. 4 is a collection of beam intensity profiles considered in the process of focus adjustment ;
Fig. 5 is a drawing defining the terms used in the detailed description ;
Fig. 6 is a perspective view of a typical mesh array and control surface ;
Fig. 7 is a drawing showing the mesh array indices superimposed on a film image ;
Fig. 8 is a graph showing offset and scale of the focus mesh ;
Fig. 9 is a two-dimensional view of a focus mesh ;
Fig. 10 is a graph showing beam radius change ;
Fig. 11 is a graph showing measurements for computing beam radius deflections ;
Fig. 12 is an illustration of orthogonality errors ;
Fig. 13 is a drawing showing the amplitude of the orthogonality correction signals ;
Fig. 14 is a drawing showing the correction for mesh rotation errors ;
Fig. 15 is a drawing showing mesh interpolation according to the present invention.
Fig. 16 is a block drawing showing one embodiment of the present invention wherein the CRT image is selectively adjusted according to removable, encoded film aperture plates ; and
Figs. 16A-D are four encoded aperture plates in more detail.

DETAILED DESCRIPTION OF THE INVENTION

A block diagram 50 in Fig. 1 of the apparatus according to the presentation includes a cathode ray tube (CRT) 82 which provides an image on an image plane, which for this embodiment is also a CRT plane 84 and is projected on the film plane 88 by a camera lens 86.

The image on the CRT plane 84 is generated from scan data stored in a scan memory 74. The scan memory 74 provides 20 bits of digitized RGB video to digital-to-analog converter (DAC) 75, which provides an analog video output and four bits of control timing to the analog-to-digital converter (ADC) 96, the integrator reset circuit, and the sample and hold (S/H) circuit 95 which digitizes the photodetector 94 signal. The scan memory 74 addresses are provided by an address generator 76 synchronized by the geometry engine 52 so that the operation of the geometry engine corresponds to the image generated from the scan memory 74. The scan memory is controlled by a microprocessor, which may include the mesh adjusting microprocessor 77. The system is aligned according to an alignment mask 90 inserted at the CRT plane 84. A movable spot is provided on the CRT plane 84 of the CRT 82 and is selectively obscured by the pattern on the alignment mask 90 (shown in Fig. 3). More generally, the alignment mesh can be any device which comprises a variable density optical element which produces variations in the spot intensity in the photodetector optical path. The portion of the light which is not obscured is received by a photodetector 94.

The alternate embodiments of the alignment mask 90 and photodetector 94 placement includes placing the mask 90 at the film plane at a focal point of the camera lens 86. When the mask 90 is operative at the film plane, the photographic film and the alignment mask are each in individual interchangeable modules (not shown) which are received in front of the CRT plane. Each such module also includes the necessary optics. Examples of further alternate embodiments in alignment mask position are shown in Fig. 1A. The alignment mask 90 can overlay the CRT on the CRT plane 84, and the photodetector 93 receives light directly or indirectly from a beamsplitting or movable mirror 87, from the CRT plane. The mask 90 may also be located at the film plane 88, such that light reflected from the mask is received by a rearward-looking photodetector 95, either directly or indirectly from a beam splitter 87 in the optical path. Moreover, a mirror 97 may be introduced at the film plane 88 to reflect light to the photodetector 95 from the transmissive portions of the alignment mask 90.

A signal from the photodetector 94 is received by sample-and-hold 95 and converted to a digital number by an analog-to-digital converter (ADC) 96. The resulting digital signal is received by the microprocessor, discussed in detail below. The geometry engine is controlled to produce an image to coincide with an external signal, including a sync signal on lead 73. The geometry engine provides an x deflection signal which is received and converted to an analog signal by DAC 56. The analog signal is received and filtered by a low pass filter (LPF) 57 and amplified by an amplifier 58 and received by the deflection coils or other deflection device by the CRT. Similarly, the geometry engine 52 provides a y deflection signal which is converted by DAC 60 filtered by the LPF 61 and amplified at 62. The focus signal is also generated by the geometry engine 52 and converted to an analog signal by DAC 64, filtered by the LPF 65 and drives the appropriate CRT grid by amplifier 66.

The above-described signals generated by the geometry engine 52 are adjusted or corrected by signals stored in the mesh random access memory (RAM) 54 and from interpolation between the stored signals, described below. The mesh signals in RAM 54 are based on a prototype mesh stored in nonvolatile memory (NVRAM or EPROM) 78. A mesh adjusting microprocessor 77 processes the prototype mesh 78 values accord-

ing to the digitized intensity signal from ADC 96 and according to the processes described below, storing the results in the mesh RAM 54.

An observed phenomenon in image recorders which record images from the face of the CRT is the variation in image brightness over the image plane of the CRT. Specifically, the image brightness is greater in the center of the CRT film plane and diminishes at the outward extremes. This phenomenon, termed "vignetting" hereinafter, is corrected by the apparatus of the present invention by scaling or multiplying the DAC 75 output signal with a signal multiplier 71 which also receives a variable vignette signal from the geometry engine 52. A contrast DAC 72 multiplies the video signal by a contrast signal. The vignette signal is converted to an analog signal by DAC 68, filtered by LPF 69 and amplified by amplifier 70 before being received by the multiplier 71.

The geometry engine 52 provides the deflection signals to provide the necessary beam deflection to create an image according to the stored video signal in the scan memory 74. The aforementioned system parameters are adjusted by mesh signals in the mesh RAM 54 by the geometry engine 52 according to the present invention to provide corrections for various system errors discussed below.

Photodetector 94 measurements provide the information required for tuning or adjustment of the prototype mesh in ROM 78. They are made by positioning the beam at a target point on the CRT and monitoring the light amplitude at the photodetector. Absolute XY position can be determined by inspecting the spot intensity as it is positioned near edges and corners of targets 100 on the alignment mask (90, Fig. 3). A profile of the spot (the brightness or energy of the spot as a function of a position along a line through the spot) can be obtained by measuring successive intensities as the spot is moved gradually past an opaque edge of the mask.

There are numerous entities in the system for aligning the prototype mask, each entity with its specific coordinate system. To reduce confusion, and provide a foundation to the mathematical description of the process, it is necessary to relate the various coordinate systems to each other.

First, there is obviously a physical coordinate system which specifies in "real world" space the dimensions and positions of things. The frame size of a 35 mm film image has an expected ratio of 2 : 3 specified as 24 mm by 36 mm. The equations in this specification reflect the 2 : 3 aspect ratio ; other film formats are accommodated by varying the appropriate equations and calculations accordingly. It is convenient to establish a "normalized" coordinate system on the frame of the image, Fig. 2. The origin is at the center of the frame 102. The horizontal axis will be denoted "X" and extends from – 1.0 at the left to + 1.0 at the right of the frame. The vertical "Y" Axis extends from – 1.0 at the bottom to + 1.0 at the top of the frame or – 2/3 and + 2/3 for a 35 mm slide.

A prototype mesh (data in ROM 78) is formed which has several coordinate systems attached to it. The term prototype refers to the initial values of the system elements, and are subject to change by microprocessor 77 according to the self-adjusting process of the present invention. One coordinate system is the array indices of the mesh. These are integers, call them j and k, and they correspond to the sequence in which the geometry engine fetches the contents of the array. The organization is in rows and columns. A row can be considered to correspond to the horizontal scan of the CRT beam. Successive rows are accessed as the beam moves down the screen.

Each beam control parameter (x and y position, focus and vignette) has its own two dimensional array. Since each element of the array holds a scalar value 112, the array can be viewed as samples of a surface 110 defined over the range of array indices in Fig. 6. Each beam parameter has its control surface 110.

In Fig. 7, note that the array indices j,k map onto the X-Y image frame coordinates of Fig.2. That is, a row of the mesh represents points on a horizontal line in the image. A column corresponds exactly to a vertical line in the image. In practice, the mesh contains additional samples 114 beyond the frame 104 to implement retrace of the CRT beam.

Because many of the operations for geometry alignment can be easily accomplished using complex numbers, a library of the fundamental vector operations is built which implement complex addition, multiplication, division, and conjugation. Focus and vignette are treated as scalars (or as a subset of complex numbers with imaginary part set to zero).

The order in which the alignment corrections are applied to the prototype mesh is determined by the type of operation required. The three different operation types by their order of precedence are resampling, scaling (multiplicative), and offset correction (additive). The resampling operation can include both the residual distortion and the rotation corrections. The other two operation types can be combined into a single linear mapping step.

Two types of corrections are made to a mesh control surface. First there are gain and offset type corrections. Second, there are corrections which require "resampling" the mesh surface. Resampling refers to the process where new mesh values are obtained by interpolation between the original mesh values which are at integer coordinates.

The measurements, which contain all of the information required for the mesh corrections, are made by

positioning the beam at a target point on the alignment mask and monitoring the light amplitude. The alignment mask contains targets in film image coordinates. The beam is controlled by points in the space of the control surfaces. The relationship between the control surface amplitudes and the image coordinates yield the information required for scaling and resampling.

The locations of the targets 100 on the alignment mask are shown in Fig. 3. The measurements which are required for geometry corrections consist of the X and Y DAC values required to position the beam at the corner of the target. The positioning algorithm conducts a search for the corner of the opaque square 100 in each target. This search can first be carried out on a nonfocussed beam to get a "coarse" position of the target. The beam is then focussed and the search performed again so as to obtain an accurate position of the target.

Finding the best focus is done by examining the horizontal 192 and vertical profiles 194 of the spot intensity, shown in Fig. 4, as the spot is brought out from behind an opaque edge. The respective derivatives 193, 195 of the intensity profile 192, 194 and the product 197 of the intensity derivatives 193, 195 is also shown. Another search is done over the range of focus voltage to find the "best" spot. This will be defined as the spot whose horizontal and vertical profile derivatives, when multiplied together, yield the maximum product. A selectively variable focus signal is then applied to the CRT 82 to control the CRT focus and adjusted for maximum product.

It is also possible to find the focus value by monitoring the light intensity of the spot as the focus voltage is adjusted. For the nonmoving (static) spot, the best focus occurs at the minimum of the light output response.

After the beam has been focussed and positioned, an intensity number should be obtained. This is the amplitude of the photodetector when viewing the spot for a fixed time period. This measurement will be used for establishing the vignette mesh.

For each target on the alignment mask, then, it is possible to obtain the quadruple of numbers T_x, T_y, T_f and T_v. These numbers are integers which represent the DAC values at the target point (except for T_v which is an ADC value from the photodetector). While they may be stored as integers, for the alignment operations that are described below, they will be treated as real, with the range -1 to $+1$.

The notation for the normalized measurements will use an uppercase T to indicate an alignment mask target, a subscript indicating the specific measurement, and a coordinate pair to specify the target location. Examples of this notation are :

$T_x(1/2,0)$	X DAC number required to position at this target.
$T_f(1, 2/3)$	Focus DAC number of best focus at upper right corner for 35 mm slide.
$T_v(-1,0)$	Intensity measurement at middle left edge. Sometimes the T_x and T_y numbers will be combined into a complex number. This will be indicated as :

$$T_{xy}(a,b) = T_x(a,b) + iT_y(a,b)$$

The mesh indices form the u, v coordinate system, discussed further below. It is necessary to locate the origin of the mesh array. The actual physical indexing of the array is by row and column integers j, k. To locate the origin index (in integer space) the size, shape and horizontal and vertical offsets of the mesh must be known. This can be obtained from the data structure in which the mesh resides. The parameters of interest are defined in Fig. 5 and below :

Res	resolution of maximum image area.
HMin	location of first visible horizontal pixel.
HMax	location of last visible horizontal pixel.
VMin	location of first visible line (vertical pixel).
VMax	location of last visible line (vertical pixel).
Box	number of pixels between mesh elements.
PStr	number of pixels from first mesh element to the geometry engine synchronization signal.
HOffset	number of pixels from the pixel specified by PStr to first visible pixel.
PMax	number of pixels per row in the mesh = Box * (k_{max} + 1).
LStr	number of lines (vertical pixels) from first mesh element to first visible line.
LMax	number of lines per column in the mesh = Box * (j_{max} + 1).

If the mesh array starts with element M[row, col] = M[0,0], then the elements of the first (top) visible line are at :

$$J = LStr/Box$$

The elements of the first visible pixels on the left hand edge are at :

$$k = (PStr + HOffset)/Box$$

Note that these may take fractional values, indicating that the starting pixels do not fall exactly on the mesh coordinates.The center of the entire image space is at Res/2, Res/2. The center of the mesh is at :

$$j_{org} = (Res/2 - VMin + LStr)/Box$$

$$k_{org} = (Res/2 - HMin + PStr + HOffset)/Box$$

This alignment procedure uses a standard 35 mm frame format, so some of the above parameters are fixed:

$$Hmin = 0$$
$$HMax = Res - 1$$
$$HOffset = 0$$
$$Vmin = Res/6$$
$$VMax = 5 * Res/6 - 1$$

Now that the mesh origin indices are known, the conversion to the normalized u, v coordinates is :

$$u = 2Box\ (k - k_{org})/Res$$

$$v = 2Box\ (j_{org} - j)/Res$$

Note that u is a function of column index only, and v is a negative function of row index in order to invert the axis direction to the normalized frame coordinate sense (increasing numbers toward the top).

The retrace areas are not considered to be part of the imaging surface. This requires that the boundaries of the image be located in the mesh. The mesh elements just outside of the upper left corner are :

$$j_{ul} = Trunc(LStr/Box)$$

$$k_{ul} = Trunc(PStr + HOffset/Box)$$

The mesh elements outside of the lower right corner are :

$$j_{lr} = Trunc(1 + (VMax - VMin + LStr + 1)/Box)$$

$$k_{lr} = Trunc(1 + (HMax - HMin + PStr + HOffset + 1)/Box)$$

These are the boundaries of the image portion of the mesh. All indices within or at these locations are subject to mapping for resampling.

The steps necessary to obtain the alignment factors which will operate on the prototype mesh are shown below.

First, the center of the frame is measured. This is just $T_x(0,0)$ and $T_y(0,0)$. Create the complex center number :

$$C = T_x(0,0) + iT_y(0,0)$$

Second, the deflection gains and beam radii are obtained. Use T(1,0), T(1, 2/3), and T(0, 2/3) for 35 mm film format examples, to compute values for K_x, K_y, Z_x and Z_y. Correct each of the measurements for the frame center :

$$T_{xy}(a,b) = T_{xy}(a,b) - C$$

Find the values for the X and Y deflection gains.

$$K_x^2 = \frac{T_x^2(1, 2/3) - T_x^2(1, 0)}{T_x^2(1,0)T_x^2(1,2/3) \cdot (1^2+2/3^2-1^2-0^2)}$$

$$K_y^2 = \frac{T_y^2(1, 2/3) - T_y^2(0,2/3)}{T_y^2(0,2/3)T_y^2(1,2/3) \cdot (1^2+2/3^2-0^2-2/3^2)}$$

Then solve for Z_x, Z_y:

$$Z_x^2 = \frac{1^2}{K_x^2 T_x^2(1,0)} - 1^2 - 0^2$$

$$Z_y^2 = \frac{2/3^2}{K_y^2 T_y^2(0,2/3)} - 0^2 - 2/3^2$$

Four sets of numbers are found, one set for each quadrant of the image. The sets can be averaged in order to obtain a single set of equivalent deflection gains and beam radii or the deflection gain and beam radii can correct the geometry of each quadrant independently.

Third, the inclination of the horizontal axis is determined. Transform the T_x, T_y measurements at (−1,0), (1,0) to image frame coordinates. Use the two transform steps:

$$T_{1xy} = T_{xy} - C$$

$$T_{2x} = \left[\frac{(Z_x^2 + Z_y^2 \tan^2 K_y T_y) \tan^2 K_x T_x}{1 - (\tan^2 K_y T_y) \tan^2 K_x T_x}\right]^{1/2}$$

$$T_{2y} = \left[\frac{(Z_y^2 + Z_x^2 \tan^2 K_x T_x) \tan^2 K_y T_y}{1 - (\tan^2 K_x T_x) \tan^2 K_y T_y}\right]^{1/2}$$

Now compute the rotation angle and a correcting complex multiplier, R:

$$\theta_{rot} = \arctan[(T_{2y}(1,0) - T_{2y}(-1,0))/T_{2x}(1,0) - T_{2x}(-1,0))]$$

$$R = \cos(-\theta_{rot}) + i\sin(-\theta_{rot})$$

Fourth, the orthogonality correction angle from the top and bottom edge targets T(0, 2/3) and T(0, −2,3) is calculated. These are then transformed to the rotation corrected image frame coordinates. First, T_{2xy} of these target measurements is computed as above, and then corrected for rotation:

$$T_{3xy} = R(-\theta_{rot}) \cdot T_{2xy}$$

The orthogonality correction angle and the gradient correction as a function of vertical mesh index v are:

$$\theta_{ortho}=\text{atan}\{(T_{3x}(0,-2/3)-T_{3x}(0,2/3))/T_{3y}(0,2/3)-T_{3y}(0,-2/3))\}$$

$$H^{(v)}_{ortho} = -v \tan\theta_{ortho}$$

Fifth, the complex constants used in the residual distortion mapping from the measurements at the corner targets T(– 1, 2/3) and T(1, – 2/3) are computed. Using the same transforms above, T_{3xy} is obtained for these targets. Then the orthogonality correction is applied to the x components of them to obtain T_{4xy}:

$$T_{4x} = T_{3x} + H_{ortho}(T_{3y})$$

$$T_{4y} = T_{3y}$$

The three constants required are :

$$A = T_{4xy}(-1, 2/3)\, T_{4xy}(1, -2/3)\, (2 - 4/3\, i)$$

$$B = [T_{4xy}(1, -2/3) - T_{4xy}(-1, 2/3)]\, (-1/3 + 2/9)\, i)$$

$$C = (1 - 2/3)\, i)\, T_{4xy}(-1, 2/3) - (-1 + 2/3\, i)\, T_{4xy}(1, -2/3)$$

Sixth, the focus levels are measured.

Seventh, the vignette factors are measured.

Having computed the required alignment parameters, the prototype mesh is ready for alignment. The stages are :

1. Resample the mesh to remove residual distortion and rotation.
2. Make a linear correction to each element to correct for orthogonality, pincushion, centering, focus and vignette.

In the first stage, the remapping of the mesh coordinates is formed from a combination of the residual distortion correction and the rotation correction. The steps required to compute the new coordinate locations are described now.

The resampling process requires that for each index of the mesh array, a new index coordinate be computed, a surface interpolation performed, and the new mesh value deposited in the mesh at the (original) index. For all j, k within :

$$j_{ul} \le j \le j_{lr}$$

$$k_{ul} \le k \le k_{lr}$$

do

$$u = 2\text{Box}\,(k - k_{org})/\text{Res}$$

$$v = 2\text{Box}\,(j - j_{org})/\text{Res}$$

$$w = u + iv$$

$$Z = R\,\frac{A\,w}{B + C\,w}$$

where A, B, C and R are the complex numbers obtained above. Now convert z back to mesh indices to find the interpolation boundaries :

$$z = x + iy$$

$$k_{new} = \text{Res } x/(2\text{Box}) + k_{org}$$

$$j_{new} = -\text{Res } y/(2\text{Box}) + j_{org}$$

Interpolate between the bounding integer values around j_{new}, k_{new} in the prototype mesh to obtain the new mesh elements $M_x[j, k]$ and $M_y[j, k]$.
For the j, k outside of the range above, copy the prototype values :

$$j < j_{ul} ; j > j_{lr}$$

$$k < k_{ul} ; k > k_{lr}$$

$$M_x[j,k] = M_{protox}[j,k]$$

$$M_y[j,k] = M_{protoy}[j,k]$$

In the second stage, with the beginnings of the new mesh obtained by resampling the prototype, a linear scaling will produce the final desired mesh :
For all j,k do

$$u = 2\text{Box } (k - k_{org})/\text{Res}$$

$$v = 2\text{Box } (j_{org} - j)/\text{Res}$$

$$w = u + iv$$

$$M_x = \frac{\sqrt{(v^2 + z^2_{\ nom})}\,K_{nom}}{\sqrt{(v^2 + z_x^{\ 2})}\,K_x} \cdot M_x + \frac{v \cdot \tan\theta_{ortho}}{K\sqrt{(v^2 + z_x^{\ 2})}} + T_x(0,0)$$

$$M_y = \frac{\sqrt{(u^2 + z^2_{\ nom})}\,K_{nom}}{\sqrt{(u^2 + z_y^{\ 2})}\,K_y} \cdot M_y + T_y(0,0)$$

At this point the geometry alignment is completed. Focus and vignette remain.

The focus mesh control surface is a parabola 120 of Fig. 8. The minima of the parabola must be set at the correct value for the center of the image. This is an offset operation. The rate of curvature for the surface must be determined by one other point. Once the best focus for that point is obtained, the surface 122 is scaled (keeping the minima fixed) to intersect the point.

As an example of resampling, assume, that, for some reason, the center 134 of the film image did not correspond to the minima 132 of the focus surface, Fig. 9. This might occur if the optical axis of the camera (alignment fixture) was not the same as the beam axis of the CRT. To correct for this error, it is necessary to resample the focus surface such that the mesh origin at u', v' = [0,0] corresponds to the point on the surface where the film origin occurred. The mesh resampling should be performed on the portion of the mesh surface which contains the visible image.

The vignette correction is done in the same way as the focus correction in that an offset and a scaling operation are performed, this time using the vignette measurements to determine the magnitude of the adjustment.

The basic corrections to all of the mesh surfaces can be accomplished using these methods and variations of them. It is felt that the number of parameters required will be small, and that the measurements to obtain them few and easy to obtain.

Additional details of the mesh correction process follow. Centering, which provides the correction for the X and Y meshes, consists of adding the appropriate constant to all elements in the mesh in order to bring the origin of the mesh (u,v = [0,0]) to the center of the image.

Static centering refers to the code required in the mesh to position the (non-moving) beam at the center of the image. The prototype mesh assumed that the tube, yoke and deflection system was perfect and used

the number 0 for this centering value (no offset).

Dynamic centering refers to the effects of the mesh filters. It can be considered to be the time delay between when a value is fetched by the geometry engine and when its effect reaches the beam. The prototype uses the delay of the nominal filter. Any variance from this filter model may cause a shift in the actual delay and introduce centering error. Note that this is a horizontal effect only, since the vertical rate of change is well beyond the averaging effects of the filter. The addition of an appropriate constant to all values in the X mesh will correct for any dynamic centering errors.

The measurement of the static center includes using a target on the alignment mask at the origin of the film coordinates, the beam is positioned by means of horizontal and vertical search methods to the center. The X and Y deflection control words are noted and saved.

The dynamic centering process provides a horizontal line segment to locate the frame center while scanning the line at the normal imaging rate. This is done using a nearly completed mesh (the dynamic centering correction is the last to be applied). Moreover, it is also possible to measure the X deflection filter response directly, using one of the diagnostic A/D channels. The diagnostic A/D (not shown, connected to mesh adjusting microprocessor 77) is selectively connected to one of sixteen test points in the system, such as at the deflection yoke, the focus power supply and other CRT signal paths. Thus, by putting step or impulse function values into the deflection DAC's (56, 60, 64, 68) and measuring the resulting analog circuit response through a loop-back measurement system, the system performance is monitored. This would yield a value for the time delay which could be compared to the nominal delay. The difference is then converted to the additive constant for the mesh.

Scaling and pincushion correction are provided as follows. The prototype mesh has been computed for the nominal yoke position on the CRT. This involves use of the "beam radius", Z, which is the effective distance between the CRT face plate and the focal point of the deflection. The computation also includes a nominal value for the angular deflection gain, K, which specifies the sensitivity of the deflection angle to the mesh numeric values :

$$\text{Sin}\,\alpha = K \cdot M$$

where α is the deflection angle ; M is the mesh value.
In practice, each system will have different values for Z and K. There will also likely be different values for K in the horizontal and vertical directions. By measuring the true values for Z and K, it is possible to correct the mesh values for the new geometry.

As shown in Fig. 10, the deflection angle, α, required to produce a given deflection d, is determined by :

$$\tan(\alpha) = d/z$$

To keep the deflection constant when the CRT beam radius Z_{CRT} is different from the nominal radius Z_{nom}, a new angle (145, Fig. 10) must be computed :

$$\alpha_{new} = \text{atan}(d/Z_{CRT})$$

This correction must be done along both horizontal and vertical axes. The desired angles are :

$$\alpha_x = \arctan(x/\sqrt{(y^2 + z_{CRT}^2)})$$
$$\alpha_y = \arctan(y/\sqrt{(x^2 + z_{CRT}^2)})$$

The positions x and y are not the quantities available at each mesh coordinate. The original angles are known, however, through the deflection gain. So the desired x and y, can be obtained :

$$\alpha_{nomx} = K_{nom} \quad M_{proto\ x}$$

$$\alpha_{nomy} = K_{nom} \quad M_{proto\ y}$$

$$x = (y^2 + z^2_{nom}) \quad \tan\alpha_{nom\ x}$$

$$y = \sqrt{(x^2 + z^2_{nom})} \quad \tan\alpha_{nom\ y}$$

The new angles are therefore obtained from the prototype mesh values by :

$$\alpha_{new\ x} = \text{atan} \frac{\sqrt{(y^2 + z^2_{nom}} \quad \tan(K_{nom} \quad M_{proto\ x})}{\sqrt{(y^2 + z^2_{CRT})}}$$

$$\alpha_{new\ y} = \text{atan} \frac{\sqrt{(x^2 + z^2_{nom}} \quad \tan(K_{nom} \quad M_{proto\ y})}{\sqrt{(x^2 + z^2_{CRT})}}$$

This can be simplified if $Z_{CRT} \approx Z_{nom}$:

$$M_{new\ x} = \frac{\sqrt{(y^2 + z^2_{nom})} \quad K_{nom}}{\sqrt{(y^2 + z^2_{CRT})} \quad K_{CRT}} \quad M_{proto\ x}$$

$$M_{new\ y} = \frac{\sqrt{(x^2 + z^2_{nom})} \quad K_{nom}}{\sqrt{(x^2 + z^2_{CRT}} \quad K_{CRT}} \quad M_{proto\ y}$$

This is an easy computation. All that is needed are values for K_{CRT} and Z_{CRT} K_{nom} and Z_{nom} are known (they are parameters used in generating the prototype mesh).

To obtain the actual beam radius and deflection gains three measurements are required. As shown in Figs. 8 and 9, the location of the tube center 134, and two distinct deflections must be measured. The center point measurement was discussed above. Two other target locations on the alignment mask can be used to provide the known deflection distances d_1 and d_2 (known in film image coordinates). Using search techniques for positioning the static CRT spot, the required mesh values to position the spot over each target are obtained. From the deflection measurements, along with the center value M_1, M_2, and M_3, and according to the geometry of the problem :

$$Z_{CRT} = d_2 \tan KM_1 = d_1 \tan KM_2$$

To solve this for the deflection gain K, first write :

$$\frac{d_2 \tan KM_1}{d_1 \tan KM_2} = 1$$

To solve analytically, a simple numerical method can be employed. Let :

$$f(K) = 1 - \frac{d_2 \tan KM_1}{d_1 \tan KM_2}$$

Finding the value of K to make f(K) equal to zero, according to Newton's method, the derivative of f(K) is required :

$$f'(K) = \frac{-d_2 \left[\tan KM_2 \, M_1 \sec^2 KM_1 - \tan KM_1 \, M_2 \sec^2 KM_2\right]}{d_1 \tan^2 KM_2}$$

This technique converges very rapidly, and given a reasonable initial approximation for K(K_{nom} is a good choice), only a few iterations of the algorithm are required.
Once K_{CRT} is computed, Z_{CRT} is found by :

$$Z_{CRT} = d_2/\tan K_{CRT} \, M_2$$

Note that the distances and consequently Z_{CRT} (144, Fig. 10), are in image frame coordinates. Since Z_{CRT} and K_{CRT} are used in ratios with Z_{nom} (146, Fig. 10) and K_{nom}, the actual dimensions used are arbitrary, so long as they are consistent.

The beam radius and the deflection gain characterize the pincushion correction required to produce a rectilinear image. By making the measurements at the film plane in the alignment module, correction of the camera lens pincushion distortion occurs at the same time. The two sources of distortion (CRT and camera) combine at the film as an "effective" single distortion which can be corrected by an equivalent beam radius and deflection gain. This is what is actually computed by making the measurements and computations described above. This correction assumes that the magnification of the prototype mesh and the pincushion corrected mesh are the same. This entered into the correction equation by keeping the net deflection d, 142, the same (Fig. 10). If the tolerance on the camera position and/or lens focal lengths results in a change in magnification, the deflection distance must change in order to maintain a constant image size. This requires a correction which resamples the control surface in order to preserve the pincushion correction and at the same time create the desired image size. Since it is expected that the magnification errors will be small, it is suggested that they be corrected within the pincushion correction. The residual distortion should fall within the acceptance tolerances for pincushioning.

The yoke will have some amount of nonorthogonality between the x and y coils. This can be compensated for by the mesh. The recommended method for accomplishing this is to manually align the horizontal deflection when the yoke is assembled onto the tube. This is an operation which is provided by accurate manufacturing of the yoke. Any remaining errors will be removed at a later stage, discussed below. As shown in Fig. 12, the y axis can now be measured and its orthogonality to X computed. The "shear" 162 of the Y axis can be removed by adding the correct constant 168 to each row in the X mesh, Fig. 13. The number will be different for each row. A linear correction is easily accomplished which adds zero at the origin and gradually increases in magnitude for rows closer to the top or bottom of the frame.

Using targets (100, Fig. 3) at the center, right edge, and top edge 164 of the alignment frame, make position measurements M_c, M_r, M_t. Compute angles θ_x, and θ_y :

$$\theta_x = \text{atan}\frac{y_r - y_c}{x_r - x_c}$$

$$\theta_y = \text{atan}\frac{y_t - y_c}{x_t - x_c}$$

The orthogonality error angle 166 is the difference between the Y axis angle and the line which is perpendicular to the X axis :

$$\theta_{ortho} = \theta_y - (\theta_x + 90°)$$

The gradient of the Y axis error is represented by this angle. The absolute amplitude is obtained from some additional. geometry, shown in Fig. 13. The distance H at the film plane can be computed from :

$$H = (2/3)\tan\theta_{ortho}$$

This is the maximum horizontal shift to be made. It occurs at the top row of the mesh, and also at the bottom row, though opposite in direction. The mesh constant, $M_{ortho}(H)$, that must be added is the angle required to produce H. This will be :

$$K\,M_{ortho}(H) = \arctan(H/\sqrt{(y^2 + Z^2)})$$

$$K_{ortho}(H) = (1/K)\arctan(H/\sqrt{(y^2 + Z^2)})$$

where K is the deflection gain and Z is the beam radius as determined earlier.

Because the error angle is small, the arctangent function may be approximated by its argument ; and, since the correction will be a linear function of Y (and hence of the mesh coordinate V), the required constants to add to each row of the X mesh :

$$M_{ortho}(v) = \frac{H}{K\sqrt{(v^2 + Z^2)}}\,(2/3)\,v$$

$$= \frac{v\,\tan\theta_{ortho}}{K\sqrt{(v^2 + Z^2)}}$$

Now that the Y axis of the image is orthogonal to the X axis, it is necessary to align the U axis of the mesh (row direction) with the horizontal (x) axis on the film. This cannot be done by a linear operation. Instead, the mesh coordinates must be rotated, and the control surface 172 resampled at the new array index locations 174 shown in Fig. 14.

First, the amount of rotation required is measured. The data to determine this has already been obtained by previous alignment mask target measurements M_r and M_c. In fact, the rotation angle has already been computed as part of the orthogonality correction :

$$\theta_{rot} = \theta_x = \text{atan}\,\frac{y_r - y_c}{x_r - x_c}$$

In order to perform the resampling a new set of mesh index locations must be computed. These are obtained

from the old locations by the transformation :

$$u_{new} = u_{old} \cos \theta_{rot} - v_{old} \sin \theta_{rot}$$

$$v_{new} = u_{old} \sin \theta_{rot} + v_{old} \cos \theta_{rot}$$

In general, the new locations will be different from the old coordinates. To compute the new mesh value an interpolation of the mesh surface is done. As an example of this linear interpolation on a surface, say that u_{new} falls between old mesh coordinates u_n and u_{n+1}, shown in Fig. 15, and that v_{new} lies between v_m and v_{m+1}. First compute the mesh values where v_{new} intersects the vertical lines at u_n and u_{n+1}. They occur at (u_n, v_{new}). Then interpolate between these two numbers to obtain the value at u_{new} :

$$M(u_n,v_{new})=\frac{v_{new}-v_m}{v_{m+1}-v_m}(M(u_n,v_{m+1}) - M(u_n,v_m)) + M(u_n,v_m)$$

$$M(u_{n+1},v_{new})=\frac{v_{new}-v_m}{v_{m+1}-v_m}(M(u_{n+1},v_{m+1}) - M(u_{n+1},v_m)) + M(u_{n+1},v_m)$$

$$M(u_{new},v_{new})=\frac{u_{new}-u_n}{u_{n+1}-u_n}(M(u_{n+1},v_{new}) - M(u_n,v_{new})) + M(u_n,v_{new})$$

The computation of u_{new}, v_{new}, and its new mesh value must be done for every element in the viewable portion of the mesh.

To reduce the visual effects of any residual nonlinear second and third order effects distortions, a conformal mapping method is provided. The bilinear transform, in complex number theory, offers the opportunity to map three points in one (distorted) coordinate system to three corresponding points in the desired coordinate system. This type of correction is a resampling technique similar to the rotation correction just described. It involves the computation of new u, v numbers using a more complicated formula than the rotation correction however.

The three mapping points will be the upper left, the center, and the lower right ends of the image frame. Since this line spans both axes, it is expected that the distortion correction will be fairly uniformly distributed over the frame. In addition, the transformation will guarantee that these points fall exactly on the desired locations in the final image.

The procedure starts by obtaining measurements of the mapping points using targets on the alignment mask. Call these measurements M_{ul}, M_c, and M_{lr}. The alignment corrections and the pincushioning must be "undone" in order to convert these numbers to image frame coordinates. This can be accomplished in stages using information already obtained. The sequence is :

First, remove the centering correction. The centering correction to the prototype mesh consisted of adding the center measurement M_c. This means that to obtain a prototype mesh value from a measured value, the center must be substrated :

$$M_1 = M - M_c$$

Second, undo the pincushion correction. This was initially performed in the prototype mesh generation. It must now be reversed to get back to image frame coordinates. The reverse operation is :

$$M_2 = r(x,y) \sin(K M_1)$$

where K is the system's measured angular deflection gain, and r(x, y) is the distance from the beam focal point to the screen :

$$r(x, y) = \sqrt{(x^2 + y^2 + Z^2)}$$

Z is the system's measured beam radius.

Third, remove the orthogonality correction. Whereas $M_{ortho}(\theta_{ortho}, v)$ was added to each prototype mesh value (after pincushion correction), it must now be subtracted :

$$M_3 = M_2 - M_{ortho}(\theta_{ortho}, v)$$

Fourth, rotate the measurements back to their unaligned positions :

$$M_4 = R_{rot}(-\theta_{rot})M_3$$

R_{rot} is the rotation transformation (in vector notation) operating on the measurement vector M_2. The individual equations were described previously.

M_4 represents the measurement in image frame coordinates. If there were no distortion remaining after the mesh corrections described, the measured coordinates would match the desired image coordinates. In general, only M_{4c} will be exactly correct (it is guaranteed to be zero). The technically "proper" thing to do with the measurements would be to perform the bilinear transform on the desired image frame coordinates and "predistort" them. This misshapened set of coordinates are then used as the starting points in the mesh generation procedure and a new prototype mesh created. This is followed by all of the alignment corrections previously determined and the best mesh producible by this method would result.

Since generating a new prototype mesh from image coordinates is a lengthy and compute intensive task, this is not a practical solution. Instead, it will be assumed that the distortion corrections are small, and that by predistorting the mesh coordinates and resampling the mesh surface, an approximation to the true solution will result. The transformation to the mesh coordinates is specified by the M_4 measurements. What is desired is for the corners and center of the mesh to map into the M_4 locations. Referring to the u, v coordinates of the prototype mesh as w, and the x, y coordinates of the resampled mesh as z, the transformation requires :

$$w_{ul} \rightarrow z_{ul} = M_{4ul}$$

$$w_c \rightarrow z_c = M_{4c}$$

$$w_{lr} \rightarrow z_{lr} = M_{4lr}$$

Since $w_c = z_c = 0$, the transformation simplifies to :

$$z = \frac{M_{ul}m_{lr} \quad (w_{lr} - w_{ul}) \quad w}{(M_{lr}-M_{ul}) \quad w_{ul}w_{lr}+(w_{lr}M_{ul}-w_{ul}M_{lr}) \quad w}$$

The way this formula is used is to substitute the corner values of the mesh indices :

$$w_{ul} = [-1, 2/3]$$

$$w_{lr} = [1, -2/3]$$

and the values for the measured corners :

$$M_{ul} = M_{4ul}$$

$$M_{lr} = M_{4lr}$$

The formula is in the complex number domain and represents a vector operation. It can be written as :

$$z = \frac{A \cdot w}{B + C \cdot w}$$

where A, B, and C are complex numbers obtained from :

$$A = M_{ul}M_{lr}(w_{lr} - w_{ul})$$

$$B = (M_{lr} - M_{ul})\, w_{ul} w_{lr}$$

$$C = w_{lr} M_{ul} - w_{ul} M_{lr}$$

The present invention also provides film images which are predistorted. The predistortion is provided by defining an image boundary which complements and corrects for the distortion and adjusting the mesh accordingly. For instance, a Keystone distortion would require adjusting and mest to form an inverted Keystone ; projection on a sphere would require the mesh to be adjusted to provide severe pincushion predistortion, and so forth.

The image parameters, such as image size and position are also altered according to the various formats of the films to be used. The present invention automatically accommodates a variety of film formats in a common enclosure 200 which is adapted to the particular film formats, such as 16 mm, 35 mm and 46 mm films with removable and interchangeable mechanical supports within the enclosure 200, Fig. 16. However, since the film aperture plates 202 define the image 204 size and position on the film 206, the particular film aperture plates 202A-D, Fig. 16A, used signal the mesh adjusting microprocessor 77 to adjust the image position and size parameters to the CRT 82. The aperture plates 202 (202 B-D, Fig. 16 B-D) are encoded with recesses 210, 212 which are read by switches 214, 216 and linkage pins 218, 220, respectively. Thus, for one of four apertures, two aperture positions provide sufficient encoding (2^2) to indicate a unique film aperture to the mesh adjusting microprocessor 77, which provides the corresponding CRT image adjustment. Other aperture encoding methods, such as electrical or optical are also envisioned, and the encoded signal may be adjusted to accommodate a larger variety of aperture plates or other interchangeable enclosure 200 components.

Another feature of the present invention, called Pixel Replication, is designed to eliminate the problem encountered by film recorders which support more than one resolution CRT image. When changing from a higher resolution to a lower resolution CRT image, one encounters the problem of trying to keep the film exposure constant so that the film density and color balance will remain the same. Other film recorders do this by either increasing the exposure time per pixel at the lower resolution or by increasing the CRT beam current. Both of these techniques introduce errors because the corrections are nonlinear and therefore require correction via compensation tables that must be changed for each resolution. The apparatus according to the present invention solves this problem by, in effect, always running at the higher resolution. When a reduced resolution picture is exposed (at either one half or one quarter of the highest resolution), the present invention automatically draws each pixel four or sixteen times as necessary (i.e., doubles or quadruples the pixel in both the X and Y direction). This is performed by the mesh adjusting processor 77 from image data in the scan memory 74, by repeating the appropriate memory 74 address. Thus, the nonlinear image problems are avoided and the film exposure remains constant.

Moreover, while other film recorders modify the film exposure by controlling either the duration of each pixel (time modulation) or the brightness of each pixel (intensity modulation), the present invention uses a combination of both. Depending on the horizontal sweep speed, each pixel is divided into between 6 and 256 time slices. In each pixel, the present invention can set any number of the time slices to a full intensity setting, and one slice may be set to any of 4096 settings. This process gives a finer control of film exposure than the traditional techniques, and representative values of time and intensity are shown in Table 1, below. The table variables are defined as follows :

Count	– number of time units (62.5 nsec each) of full amplitude video signal in a pixel.
Partial	– Expressed as a value from 0 to 1 (non inclusive). It represents the fraction of full amplitude video signal used for 1 time unit following the count full amplitude time units.
Slices	– Number of time units in each pixel. Slices ≧ count + 1 after drawing count + 1 time units, the remaining portion of a pixel (Slices-Count – 1) is drawn at zero amplitude.
Contrast	– A voltage level selected to produce a bright white as determined by film sensitivity ; other parameters then adjusted for gray scale. In the following tables, slices = 16

Count	Partial	Light output for 256 pixels Contrast=5.09	Contrast=3.35	Contrast=3.30
0	0	16	2	1
3	0	192	20	12
4	0	560	56	32
-	-	1120	108	61
6	0	1776	186	103
7	0	2512	278	154
8	0	3376	384	215
8	1/2	3712	430	241
9	0	4208	502	279
9	1/2	4576	550	307
10	0	5104	628	350
10	1/2	5488	680	380
11	0	6016	760	426
11	1/2	6416	820	459
12	0	6992	912	511
12	1/2	7456	980	550
13	0	8048	1082	609
13	1/2	8608	1166	656
14	0	9280	1276	720
14	1/2	9952	1386	782
14	3/4	10368	1452	821
15	0	10768	1512	853
15	1/4	11264	1604	905
15	1/2	11856	1732	979
15	3/4	12480	1868	1061
15	4095	12944	1982	1130
	4096			

Other embodiments and modifications of the present invention by one skilled in the art, such as alignment of a laser, rather than a CRT based image system, are within the scope of the present invention, which is not to be limited, except by the claims which follows :

* C L M S *

Claims

1. An image recorder providing a photographic copy of a Crt image at an image plane (84) onto a photographic film plane (88) comprising :
lens means (86) for transforming light from the image plane (84) to the photographic film plane (88) ;
an alignment mask (90) having a target image thereon interposed in the optical path between the image plane (84) and the photographic film plane (88) ;
means to operate the CRT (82) according to at least one of a deflection signal and an intensity signal ;
photodetector means (94) positioned to receive the target image selectively illuminated by the CRT (82) and producing a target signal therefrom ;
characterized in that the CRT is scanned to illuminate the alignment mask and means are provided for storing data for adjusting at least one of said deflection signal and said intensity signal in response to the target signal, thereby at least partially to correct one of intensity, focus, image position, rotation, orthogonality, pincushion and size in a subsequent image-carrying operation of the CRT.

2. An image recorder according to claim I wherein the alignment mask (90) is located at the image plane (84).

3. An image recorder according to claim I wherein the alignment mask (90) is located at the photographic film plane (88).

4. An image recorder according to claim 3 wherein the photographic film is contained within a first removable module and the alignment mask is contained within a second removable module wherein the first and second removable modules are selectively interchangeable.

5. An image recorder according to claim 3 or claim 4 wherein the photographic film is displaced from the film plane (88) and the alignment mask (90) is substituted in the place of the film during adjustment by the means for adjusting.

6. An image recorder according to any one of the preceding claims wherein the optical path includes a mirror (97).

7. An image recorder according to any one of the preceding claims wherein the alignment mask (90) has one of an opaque, a transparent and a reflective target image thereon.

8. An image recorder according to any one of the preceding claims further including focus adjustment means responsive to said target signal to provide a focused image on said photographic film.

9. The image recorder according to claim 8 wherein said focus adjustment means comprises means for adjusting the focus of said CRT image.

10. The image recorder according to claim 9 wherein the alignment mask (90) comprises a clear plate with at least one opaque target thereon and said CRT image comprises a spot ; said target signal corresponds to the intensity of the CRT image ; and said means for adjusting the focus of said CRT provides a minimum target signal.

11. An image recorder according to claim 10 wherein
said alignment mask (90) includes a plurality of said opaque targets distributed over the CRT image plane (84) ;
said means for adjusting provides the corrections at the targets ; and further includes
interpolation means for providing said corrections adjacent to said targets.

12. An image recorder according to any one of the preceding claims wherein the alignment mask (90) comprises a clear plate with at least one opaque target thereon and said means for adjusting includes :
means for detecting an edge of the opaque target ; and
means for determining the position of said CRT image according to the detected edge of said target.

13. An image recorder according to any one of the preceding claims wherein
said means for selectively illuminating the alignment mask (90) includes means to provide a movable illuminated focused spot, and wherein said means for adjusting further includes
means for determining the intensity profile of said spot ; and
means for adjusting the focus of said spot according to said intensity profile.

14. An image recorder according to any one of the preceding claims wherein said means for adjusting includes a prototype mesh for providing preliminary correction.

15. An image recorder according to claim 14 wherein said means for adjusting further includes a mesh correction processor (77) responsive to said prototype mesh and said sampled target signal, and providing a corrected mesh signal.

16. An image recorder according to claim 15, wherein said means for adjusting further includes a random access memory (54) for storing said corrected mesh signal.

17. An image recorder according to any one of the preceding claims wherein said means for adjusting

includes at least one of :

means for sampling the target signal ;

multiplication means (71) for providing scaling correction to at least one image characteristics including image position, rotation, orthogonality, pincushion, size and vignette according to the sampled target signal ; and

addition means for providing anoffset correction to at least one image characteristic including image position, rotation, orthogonality, pincushion, size and vignette according to the sampled target signal.

18. An image recorder according to any one of the preceding claims wherein said means for adjusting further includes a geometry engine (52) providing control signals to the CRT (82) including at least one of deflection, focus and vignette signals.

19. An image recorder according to any one of the preceding claims further including a film holder (200) comprising

an aperture plate (202) having an aperture therein corresponding to a selected film format ;

means (210, 212 ; 214, 216) for providing an encoded signal corresponding to the selected format ;

wherein means are provided for adjusting the CRT image size and/or position according to the encoded signal.

20. An image recorder according to claim 19 wherein the means for providing the encoded signal comprises recesses (210, 212) in the aperture plate (202), and switches (214, 216) operative according to the presence of the recesses (210, 212).

21. An image recorder according to any one of the preceding claims wherein the CRT image may be provided at a plurality of resolutions by means of a corresponding plurality of pixel arrays each with a respective pixel density, and wherein means are provided for replicating a pixel array with a lower pixel density into a pixel array of higher pixel density, thereby to permit colour matching on the film.

22. An image recorder according to claim 21 wherein the replicating means provides an even multiple of each pixel in the pixel array of lower pixel density into the pixel array of higher pixel density.

23. A method of alignment of an image recorder having a CRT (82) and photographic film disposed on a film plane (88), comprising the steps of :

providing an alignment mask (90) having a target image thereon ;

generating a deflection or intensity signal ;

scanning said alignment mask (90) with a point light source from the CRT, wherein the target image partially obscures said selective illumination to generate an image ;

detecting the image generated by the selective illumination of the alignment mask (90) ;

characterised by calculating the intensity profile of the generated image ;

storing data for adjusting a display parameter of the point light source according to the intensity profile : and

subsequently, operating the CRT carrying an image to be recorded in accordance with the adjustment data stored.

24. A method according to claim 23, further including the steps of :

calculating the position of the point light source ;

comparing the calculated position of the point light source to a specified position and providing an error signal therefrom ; and

adjusting said expected position signal according to said error signal to provide correction for at least one of image position, image rotation, coordinate non-orthogonality, pincushion distortion and size distortion.

25. A method according to claim 24, wherein said step of adjusting said expected position signal includes the step of generating a prototype position.

26. A method according to claim 23 comprising the steps of :

providing a prototype mesh having preliminary display parameters therein ;

correcting said prototype mesh as a result of the scanning ;

storing corrected mesh parameters ;

generating display parameters ;

correcting the display parameters by said corrected mesh parameters.

Ansprüche

1. Bildaufzeichnungsgerät zum Herstellen einer fotografischen Kopie des Bildes einer Katodenstrahlröhre in einer Bildebene (84) auf eine Ebene (88) eines fotografischen Filmes, enthaltend :

ein Objektiv (86) zum Umsetzen von Licht von der Bildebene (84) auf die Ebene (88) des fotografischen

Filmes ;
eine Ausrichtmaske (90) mit einem Zielbild darauf, die in dem optischen Weg zwischen der Bildebene (84) und der Ebene (88) des fotografischen Filmes angeordnet ist ;
eine Einrichtung zum Betreiben der Katodenstrahlröhre (82) entsprechend mindestens einem von einem Ablenksignal und einem Intensitätssignal ;
eine Fotodetektoreinrichtung (94), die angeordnet ist
zur Aufnahme des von der Katodenstrahlröhre (82) selektiv erhellten Zielbildes und zum Erzeugen eines Zielsignals davon ;
dadurch gekennzeichnet, daß die Katodenstrahlröhre abgetastet wird, um die Ausrichtmaske zu erhellen, und daß eine Einrichtung vorgesehen ist zum Speichern von Daten zum Einstellen von mindestens einem von dem Ablenksignal und dem Intensitätssignal in Ansprache auf das Zielsignal, um dadurch mindestens teilweise eines von Intensität, Fokus, Bildposition, Drehung, Rechtwinkligkeit, Kissenverzeichnung und Größe bei einem darauf folgenden bildübertragenden Betrieb der Katodenstrahlröhre zu korrigieren.

2. Bildaufzeichnungsgerät nach Anspruch 1, bei dem die Ausrichtmaske (90) in der Bildebene (84) angeordnet ist.

3. Bildaufzeichnungsgerät nach Anspruch 1, bei dem die Ausrichtmaske (90) in der Ebene (88) des fotografischen Filmes angeordnet ist.

4. Bildaufzeichnungsgerät nach Anspruch 3, bei dem der fotografische Film in einem ersten entfernbaren Modul enthalten ist und die Ausrichtmaske in einem zweiten entfernbaren Modul enthalten ist, wobei das erste und zweite entfernbare Modul wahlweise gegeneinander auswechselbar sind.

5. Bildaufzeichnungsgerät nach Anspruch 3 oder 4, bei dem während der Einstellung durch die Einstelleinrichtung der fotografische Film von der Filmebene (88) entfernt und die Ausrichtmaske (90) an der Stelle des Filmes eingesetzt wird.

6. Bildaufzeichnungsgerät nach einem der vorhergehenden Ansprüche, bei dem der optische Weg einen Spiegel (97) enthält.

7. Bildaufzeichnungsgerät nach einem der vorhergehenden Ansprüche, bei dem die Ausrichtmaske (90) ein undurchsichtiges, ein durchsichtiges oder ein reflektierendes Zielbild darauf aufweist.

8. Bildaufzeichnungsgerät nach einem der vorhergehenden Ansprüche, das weiterhin eine auf das Zielsignal ansprechende Fokuseinstelleinrichtung enthält zum Erzeugen eines fokusierten Bildes auf dem fotografischen Film.

9. Bildaufzeichnungsgerät nach Anspruch 8, bei dem die Fokuseinstelleinrichtung eine Einrichtung zum Einstellen des Fokus des Katodenstrahlröhrenbildes aufweist.

10. Bildaufzeichnungsgerät nach Anspruch 9, bei dem
die Ausrichtmaske (90) eine durchsichtige Platte mit mindestens einem undurchsichtigen Ziel darauf enthält und das Katodenstrahlröhrenbild einen Punkt aufweist ;
das Zielsignal der Intensität des Katodenstrahlröhrenbildes entspricht ; und
die Einrichtung zum Einstellen des Fokus der Katodenstrahlröhre ein Minimum Zielsignal erzeugt.

11. Bildaufzeichnungsgerät nach Anspruch 10, bei dem
die Ausrichtmaske (90) ein Anzahl von über die Bildebene (84) der Katodenstrahlröhre verteilte undurchsichtige Ziele enthält ;
die Einstelleinrichtung die Korrekturen in den Zielen bewirkt ; und weiterhin
eine Interpolationseinrichtung zum Bewirken der Korrekturen in der Nachbarschaft der Ziele enthält.

12. Bildaufzeichnungsgerät nach einem der vorhergehenden Ansprüche, bei dem die Ausrichtmaske (90) eine durchsichtige Platte mit mindestens einem undurchlässigen Ziel darauf aufweist und die Einstelleinrichtung enthält :
eine Einrichtung zum Erfassen einer Kante des undurchsichtigen Ziels ; und
eine Einrichtung zum Bestimmen der Lage des Katodenstrahlröhrenbildes entsprechend der erfaßten Kante des Ziels.

13. Bildaufzeichnungsgerät nach einem der vorhergehenden Ansprüche, bei dem
die Einrichtung zum selektiven Erhellen der Ausrichtmaske (90) eine Einrichtung zum Erzeugen eines beweglichen erhellten fokussierten Punktes enthält und bei dem die Einstelleinrichtung weiterhin enthält
eine Einrichtung zum Bestimmen des Intensitätsprofils des Punktes ; und
eine Einrichtung zum Einstellen des Fokus des Punktes entsprechend dem Intensitätsprofil.

14. Bildaufzeichnungsgerät nach einem der vorhergehenden Ansprüche, bei dem die Einstelleinrichtung ein Mustergitter zum Erzeugen einer vorläufigen Korrektur enthält.

15. Bildaufzeichnungsgerät nach Anspruch 14, bei dem die Einstelleinrichtung weiterhin einen Gitterkorrekturprozessor (77) enthält, der auf das Mustergitter und das abgetastete Zielsignal anspricht und ein korrigiertes Gittersignal erzeugt.

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16. Bildaufzeichnungsgerät nach Anspruch 15, bei dem die Einstelleinrichtung weiterhin einen speicher (54) mit wahlfreiem Zugriff zum Speichern des korrigierten Gittersignals enthält.

17. Bildaufzeichnungsgerät nach einem bei vorhergehenden Ansprüche, bei dem die Einstelleinrichtung mindestens eine der folgenden Einrichtungen enthält :

eine Einrichtung zum Abtasten des Zielsignals ;

eine Multiplikationseinrichtung (71) zum Erzeugen einer Skalierungskorrektur für mindestens eine Bildeigenschaft, enthaltend Bildlage, Drehung, Rechtwinkligkeit, Kissenverzeichnung, Größe und Vignettierung entsprechend dem abgetasteten Zielsignal ; und

eine Additionseinrichtung zum Erzeugen einer Nullpunktkorrektur für mindestens eine Bildeigenschaft, enthaltend Bildlage, Drehung, Rechtwinkligkeit, Kissenverzeichnung, Größe und Vignettierung entsprechend dem abgetasteten Zielsignal.

18. Bildaufzeichnungsgerät nach einem der vorhergehenden Ansprüche, bei dem die Einstelleinrichtung weiter einen Geometrieerzeuger (52) enthält, der an die Katodenstrahlröhre (82) mindestens eines der Ablenk-, Fokus- und Vignettierungssignale enthaltende Steuersignale liefert.

19. Bildaufzeichnungsgerät nach einem der vorhergehenden Ansprüche weiterhin enthaltend einen Filmhalter (200) mit

eine Öffnungsplatte (202), die eine einem ausgewählten Filmformat entsprechende Öffnung darin aufweist;

eine Einrichtung (210, 212, 214, 216) zum Erzeugen eines dem ausgewählten Format entsprechenden kodierten Signals ;

wobei eine Einrichtung vorgesehen ist zum Einstellen der Größe und/oder Lage des Katodenstrahlröhrenbildes entsprechend dem kodierten Signal.

20. Bildaufzeichnungsgerät nach Anspruch 19, bei dem die Einrichtung zum Erzeugen des kodierten Signals Ausnehmungen (210, 212) in der Öffnungsplatte (202) und entsprechend dem Vorhandensein der Ausnehmungen (210, 212) wirksame Schalter (214, 216) aufweist.

21. Bildaufzeichnungsgerät nach einem der vorhergehenden Ansprüche, bei dem das Katodenstrahlröhrenbild bei einer Vielzahl von Auflösungen mittels einer entsprechenden Vielzahl von Bildpunktfeldern mit jeweils einer entsprechenden Bildpunktdichte erzeugt werden kann und wobei eine Einrichtung vorgesehen ist zum Wiedergeben eines Bildpunktfeldes mit einer niedrigeren Bildpunktdichte als Bildpunktfeld einer höheren Bildpunktdichte, so daß eine Farbanpassung an den Film ermöglicht wird.

22. Bildaufzeichnungsgerät nach Anspruch 21, bei dem die Wiedergabeeinrichtung ein geradzahliges Vielfaches jeden Bildpunkts in der Bildpunktanordnung niedrigerer Bildelementdichte in die Bildpunktanordnung höherer Bildelementdichte liefert.

23. Verfahren zum Ausrichten eines Bildaufzeichnungsgerätes mit einer Katodenstrahlröhre (82) und einem auf einer Filmebene (88) angeordneten fotografischen Film, enthaltend die Verfahrensschritte :

Vorsehen einer Ausrichtmaske (90) mit einem Zielbild darauf ; Erzeugen eines Ablenk- oder Intensitätssignals ;

Abtasten der Ausrichtmaske (90) mit einer Punktlichtquelle von der Katodenstrahlröhre, wobei das Zielbild teilweise die selektive Erhellung zum Erzeugen eines Bildes verdunkelt ;

Erfassen des durch die selektive Erhellung der Ausrichtmaske (90) erzeugten Bildes ;

gekennzeichnet durch

Berechnen des Intensitätsprofiles des erzeugten Bildes ;

Speichern von Daten zum Einstellen eines Anzeigeparameters der Punktlichtquelle entsprechend dem Intensitätsprofil ; und

daraufhin Betreiben der ein aufzuzeichnendes Bild übertragenden Katodenstrahlröhre entsprechend den gespeicherten Einstelldaten.

24. Verfahren nach Anspruch 23, weiterhin enthaltend die Verfahrensschritte :

Berechnen der Lage der Punktlichtquelle ;

Vergleichen der berechneten Lage der Punktlichtquelle mit einer spezifizierten Lage und Erzeugen eines Fehlersignals daraus ; und

Einstellen des erwarteten Lagesignals entsprechend dem Fehlersignal zum Bewirken der Korrektur für mindestens eines von Bildlage, Bilddrehung, Koordinatennichtrechtwinkligkeit, Kissenverzerrung und Größenverzerrung.

25. Verfahren nach Anspruch 24, bei dem der Schritt des Einstellens des erwarteten Lagesignals den Schritt des Erzeugens einer Musterlage enthält.

26. Verfahren nach Anspruch 23, enthaltend die Verfahrensschritte :

Erzeugen eines Mustergitters mit vorläufigen Anzeigeparametern darin ;

Korrigieren des Mustergitters als Ergebnis des Abtastens ;

Speichern korrigierter Gitterparameter ;

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Erzeugen von Anzeigeparametern ;
Korrigieren der Anzeigeparameter durch die korrigierten Gitterparameter.

Revendications

1. Enregistreur d'images formant une copie photographique d'une image d'un tube à rayons cathodiques à un plan d'image (84) vers un plan d'un film photographique (88), comprenant :
un moyen formant lentille (86) pour transformer la lumière du plan d'image (84) au plan du film photographique (88) ;
un masque d'alignement (90) ayant une image cible, interposé dans le trajet optique entre le plan d'image (84)et le plan du film photographique (88) ;
un moyen pour faire fonctionner le tube à rayons cathodiques (82) selon au moins l'un d'un signal de déviation et d'un signal d'intensité ;
un moyen photodétecteur (94) placé pour recevoir l'image cible sélectivement éclairée par le tube à rayons cathodiques (82) et en produisant un signal cible ;
caractérisé en ce que le tube à rayons cathodiques est exploré pour éclairer le masque d'alignement et des moyens sont prévus pour stocker des données pour ajuster au moins l'un dudit signal de déviation et dudit signal d'intensité en réponse au signal cible, pour au moins ainsi partiellement corriger l'une de l'intensité, de la focalisation, de la position de l'image, de la rotation, de l'orthogonalité, de la distorsion en coussinet et de la taille dans une opération subséquente de support de l'image du tube à rayons cathodiques.

2. Enregistreur d'images selon la revendication 1 où le masque d'alignement (90) est placé au plan de l'image (84).

3. Enregistreur d'images selon la revendication 1 où le masque d'alignement (90) est placé au plan du film photographique (88).

4. Enregistreur d'images selon la revendication 3 où le film photographique est contenu dans un premier module amovible et le masque d'alignement est contenu dans un second module amovible où les premier et second modules amovibles sont sélectivement interchangeables.

5. Enregistreur d'images selon la revendication 3 ou la revendication 4 où le film photographique est déplacé du plan du film (88) et le masque d'alignement (90) est mis à la place du film pendant l'ajustement par le moyen d'ajustement.

6. Enregistreur d'images selon l'une quelconque des revendications précédentes où le trajet optique contient un miroir (97).

7. Enregistreur d'images selon l'une quelconque des revendications précédentes où le masque d'alignement (90) a l'une parmi une image cible opaque, transparente et réfléchissante.

8. Enregistreur d'images selon l'une quelconque des revendications précédentes comprenant de plus un moyen d'ajustement de la focalisation répondant audit signal cible pour produire une image focalisée sur ledit film photographique.

9. Enregistreur d'images selon la revendication 8 où ledit moyen d'ajustement de focalisation comprend un moyen pour ajuster la focalisation de ladite image du tube à rayons cathodiques.

10. Enregistreur d'images selon la revendication 9 où le masque d'alignement (90) comprend une plaque transparente portant au moins une cible opaque et l'image du tube à rayons cathodiques comprend un spot ; ledit signal cible correspond à l'intensité de l'image du tube à rayons cathodiques ; et ledit moyen pour ajuster la focalisation dudit tube à rayons cathodiques produit un signal cible minimum.

11. Enregistreur d'images selon la revendication 10 où
ledit masque d'alignement (90) comprend un certain nombre de cibles opaques qui sont distribuées sur le plan d'image (84) du tube à rayons cathodiques ;
ledit moyen pour ajuster produit les corrections sur les cibles ; et comprend de plus
un moyen d'interpolation pour produire lesdites corrections adjacentes auxdites cibles.

12. Enregistreur d'images selon l'une quelconque des revendications précédentes où le masque d'alignement (90) comprend une plaque transparente avec au moins une cible opaque et ledit moyen d'ajustement comprend :
un moyen pour détecter un bord de la cible opaque ; et
un moyen pour déterminer la position de ladite image du tube à rayons cathodiques selon le bord détecté de ladite cible

13. Enregistreur d'images selon l'une quelconque des revendications précédentes où
ledit moyen pour éclairer sélectivement le masque d'alignement (90) comprend un moyen pour former un spot focalisé éclairé mobile, et en ce que ledit moyen pour ajuster comprend de plus

un moyen pour déterminer le profil de l'intensité dudit spot ; et
un moyen pour ajuster la focalisation dudit spot selon ledit profil d'intensité.

14. Enregistreur d'images selon l'une quelconque des revendications précédentes où ledit moyen pour ajuster comprend une maille prototype pour produire une correction préliminaire.

15. Enregistreur d'images selon la revendication 4 où ledit moyen pour ajuster contient de plus un processeur de correction en maille (77) répondant à ladite maille prototype et audit signal cible échantillonné et produisant un signal en maille corrigé.

16. Enregistreur d'images selon la revendication 15 où ledit moyen pour ajuster comprend de plus une mémoire à accès aléatoire (54) pour stocker ledit signal en maille corrigé.

17. Enregistreur d'images selon l'une quelconque des revendications précédentes où ledit moyen pour ajuster comprend au moins l'un de :
un moyen pour échantillonner le signal cible ;
un moyen de multiplication (71) pour produire une correction de pondération d'au moins l'une des caractéristiques d'image comprenant la position de l'image, sa rotation, son orthogonalité, sa distorsion en coussinet, sa taille et sa vignette selon le signal cible échantillonné ; et
un moyen d'addition pour produire une correction décalée d'au moins une caractéristique d'image comprenant sa position, sa rotation, son orthogonalité, sa distorsion en coussinet, sa taille et sa vignette selon le signal cible échantillonné.

18. Enregistreur d'images selon l'une quelconque des revendications précédentes où ledit moyen pour ajuster comprend de plus un moteur à géométrie (52) appliquant des signaux de commande au tube à rayons cathodiques (82) comprenant au moins l'un des signaux de déviation, de focalisation et de vignette.

19. Enregistreur d'images selon l'une quelconque des revendications précédentes comprenant de plus un support de film (200) comprenant :
une plaque à ouverture (202) ayant une ouverture correspondant à un format de film sélectionné :
un moyen (210, 212 ; 214, 216) pour produire un signal codé correspondant au format sélectionné ;
où des moyens sont prévus pour ajuster la taille de l'image du tube à rayons cathodiques et/ou sa position selon le signal codé.

20. Enregistreur d'images selon la revendication 19 où le moyen pour produire le signal codé comprend des évidements (210, 212) dans la plaque à ouverture (202) et des commutateurs (214, 216) fonctionnant selon la présence desdits évidements (210, 212).

21. Enregistreur d'images selon l'une quelconque des revendications précédentes où l'image du tube à rayons cathodiques peut être prévue en un certain nombre de résolutions au moyen d'une pluralité correspondante de séries d'éléments d'image, chacune ayant une densité respective d'éléments d'image, et en ce que des moyens sont prévus pour reproduire une série d'éléments d'image avec une moindre densité des éléments d'image en une série d'éléments d'image de plus haute densité d'éléments d'image pour ainsi permettre l'adaptation des couleurs sur le film.

22. Enregistreur d'images selon la revendication 21 où le moyen de reproduction produit un multiple pair de chaque élément d'image dans la série d'éléments d'image de plus faible densité d'éléments d'image vers la série d'éléments d'image de plus forte densité d'éléments d'image.

23. Procédé d'alignement d'un enregistreur d'images ayant un tube à rayons cathodiques (82) et un film photographique disposé sur un plan du film (88),comprenant les étapes de :
prévoir un masque d'alignement (90) portant une image cible ;
produire un signal de déviation ou d'intensité ;
explorer ledit masque d'alignement (90) au moyen d'une source de lumière ponctuelle du tube à rayons cathodiques, où l'image cible obscurcit partiellement ledit éclairement sélectif pour produire une image ;
détecter l'image produite par l'éclairement sélectif du masque d'alignement (90) ;
caractérisé en ce qu'on calcule le profil d'intensité de l'image produite ;
on stocke la donnée pour ajuster un paramètre de visualisation de la source de lumière ponctuelle selon le profil d'intensité ; et
on fait subséquemment fonctionner le tube à rayons cathodiques portant une image à enregistrer selon les données d'ajustement stockées

24. Procédé selon la revendication 23, comprenant de plus les étapes de :
calculer la position de la source de lumière ponctuelle ;
comparer la position calculée de la source de lumière ponctuelle à une position spécifiée et en produire un signal d'erreur ; et
ajuster ledit signal attendu de position selon ledit signal d'erreur pour produire une correction pour au moins une position de l'image, une rotation de l'image, une non orthogonalité des coordonnées, une distorsion en coussinet et une distorsion de taille.

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25. Procédé selon la revendication 24, où ladite étape d'ajuster le signal attendu de position comprend l'étape de produire une position prototype.

26. Procédé selon la revendication 23 comprenant les étapes de :

produire une maille prototype contenant des paramètres préliminaires de visualisation ;

corriger ladite maille prototype par suite de l'exploration ;

stocker les paramètres corrigés de la maille ;

produire des paramètres de visualisation ;

corriger les paramètres de visualisation par lesdits paramètres corrigés de la maille.