Title: LIQUID CRYSTAL PROJECTOR HAVING INCREASED COLOR ACCURACY

Abstract: A method of color correcting a display is provided. Initially, uncorrected color values are used to produce images whose color characteristics are measured, specifically including luminance. Then, corrected color values are calculated such that the luminance of the corrected color values are the same as that produced by the uncorrected color values. The corrected color values are then used to produce images whose color characteristics are measured. A determination is made as to whether the corrected color values produce images having acceptable luminance and color characteristics, where acceptable luminance is based on the luminance obtained using the uncorrected color values. If not, a new set of corrected color values are produced. The process repeats until acceptable/desirable color characteristics are achieved. The method is useful for obtaining look-up table values, and for single-panel LCDs that use look-up tables. An interpolation technique for sparsely filled look-up tables is also provided.
as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations

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LIQUID CRYSTAL PROJECTOR HAVING INCREASED COLOR ACCURACY

This invention relates to improving the color accuracy of liquid crystal projectors.

Color imaging systems are widely used to provide viewers with information. For example, color printers and color copiers produce hardcopy color images, while televisions and computers produce images on a display, often a cathode ray tube (CRT). While CRTs have been successfully used for many years, desires for both low power, lightweight displays, such as for portable computers, and for large-area displays, such as for large screen televisions, have spurred the development of numerous alternatives, specifically including LCD projectors.

Color imaging systems that accurately and consistently produce high quality color images are in high demand. Unfortunately, producing an accurate color image consistently is difficult. Some problems that limit color accuracy include light sources that emit only a limited amount of light, the color spectrum (peaky or smooth) produced by light sources, properties of optical elements such as prisms, polarizers, filters, and lenses that distort and attenuate the color image, and electronic subsystems that have a limited ability to process the infinite range of possible colors.

Color accuracy issues have been addressed in various ways. With color printers and color copiers, color patches have been printed and scanned, and the scan results have been used to produce look-up tables that compensate for color errors. For example, US Patent 5,649,072, issued to Balasubramanian on July 15, 1997, entitled, “Iterative Technique for Refining Color Correction Look-Up Tables” discloses an iterative technique of converting colorimetric RGB (RED-GREEN-BLUE) values into device RGB values. US Patent 5,649,072 teaches converting input RGB values to printer CMYK (CYAN-MAGENTA-YELLOW-BLACK) values using a look-up table. The look-up table stores values determined by inputting a set (of about 1000) of RGB values to the printer, which then prints a corresponding set of color patches. A measurement device then measures each color patch in device RGB values. To produce the look-up table values, a transformation processor calculates transformation vectors that represent interpolated transformation differences between the input set of RGB values and the device RGB values. The transformation vectors are used to produce a first set of look-up table RGB values. Then, to verify the table accuracy, the original input set of RGB values are applied
to the look-up table, and the corresponding table outputs are compared to the measured results. Then, residual errors between how the look-up table maps the original input set to the measured results and the measured results themselves are determined and used to “correct” the look-up table values, which are again tested using the original input set and the measured result. This process repeats until the residual errors are within acceptable limits.

While the color correction technique disclosed in US Patent 5,649,072 may be beneficial in color printers and color copiers, that technique inherently depends on output color constancy. That is, every time a particular colorimetric RGB value is applied to a color printer, that printer will produce the same color, completely independent of all prior images. In particular, US Patent 5,649,072 specifically teaches a process that uses only one set of measurements. The color correcting look-up table values are adjusted until the original set of input RGB values produce the measured color patches after mapping by the look-up table. Unfortunately, not all color-imaging systems exhibit color constancy. Color imaging systems that do not include the single-panel LCD and the LCoS projector.

A single-panel LCD or LCoS color projector operates by rapidly and sequentially scrolling different colors of light, typically red (R), green (G), and blue (B), across a single LCD panel modulator. The LCD panel modulator modulates the different colors of light in accordance with color video information that is usually applied by frames, each of which is composed of component color sub-frames, one for each of the different colors of light, i.e. red, green and blue sub-frames. Thus, each color of light is modulated in each frame. Unfortunately, without a corrective mechanism, the color that is produced in one sub-frame depends on the image of the previous sub-frame. This is believed to be a result of the liquid-crystal material response times and inter-color mixing caused by stray electric effects. Therefore, one cannot accurately predict the color that is produced in a sub-frame without knowing what was produced in the previous sub-frame.

One prior art color corrective mechanism for compensating single-panel LCD color projectors for their lack of color accuracy is to pre-write black before each sub-frame. Pre-writing black forces the LCD material to be in a predetermined state before each sub-frame is produced. Since each sub-frame starts from the same initial state the color that is produced in a sub-frame can be accurately predicted. While pre-writing black successfully addresses previous sub-frame color artifacts, pre-writing black has the very serious drawback of reducing display brightness.
Therefore, a new corrective technique for achieving color accuracy in LCD projectors would be beneficial. Even more beneficial would be a new corrective technique for achieving color accuracy in LCD projectors without reducing brightness. In particular, a technique of using a look-up table to achieve color accuracy would be especially useful.

Also useful would be a method of obtaining values for a look-up table, where the obtained values provide for color accuracy in LCD projectors without pre-writing black data in each sub-frame. The technique of using a look-up-table to achieve color accuracy can also be applied in conjunction with the method of pre-writing black to obtain a higher degree of color accuracy.

The principles of the present invention provide for using a look-up table to achieve increased color accuracy in a manner that does not require pre-writing data in each sub-frame. Furthermore, those principles provide for a procedure of obtaining look-up tables values that enable color accuracy. The principles of the present invention also provide for a color corrective technique that uses look-up tables to achieve increased color accuracy in LCD projectors without reducing brightness. Those principles also provide for single-panel LCD projectors that achieve increased color accuracy without pre-writing data in each sub-frame.

A single-panel LCD projector that is in accord with the principles of the present invention includes a color correction network that maps input tristimulus (usually RGB) data obtained from input signals (such as from a computer) to color corrected tristimulus (RGB) data which compensate for the transfer characteristics of the LCD projector. Such an LCD projector further includes a modulator to selectively modulate colored light beams in response to the color corrected tristimulus data so as to produce an image on a screen using the modulated input light beams. Preferably, to avoid a loss of brightness, the single-panel LCD projector does not pre-write data in each sub-frame. But the use of a color correction network does not preclude the use of pre-write of data in each sub-frame.

A color correction network that is in accord with the principles of the present invention includes a look-up table that assists mapping input RGB data to color corrected RGB data. Also beneficially, the color correction network implements an interpolation technique to reduce the hardware requirements of mapping input RGB data to color corrected RGB data.

The principles of the present invention also provide for a procedure of obtaining the color corrected values that are stored in the look-up table. According to that procedure,
uncorrected color values are used to produce images whose color characteristics, specifically including luminance, are measured. Then, corrected color values are calculated such that the luminance of the corrected color values are substantially the same as that produced by the uncorrected color values, and such that the corrected color values compensate for the characteristics of the system. The corrected color values are then used to produce images whose color characteristics are measured. A determination is then made as to whether the corrected color values produce images having acceptable luminance and color characteristics, where acceptable luminance is based on the luminance characteristics obtained using the uncorrected color values. If not, a new set of corrected color values are produced, beneficially by using the results of the previous determination. The process repeats until acceptable color characteristics are achieved. The corrected color values that produce images having acceptable luminance and color characteristics are stored and used in the look-up table. Beneficially, the color corrected data and the uncorrected color values are in the RGB color format.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only. Other embodiments, variations of embodiments, and equivalents, as well as other aspects, objects, and advantages of the invention, will be apparent to those skilled in the art and can be obtained from a study of the drawings, the disclosure, and the appended claims, or may be learned by practicing the invention.

In the drawings:
Figure 1 is a schematic depiction of a single-panel LCD projector that is in accord with the principles of the present invention;

Figure 2 is a flow diagram of a procedure used to determine the look-up table values used in the single-panel LCD projector illustrated in Figure 1; and

Figure 3 is a flow diagram of an interpolation procedure, which is implemented in the single-panel LCD projector illustrated in Figure 1, for obtaining corrected color values from a reduced register space look-up table.

Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying figures.

Figure 1 schematically illustrates a single panel LCD projector 8 that is suitable for practicing the principles of the present invention. It should be understood that the LCD
projector 8 represents a nonspecific projector that is illustrated in a manner to show how
image projection systems in general can benefit from the present invention.

The purpose of the LCD projector 8 is to project a modulated light beam 10 onto a
screen 12 so as to create images that are in accord with input signals, such as television
signals, computer generated signals, or other types of digitized or analog signals. As
shown, the inputs signals are input on a port 14 of an input system 16. In practice, the
input signals are applied in frames (see above).

The LCD projector 8 further includes a controller 18 that controls the overall
operation of the projector. During initialization, the controller 18 retrieves look-up table
data from a memory 20. The controller 18 sends the look-up table data, via a data bus 28
having enable lines, to a color-compensating network 29 having a look-up table 21. Under
the control of the controller 18, the color compensating network 29 selectively outputs
color corrected data (RED, GREEN, and BLUE) to a gamma correction network 40 during
the color sub-frames (see above). Thus, the color-compensating network 29 effectively
implements a RED output table 22, a GREEN output table 24, and a BLUE output table 26.
Since the look-up table values are significant, a procedure of determining those values will
be explained in more detail subsequently. Additionally, to reduce the size of the look-up
table 21, the color compensating network 29 implements an interpolation procedure that is
also discussed subsequently.

The controller 18 also controls the overall operations of the input system 16, of a
light source 30, of a modulator 41 (typically an LCD panel), and of the gamma correction
network 40. The input system 16 converts incoming data signals (such as television
signals) on the port 14 to 8-bit color image signals R\textsubscript{IN}, G\textsubscript{IN}, and B\textsubscript{IN} that represent a color
image that is to be produced in a particular frame. Those signals are input to the color-
compensating network 29. Based on the look-up table data from the memory 20, the color
compensating network 29 maps R\textsubscript{IN} to corrected RED data on a bus 34, G\textsubscript{IN} to corrected
GREEN data on a bus 36, and B\textsubscript{IN} to corrected BLUE data on a bus 38.

Because the following discusses multiple sets of color data, for clarity it is
important to differentiate the various sets. Therefore, the set of color data applied to the
color compensating network 29 will be referred to as R\textsubscript{IN}G\textsubscript{IN}B\textsubscript{IN} data, while the set of color
data from the color compensating network 29 will be referred to as R'G'B' data. Other
color data sets are introduced subsequently.
Still referring to Figure 1, the R’G’B’ data (on busses 34, 36, and 38) is applied to a gamma correction network 40. The gamma correction network 40 includes a look-up table or tables that gamma corrects the R’G’B’ data to produce R’g’G’b’ data, where the g subscript signifies gamma corrected information. The R’g’G’b’ data is applied to the modulator 41 via a bus 49.

The controller 18 controls the light source 30 such that RED light R, GREEN light G, and BLUE light B are sequentially applied to the modulator 41. In a first color sub-frame the RED light R is applied to the modulator 41, which modulates the RED light R in accord with the R’g’ data to produce the modulated light beam 10. The modulated light beam 10 passes through an optical system 48 that sweeps the modulated light beam 10 across the screen 12. In the next color sub-frame the GREEN light G is applied to the modulator 41, which modulates the GREEN light G in accord with the G’b’ data to produce the modulated light beam 10. In the next color sub-frame the BLUE light B is applied to the modulator 41, which then modulates the BLUE light B in accord with the B’g’ data to produce the modulated light beam 10. By rapidly switching between RED, GREEN, and BLUE an observer sees a full color image on the screen 12.

As noted previously, determining the look-up table values that produce the R’G’B’ data is significant. Each LCD projector 8 has an associated color gamut—the range of colors that the LCD projector can produce by a superimposing modulated colored light 10 on the screen 12. A color is described and measured quantitatively using sets of three values, for example the tristimulus set (X, Y, Z) {typically RGB}, or the (L, u’, v’) set, where L represents the color’s luminance, and u’ and v’ when taken together reflect the color point in terms of color saturation and hue. Each set of color triples can be converted to the other set using mathematical transformations. For convenience, the following will make use of the (L, u’, v’) set, primarily because color differences in the (L, u’, v’) set correspond closely to perceived color differences. In terms of color accuracy, achieving a close match between two colors is equivalent to minimizing the Euclidean distance in the color (u’-v’) space. Mathematically, achieving a close match between two colors is equivalent to minimizing a color difference measure – ΔC:

\[ ΔC = \sqrt{(u_1 - u_2)^2 + (v_1 - v_2)^2} \]

where

(u_1, v_1) and (u_2, v_2) are the (u’, v’) components of the two colors being matched. A ΔC of 0.015 or less is generally considered sufficient for consumer applications.
A given color set \( R_{IN} G_{IN} B_{IN} \) from the input system 16 is mapped to R'G'B' data based on the values stored in the look-up table 21. That data (after gamma correction) modulates the RED, GREEN, and BLUE light imaged on the screen 12. The screen image can be characterized by a specific color valued triple \((L, u', v')\). If the display were an ideal display, i.e., if the effects of inter-color mixing did not occur, the LCD projector 8 would produce \((L, u', v')\) values that only depended upon the \((L, u', v')\) values of the three primary color points and on certain transfer characteristics of the system. The theoretical values will be designated as \((L_t, u_t', v_t')\), where the subscript denotes theoretical values. However, if \( R_{IN} G_{IN} B_{IN} \) data were directly applied to the gamma correction network 40, the screen 12 would produce an image with a different \((L, u', v')\) combination than the theoretical. The resulting \((L, u', v')\) combination when \( R_{IN} G_{IN} B_{IN} \) data is directly applied will be designated as measured \((L_m, u_m', v_m')\) values.

In the LCD projector 8, the color compensating network 29 maps \( R_{IN} G_{IN} B_{IN} \) to R'G'B' such that an \((L, u', v')\) combination results, with \( L = L_m, u' = u'_m \) and \( v' = v'_m \), beneficially within a tolerance of \( \Delta C \) of 0.015 and \( \Delta L/L_m \) of 0.02 (i.e., no more than a 2% error in luminance). Thus, the color-compensating network 29 corrects its input data such that there is almost no loss in luminance when compared to using \( R_{IN} G_{IN} B_{IN} \) directly, while also producing high color accuracy in a manner that achieves color accuracy.

The procedure 200 used to compute the R'G'B' values is iterative in nature and is explained with the assistance of Figure 2. It is assumed that the gamma correction tables in the projector have been determined prior to this procedure. The gamma correction tables ensure the proper reproduction of gray level information according to a power-law function (typically a power-law/gamma between 2.2 and 2.5). The power-law function relates gray level data input to the projector to the light output by the projector for each color channel.

The procedure 200 starts, step 202, and proceeds by loading the look-up table 21 with a set of (uncorrected) \( R_{IN} G_{IN} B_{IN} \) inputs, step 204. Those \( R_{IN} G_{IN} B_{IN} \) inputs are then used to produce color images (one in each sub-frame), and color measurements are taken on the resulting images to obtain measured \((L_m, u_m', v_m')\) values, step 206. Then, using the theoretical values \((L_t, u_t', v_t')\), the measured \((L_m, u_m', v_m')\) values, and the non-linear transfer function of the LCD projector 8 is used to produce a set of R''G''B'' values that are loaded into the look-up table 21, step 208. The double prime superscript is used to designate an interim set of color values. It should be noted that for each \( R_{IN} G_{IN} B_{IN} \) input, a target
luminance \(L_m\) and a theoretical color point \((u'_t, v'_t)\) are used to determine the R"G"B" set. That is, the luminance is fixed.

Then, using the R"G"B" set, new color measurements are taken to obtain \((L, u', v')\) values for the R"G"B" set, step 210. Calculations are then made to find differences between the \((L_m, u'_t, v'_t)\) values and the \((L, u', v')\) values to determine if the \((L, u', v')\) values are acceptable (see below), step 212. If not, the procedure loops back to step 208 to calculate and load another R"G"B" set. That R"G"B" set is then used to obtain new \((L, u', v')\) values, step 210, and differences between the \((L_m, u'_t, v'_t)\) values and the \((L, u', v')\) values are used to determine if the \((L, u', v')\) values are now acceptable, step 212. The iterations continue until \(\Delta C\) and \(\Delta L/L_m\) are lower than .015 and 0.02, respectively.

Beneficially, the differences between \((L_m, u'_t, v'_t)\) values and the \((L, u', v')\) values are used to scale the step size from one iteration to the next. Once acceptable values are achieved, the R"G"B" set is stored in the memory 20 (see Figure 1) for future use as the R'G'B' set, step 214. The procedure 200 then stops, step 216.

Significantly, the resulting luminance when using the R'G'B' set is at or very near \(L_m\). Furthermore, while the luminance in each iteration remains at or near the originally obtained value \(L_m\) at the end of the iterations, the values of \(L, u', v'\) should be \(L_m, u'_t, v'_t\) respectively meeting the \(\Delta C\) and \(\Delta L\) criteria.

While the foregoing is beneficial, in practice it can be costly to directly implement.

To understand this, consider using 8-bit \(R_{IN}, G_{IN},\) and \(B_{IN}\) values. Such would require an expensive look-up table (or tables) having a 24-bit input address with 16777216 registers. Therefore, instead of using a complete 24-bit input address look-up table, the color-compensating network 29 uses a sparsely filled look-up table 21 and implements an interpolation procedure that combines look-up table values in an appropriate manner.

Figure 3 illustrates a suitable interpolation procedure 300 for determining an appropriate R'G'B' output when using the look-up table 21 with a restricted register space.

The procedure 300 starts, step 302, and proceeds by obtaining an RGB value from the input system 16 (see Figure 1), step 304. The color-compensating network 29 then determines if the obtained \(R_{IN}G_{IN}B_{IN}\) value is directly mapped in the look-up table 21, step 306. If it is, the color compensating network 29 outputs the directly mapped R'G'B' value, step 308, and the procedure 300 stops, step 310.

However, if the obtained \(R_{IN}G_{IN}B_{IN}\) value is not directly mapped in the look-up table 21, the color compensating network 29 finds both a) the \(R_{IN}G_{IN}B_{IN}\) values that are
nearest the obtained $R_{IN}G_{IN}B_{IN}$ value and that are directly mapped in the look-up table 21 (those $R_{IN}G_{IN}B_{IN}$ values are subsequently referred to as the nearest neighbors), and b) the color space Euclidean distances of the nearest neighbors from the obtained $R_{IN}G_{IN}B_{IN}$ value, step 312. The Euclidean distances are measured in ($L$, $u'$, $v'$) space since the color error criterion is defined in that space. The color compensating network 29 then uses those nearest neighbors and distances to calculate an interpolated R'G'B' value, step 314. The closer the obtained $R_{IN}G_{IN}B_{IN}$ input is to a particular neighbor, the closer the interpolated R'G'B' output is to that neighbor's associated R'G'B' value. Once the interpolated R'G'B' value is calculated, that interpolated value is subsequently used, step 316. Finally, the procedure 300 stops, step 310. The interpolation procedure 300 can require much less hardware to implement than a 16777216 register look-up table. Variations in the interpolation procedure include the use of more than two nearest neighbors and interpolation using non-linear combinations of R'G'B' values of those neighbors.

The procedure for obtaining improved color accuracy may also be beneficially used to modify the gamut of the display. If, for each RinGinBin values, the desired ($L$, $u'$, $v'$) values are based not upon the primaries of the actual display, but on some other primaries that are reproducible by the display (let's call this the target color gamut) the look-up-table as determined by the procedure outlined earlier, will provide a transformation of the color gamut from the display's native color gamut to the target color gamut while at the same time compensating for inter-color mixing artifacts.

The embodiments set forth herein are presented to explain the present invention and its practical application so as to thereby enable those skilled in the art to utilize the invention. Other variations and modifications of the present invention will be apparent to those of skill in the art. Therefore, it is intended that the scope of the present invention be defined by the appended claims, giving full cognizance to equivalents in all respects.
CLAIMS:

1. A method of determining color corrected values comprising:
   (a) using a set of uncorrected values to produce images on a display;
   (b) measuring the color parameters of the images produced in step (a);
   (c) obtaining the luminance characteristics of the images from the color parameters measured in step (b);
   (d) calculating a set of corrected values such that the luminance characteristics of the set of corrected values are substantially equal to the luminance characteristics obtained in step (c);
   (e) using the set of corrected values calculated in step (d) to produce images on the display;
   (f) measuring the color parameters of the images produced in step (e);
   (g) determining from the measurements of step (f) whether the images produced in step (e) are within acceptable levels of luminance and color characteristics, wherein acceptable levels of luminance are based on the luminance characteristics obtained in step (c), and wherein acceptable color characteristics are based on a theoretical set of color values; and
   (i) repeating steps (d) through (h) until the set of corrected values calculated in step (d) produce acceptable levels of luminance and acceptable color characteristics.

2. A method of producing corrected color values according to claim 1, wherein the set of uncorrected values and the set of set of corrected values are RGB (RED, GREEN, and BLUE) data.

3. A method of producing corrected values according to claim 1, wherein step (d) includes using errors between the luminance characteristics obtained in step (c) and the color parameters measured in step (f).

4. A method of producing corrected values according to claim 3, wherein step (d) further includes using errors between the color parameters measured in step (f) and on the theoretical set of color values.
5. A method of producing corrected values according to claim 1, wherein the theoretical set of color values are based on a mathematical relationship between the uncorrected values and measured color parameters.

6. A method of achieving color accuracy in an LCD display, comprising the steps of:
   (a) using a set of uncorrected RGB data (RinGinBin) to produce images on an LCD display;
   (b) measuring the color characteristics of the images produced in step (a);
   (c) obtaining the luminance characteristics of the images from the color characteristics measured in step (b);
   (d) calculating a set of corrected RGB values such that the luminance characteristics of the set of corrected RGB values are substantially equal to the luminance characteristics obtained in step (c);
   (e) using the set of corrected RGB values calculated in step (d) to produce images on the display;
   (f) measuring the color parameters of the images produced in step (e);
   (g) determining from the measurements of step (f) whether the images produced in step (e) are within acceptable levels of luminance and color characteristics, wherein acceptable levels of luminance are based on the luminance characteristics obtained in step (c), and wherein acceptable color characteristics are based on a theoretical set of color values;
   (h) repeating steps (d) through (g) until the corrected RGB values produce acceptable levels of luminance and acceptable color characteristics; and
   (i) storing the set of corrected RGB values that produce acceptable levels of luminance and acceptable color characteristics for future use.

7. The method of claim 6, wherein step (d) includes using errors between the color parameters measured in step (f) and the theoretical set of color values.
8. A single-panel LCD projector, comprising:
   a color correction network for mapping input RGB data to color corrected RGB data;
   a modulator for selectively modulating input light in response to the color corrected RGB data;
   a light source for selectively inputting RED, GREEN and BLUE light to the modulator;
   an input system for applying input RGB data to the color correction network; and
   an imaging system for producing an image on a screen using the modulated light beams;
   wherein the color correction network produces color corrected RGB data that produces the image such that the image has substantially the same luminance as if the input RGB data was directly used and such that the color corrected RGB data compensates for a non-linear color transfer function of the single-panel LCD projector.

9. A single-panel LCD projector according to claim 8, wherein the input system produces the uncorrected RGB data from incoming data signals.

10. A single-panel LCD projector according to claim 8, wherein the color compensating network includes a look-up table.

11. A single-panel LCD projector according to claim 10, wherein the look-up table retains color corrected RGB data obtained by:
   (a) using a set of uncorrected RGB data (RinGinBin) to produce images on the screen;
   (b) measuring the color characteristics of the images produced in step (a);
   (c) obtaining the luminance of the images from the color characteristics measured in step (b);
   (d) calculating a set of corrected RGB values such that the luminance of the set of corrected RGB values are substantially equal to the luminance obtained in step (c);
   (e) using the set of corrected RGB values calculated in step (d) to produce images on the screen;
   (f) measuring the color parameters of the images produced in step (e);
(g) determining from the measurements of step (f) whether the images produced in step (e) have acceptable luminance and color characteristics, wherein acceptable luminances are based on the luminances obtained in step (c), and wherein acceptable color characteristics are based on a theoretical set of color values;

(h) repeating steps (d) through (g) until a set of corrected RGB values that produce acceptable levels of luminance and acceptable color characteristics is found; and

(i) storing the set of corrected RGB values that produce acceptable levels of luminance and acceptable color characteristics in the look-up table.

12. A single-panel LCD projector according to claim 11, wherein step (d) uses errors between the color parameters measured in step (f) and on the theoretical set of color values.

13. A single-panel LCD projector according to claim 10, wherein the color correction network implements an interpolation process of finding corrected RGB values.

14. A single-panel LCD projector according to claim 13, wherein the interpolation processor operates by:

(a) obtaining uncorrected RGB data;

(b) determining if the uncorrected RGB data is directly mapped by the look-up table to a corrected RGB value;

(c) outputting the directly mapped RGB value if the uncorrected RGB data is directly mapped;

(d) determining the nearest neighbors of the uncorrected RGB data if the uncorrected RGB data is not directly mapped by the look-up table to a corrected RGB value;

(e) interpolating a corrected RGB value using the corrected RGB values associated with the nearest neighbors; and

(f) outputting the interpolated corrected RGB value if the uncorrected RGB data is not directly mapped.
15. A single-panel LCD projector according to claim 14, wherein the interpolation processor interpolates a corrected RGB value based on distances between each nearest neighbor and the uncorrected RGB data.

16. A single-panel LCD projector according to claim 14, wherein the look-up table retains color corrected RGB data obtained by:
   (a) using a set of uncorrected RGB data (RinGinBn) to produce images on the screen;
   (b) measuring the color characteristics of the images produced in step (a);
   (c) obtaining the luminance of the images from the color characteristics measured in step (b);
   (d) calculating a set of corrected RGB values such that the luminance of the set of corrected RGB values are substantially equal to the luminance obtained in step (c);
   (e) using the set of corrected RGB values calculated in step (d) to produce images on the screen;
   (f) measuring the color parameters of the images produced in step (e);
   (g) determining from the measurements of step (f) whether the images produced in step (e) have acceptable luminance and color characteristics, wherein acceptable luminances are based on the luminances obtained in step (c), and wherein acceptable color characteristics are based on a theoretical set of color values;
   (h) repeating steps (d) through (g) until a set of corrected RGB values that produce acceptable levels of luminance and acceptable color characteristics is found; and
   (i) storing the set of corrected RGB values that produce acceptable levels of luminance and acceptable color characteristics in the look-up table.

17. A single-panel LCD projector according to claim 8, further including a controller that controls the color correction network, the modulator, the light source, and the input system.

18. A single-panel LCD projector according to claim 8, wherein the input RGB data is applied by frames.
19. A single-panel LCD projector according to claim 19, wherein the modulator includes an LCD panel.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 HO4N9/73

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 HO4N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
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<th>Relevant to claim No.</th>
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<td>Y</td>
<td>WO 00/05706 A (SILICON GRAPHICS INC)</td>
<td>1-7</td>
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<tr>
<td></td>
<td>3 February 2000 (2000-02-03) abstract; claims 24,25; figures 15,16 page 3, line 15 - line 20</td>
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<td>abstract; figures 2,3,18 paragraphs '0091!, '0120! - '0138!</td>
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** Further documents are listed in the continuation of box C. **

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Date of the actual completion of the international search

29 July 2004

Date of mailing of the international search report

05/08/2004

Name and mailing address of the ISA

European Patent Office, P.B. 5618 Patentlaan 2 NL - 2280 HV Rijswijk
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