A Study on Correction Systemic Algorithm for LCD Projection Display Color Uniformity

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Abstract

According to the application of two-dimensional CCD camera and the computer composing principles and characteristics of uniformity correction system of LCD projection display color, this paper experiments, analyzes and compares the process of seeking color correction value between improved binary algorithm and traditional stepping technique. The experimental results indicate that, compared with traditional stepping technique, the advantage of improved binary algorithm lies in the fact that it has universal adaptability and can be applied to the color uniformity correction of LCD projection system with various optical properties; besides, it has uniform convergence as to the search of correction value in different areas in the process of correction, which enables the correction time of the projection system to be a constant; what’s more, in comparison with stepping technique, improved binary algorithm has a higher algorithmic efficiency with the same precision and its correction time reduces to 60% of the stepping technique. The related experiment shows that improved binary algorithm is the ideal algorithm that appropriate to be applied in the display color uniformity correction of LCD projection system.

1. Introduction

Along with the development of LC manufacturing technology and the decline in development cost, LC projection display system is increasingly being used in various fields and at the same time, the requirements of LC projection display picture quality are becoming increasingly higher. As one of the important indexes of LC projection display [1], the color uniformity has become a major concern accordingly. In order to meet the high uniformity requirement of LCD system, major chip manufacturers added color uniformity correction circuit to the liquid crystal type driving chip. When used as an average display device, this circuit function is normally disabled; when the display device requires higher color uniformity (Such as using LC projection system to realize multi-screen display), the manufacturers can use the function of this circuit to correct the uniformity of liquid-crystal display so as to obtain good display uniformity effect. As the commonly used correction points of this circuit are various, it’s impossible to set
the correction value of these points simply by manual adjustment. Therefore, it’s especially valuable to find out reasonable method and technique to test and correct the color uniformity of LC projection system.

In the reference [2], the method of collecting the brightness of red, green and blue colors in different areas of the whole LCD screen by adopting CCD has been proposed, and it is advised to compare the brightness scale values of these three colors to measure the colors uniformity distribution of each area in the screen. The correction value of each area on the screen will be obtained through analysis and calculation of these brightness values. The brightness scale of the three colors of red, green and blue (RGB) in different areas of the screen needs to do some fine-tuning by controlling the color uniformity correction circuit in the liquid-crystal driving chip and setting corresponding register in order to finally achieve the color uniformity correction of LC projection system. The system in [2] can achieve a better effect in its actual application, but the correction areas on the screen are divided meticulously, which enables that a lot of areas have to be corrected. Meanwhile, a large number of registers need to be repeatedly set up and the effect of uniformity correction requires to be tested in the process of correction while searching the values preset in the registers in a very wide range, all in all, the whole correcting process proceeds very slow, which cannot be applied to the actual production of projection equipments. Therefore, it becomes pressing to find out a fast and effective color uniformity correction algorithm in order to make this system applicable to the production of LC projection system.

The algorithm of color uniformity correction used in [2] is a kind of steeping method, namely, the proportion of RGB needs to be firstly obtained by testing and then dividing the searched values of registers into two zones with one big-and-long stepping zone and the other small-and-long stepping zone. When the measured value of the brightness scale of RGB and the deviation of the ideal correction value is pretty large, it indicates that the current correcting value calculated from the register and the actual correcting value has a large deviation, then big step size can be adopted to raise the efficiency of search. Otherwise, if the above-mentioned derivation is not very large, the efficiency of search can be improved by applying smaller step size. Though stepping method can be used to achieve a better uniformity correcting effect for a single LC projection system, its disadvantages are still obvious: (1) For machines with different display uniformity, the range between large-step zone and small-step zone has to be confirmed according to the brightness scale of RGB, and at the same time, the respective stepping length of the two zones also needs to be tested, which directly determines the efficiency of the stepping algorithm. Thus, stepping algorithm can not be used as a universal method and does not apply to the projection system with different optical properties; (2) As the finally found correcting values corresponding to the registers in different areas have large numerical differences in the process of correction, the correction time by using stepping algorithm varies in different area, therefore, the systematical correction time depends on the longest time. Accordingly, the correction of each area by stepping algorithm has no consistency and the efficiency is not high. (3) Owing to the measurement error by adopting CCD and the high-frequency flashing of the lights in the projection system, the actual measured value of the brightness scale of RGB will not completely achieve the ideal value, as a result, usually, the correction can be regarded as completion only if the measured value is within a slight error scope of the ideal value. However, for this error scope is commonly determined by the optical property of the projection system and the measurement error of CCD, therefore, in the application of stepping algorithm, a value needs to be determined based on the different optical properties of the projection system, but generally, the value is always difficult to determine, the result of which needs to be worked out after repeated correction.

An improved binary algorithm is proposed in order to overcome the above-listed disadvantages of steeping algorithm in the process of correction. Through the use of improved dichotomy, the correction system in reference [2] can not only achieve a satisfying accuracy in calibration, but also has a universal applicability as to the projection system with different optical properties. What’s more, improved binary algorithm also has a higher algorithmic efficiency, which is completely suitable for being applied to the manufacturing process of LC projection products.
2. Principles of this system

The theoretical basis for color uniformity measurement and correction of LC projection system is: In LC projection display, the color of a certain area on the screen is composed by the superimposition of RGB with different brightness [2]. Suppose that the CIE coordinates of the three primary colors are respectively \((x_1, y_1)\), \((x_2, y_2)\), and \((x_3, y_3)\), and the tristimulus values are respectively \(X_1, Y_1, Z_1\), \(X_2, Y_2, Z_2\), and \(X_3, Y_3, Z_3\), while the relation between CIE coordinates are respectively \(X_1 = \frac{x_1}{y_1}\), \(X_2 = \frac{x_2}{y_2}\), and \(X_3 = \frac{x_3}{y_3}\). Then let \(a = \frac{Y_2}{Y_1}\) and \(b = \frac{Y_3}{Y_1}\), thus the tristimulus value of this point will be \(X = Y_1 \left(\frac{x_1}{y_1} + a \frac{x_2}{y_2} + b \frac{x_3}{y_3}\right)\), \(Y = Y_1 (1 + a + b)\), \(Z = Y_1 \left(\frac{1-x_1-y_1}{y_1} + a \frac{1-x_2-y_2}{y_2} + b \frac{1-x_3-y_3}{y_3}\right)\) while the CIE coordinate of this color is \((x = \frac{X}{X+Y+Z}, y = \frac{Y}{X+Y+Z})\). As in the secondary color of the whole screen, the CIE coordinates of the three primary colors are fixed, as a result, the CIE coordinate of their secondary color is completely determined by their brightness scale \((1: a: b)\). The inconsistent brightness scale of three primary colors in different zones on the screen results in the uneven color distribution. The application of color uniformity correction system just realizes \(a_{i,j,k} = a_{s,k}\) and \(b_{i,j,k} = b_{s,k}\) (where \(i=1, 2, \ldots, 31, 32\) which represents the number of different correcting areas in a row, \(j=1, 2, \ldots, 23, 24\) which represents the number of different correcting areas in a column, \(k=1, 2, 3\) which represents the number of gray layer to be corrected, \(a_{s,k}\) and \(b_{s,k}\) respectively represent the standard values of \(a\) and \(b\) in layer \(k\), and the values of \(i, j\) and \(k\) are determined by the register structure of the color uniformity correction chip). Suppose that the average CIE coordinate of different areas on the screen is \((x_m, y_m)\), then the derivation between the average value and the CIE coordinate is \(\delta = \sqrt{(x_m - x)^2 + (y_m - y)^2}\), thus the degree of color uniformity can also be measured by the value of \(\delta\).

The structured flowchart of the measurement of color uniformity and the correction system is showed as figure 1: this system is composed of the video test signal generator, projector screen, CCD camera and the computer. The LC projection display system mainly includes the video pre-processing circuit, 3x3x32x24 registers (which are used to store the correcting values of the three colors in 32x24 areas in the three gray layers), the drive circuit, liquid-crystal chip and camera lens. The function of the video test signal generator is to generate standard image signal assisted by the computer; after video pre-processing, the image signal will superimpose with the RGB corrections in the 3x3x32x24 8-bit registers (3 gray-level correction, the three colors of RGB, a row of 32 correcting areas and a column of 24 correcting areas), then the image will be projected on the screen through the control of drive circuit. Array CCD is applied to the fast collection of the two-dimensional brightness distribution of the three colors on the screen; the collected data will be transferred to the computer to compute, analyze and process; then, readjust the system according to the results of the current correction, in this way, a closed-loop color uniformity system with self-adjusting function is built up. The whole correction is to search for appropriate settings of 3x3x32x24 registers and finally achieve the color uniformity correction of the displayed image.
3. The principle of color uniformity correction system with the improved binary algorithm

From the above-mentioned principle, the color uniformity correction is just the process of searching for appropriate settings in the 3x3x32x24 registers through the negative feedback correction system showed in figure 1. Let $a = \frac{Y_i}{Y_c} = f(x)$, when the value in the register is x, the brightness scale of green heft and red heft collected with CCD in a certain correcting area can be calculated, then it can be obtained that a is the function of x, thus the color uniformity correction is a process to make $d_{s,k} = f(x)$, and manage to get the value of x. The setting in the register is an 8-bit sign extension, the value range of which is [-128, 127], an appropriate correcting value must be one of the numbers in this range. Therefore, the color uniformity correction becomes a process to search the correcting value in the range of [-128, 127] according to the proportion of three primary colors acquired with CCD, and meanwhile, as f(x) is the monotone increasing function of x, the binary search algorithm can be used. Different from common-used binary algorithm, its comparison domain and the search domain are not the same one here: the comparison domain refers to the relationship between the value of f(x) calculated with CCD and the target value $d_{s,k}$ while the search domain is the setting range [-128, 127] in the register. The searching efficiency of this algorithm is the same with common binary algorithm, which is $n = \log_2 256 = 8$. Similarly, it’s still true that the brightness scale of the blue heft and red heft $b_{s,k}$ can also be obtained through the above algorithm. The correction of the heft of the three primary colors in unit area with binary algorism is showed in figure 2.

![Figure 1. The structured flowchart](image-url)
The advantages of using improved binary algorism are: (1) It only needs to search for the correcting value in the value range set in the register, which has nothing to do with the optical properties of the projection system. Thus, binary algorism has a general applicability in respect to those color uniformity correction system with the same circuit, and it’s unnecessary to adjust the algorithm according to the optical properties of different projection system, and what’s more, this algorithm doesn’t like the stepping method which needs to set the step field and adjust the step length. (2) In the application of binary algorism, when the value range in the register is fixed, the number of correction to each area is also a fixed value and the correction time is an constant. In addition, when the register width is 8-bit, the maximum number of correction is \[ n = \log_2 256 + 1 = 9 \], the number of correction at each point has a good consistency and the algorithmic efficiency has improved a lot comparing with stepping algorithm. (3) Because of the convergence of binary algorithm, the completion of the correction can be determined from the condition of Max<=Min, which does not need to be estimated according to the derivation value \( \Delta \) of the measured value and the ideal value due to the measurement error with CCD and high-frequency flashing of the lights in the projection system.

4. Experiments and Results

By adopting the computer and serial port communication in the LC projection display system to realize the color uniformity correction, about 23s is required in order to calculate the next settings in the registers through real measurement that the correction system’s completion of a single amendment of the register value in the full-screen color uniformity correction circuit and acquisition of the feedback brightness scale. In the correction of the same batch LC projection system with stepping algorithm, the value of the register will search from the original value 0 to both sides of the positive and negative values. On the basis of the
accuracy of the correction, the optimal length of the large step is 10 and the small step is 1. After testing, the number of correction is 20 times and the average number is 15 in the worst case, and as a result, the average correction time is \( t = 15 \times 23 = 345 \) seconds. By contrast, employing improved binary algorithm, the number of correction to all the projection systems is 9 and the correction time is \( 9 \times 23 = 207 \) seconds, from which it can be seen that the algorithmic efficiency with binary method has been obviously improved in comparison with the stepping method.

Improved binary algorithm and stepping algorithm have the same accuracy corresponding to the systematic correction. After conducting color uniformity correction to the same randomized projection system respectively with the two methods, it will find that, when using stepping algorithm, on the whole screen, the maximum value of \( \delta \) is 0.0043, and the standard deviation of the value \( \delta \) in 32\times24 correcting areas is \( 5.56 \times 10^{-4} \), the distribution of \( \delta \) on the screen is showed in Figure 3; while using improved binary algorithm, the maximum value of \( \delta \) is 0.0046, and the standard deviation is \( 5.47 \times 10^{-4} \). The distribution of \( \delta \) on the screen is showed in Figure 4.

5. Conclusion

This paper proposes an improved binary algorithm, which has a general adaptability and can be applied to the color uniformity correction of various LCD projection systems with different optical properties; and at the same time, this algorithm has a consistent convergence for searching the correcting value in different areas on the screen, which allows the correction time of the projection system to be a constant. In comparison with the stepping algorithm, this improved binary method has a higher algorithmic efficiency under the same accuracy, the correction time of it is about 60% of the stepping algorithm. Through the practical verification in the production of projection systems, the improved binary algorithm is an ideal method which can be applied to the color uniformity correction of LCD projection system.
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