Improving Color Fidelity of Heritage Digital Copies through Representative Samples

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ABSTRACT

While the digital copies can represent most of the cultural information as good as the original cultural heritage, electronic archives avoid the physical protection difficulty. To preserve the authenticity of the original cultural heritage, the digital copies should retain least error of 3d shape or color. Unlike laser 3d scanner, digital camera doesn't provide uniform error of measurement due to uncontrolled light condition. In this article, we presented color fidelity verification result of digital cameras with array and line sensors, which demonstrated particularly unreliable color error. Without color correction, the average color accuracy is usually under 90%, which means certain color accuracy can be lower than 70%. In order to improve the color fidelity of heritage digital copies, we use standard color chart to calibrate color rectification curves. The average color accuracy can be raised to over 96% through separated RGB channel, with certain color accuracy still remained under 80%. Based on natural neighbor interpolation, every arbitrary color chart block can be rectified to over 99% accuracy. With the help of cluster algorithm, representative color samples can be selected to make exclusive color chart, so as to improve color fidelity of particular digital copy. The rectified digital copies of cultural heritage have better color fidelity, and match permanent document file requirement well.

KEYWORDS: Cultural Heritage Digitization, Color Correction, Curve Fitting

INTRODUCTION

An ideal digitization system should be able to record and reproduce the color of the object being digitized with high fidelity. Unfortunately, most of the digital cameras or scanners are unable to achieve the desired accuracy. Due to the sensitivity of the photoelectric sensor, a digital imaging system will map is device-related color space to the device-independent color space. Based on complex algorithms and ample statistical data, the color reproduction capability of a digital imaging device is usually calibrated to provide a sense of both accurate and full color gamut. In order to minimize the color difference between devices, a large number of color correction methods and related standards are used by the industry.

Among a variety of color correction methods, color chart based color correction method is more classical [1]. In practice, Adobe DNG Profile Editor can be used to create color correction profile for specific digital camera and specific lighting condition based on a classic X-Rite ColorChecker chart. The color checker chart is a color calibration target consisting of 24 squares of painted samples, which are scientifically prepared natural, chromatic, primary and grayscale colored squares in a wide range of colors. Theoretically, with the Adobe DNG Profile Editor software, the color of a digital photo can be corrected to close to standard values, especially on the 24 selected colors. However, in order to keep the uniform and smoothness of the color distribution, there will eventually leave uncertain deviations between the correction result and the standard value.

In many cases, color checker chart with less kinds of color or gray chart with only one kind of color were used for facilities. In such circumstances, many software, such as Adobe Lightroom, can provide color correction capability based on white balance. The user can perform a click-balance by pointing to a white or gray region in the image and letting the software calculate the appropriate correction factors from that area [2].

In the field of cultural heritage digitization, the use of digital cameras is more common than the scanner. Because of the uncertainties in lighting conditions, the color checker chart based color correction methods were widely adopted. At the same time, the accuracy of the color correction software was overestimated.

One X-Rite ColorChecker Color Rendition Chart was used to test the color reproduction ratio, shown as figure 1. After taking one picture with two flash light located at the back side of the camera, we performed auto white balance correction based on the color of bottom row second left square. The range of color reproduction ratio distributed from 66.4% to 99.2%, with an average of 88.3%.

Figure 1: Color reproduction ratio of regular software correction result.

Since 66.4% is too low as a color reproduction level, the work carried out under this condition is not credible. Such digital images of culture heritage can note be adopted as permanent document file.

THEORY

There are many factors that can affect the degree of color reproduction, including the spectral parameters of the light source, the camera's photographic characteristic, the color of and the BRDF (Bidirectional Reflectance Distribution Function) parameters of the object. Once the intensity, location and orientation of lights is fixed, and the location, orientation and intrinsic parameters of the camera stay in constant, we can achieve higher fidelity of cultural heritage digitization by carefully rectify the color adjust parameter through color checker charter.

Variety of needs have been taken cared by commercial software when implementing color correction operation, including the completeness of the target color space, the color psychological optimization of color mapping, etc. However, for the digitization of cultural heritage, the consistency of color sampling data and original object is still the most important assessment indicator. For the above consideration, we should establish a color mapping system to best match a local color region while leaving other color space uncalibrated or less-calibrated.

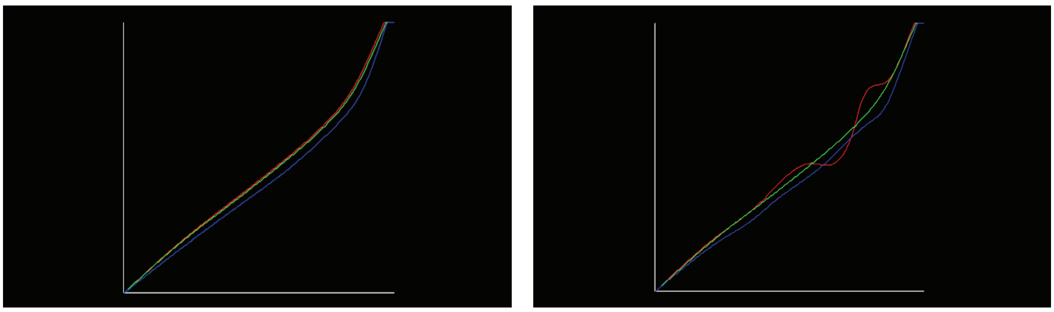

Figure 2: Curves generated by the first two algorithms. Left, algorithm1. Right, algorithm 2.

Three different kinds of correction Algorithms have been designed and tested. The first algorithm upgrade single color based white balance to full gray level correction. The brightness value of the six gray squares can be used to interpolate to generate a curve, which can be used to remap all the color by the correspondence of brightness.

The second algorithm processed each channel individually. The R, G and B data of 24 squares split into three group, and construct three different curves to rectify each channel separately.

The result curves of these two algorithms are shown in figure 2, all corresponding to the image in figure 1.

In the third algorithm, color was treated as three-dimensional vector. 24 samples were used as control points to perform natural neighbor interpolation [3]. The interpolation hierarchy is shown in figure 3.

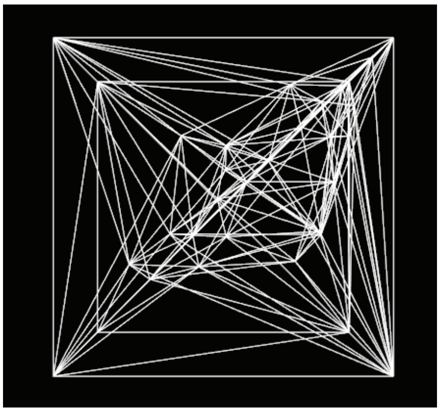

Figure 3: Interpolation hierarchy of algorithm 3.

The first algorithm is more focusing on global data interpolation than the other two, while the third algorithm is most concerned with local data fitting. The average color reproduction ratio of each algorithm increased to 96.5%, 96.7 and 99.6%. The last algorithm gave the best result as expect.

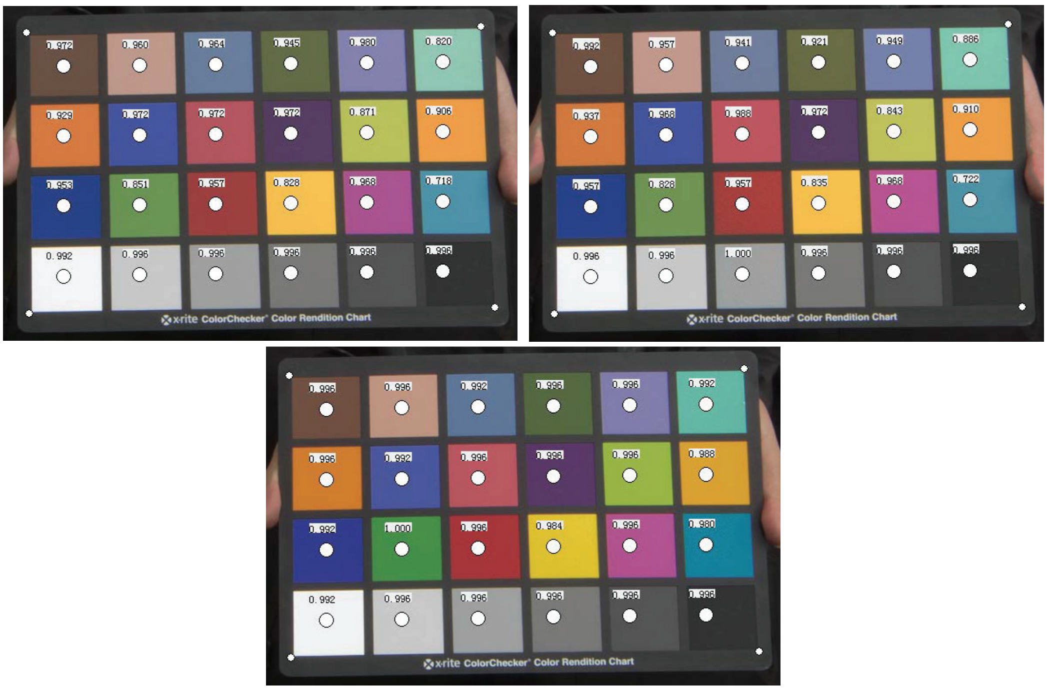

Figure 4: Color correction result of the color checker chart image of algorithm 1 to 3.

EXPERIMENTAL

In addition to the third algorithm, color quantization techniques [4][5] can be used to generate customized color checker chart, so as to generate more specific natural neighbor interpolation control points. We applied this technique to the silk relic digitization practice. With the help of color correction, the digital image result became more authentically and saturated. Comparison between original image and corrected image shown as Figure 5.

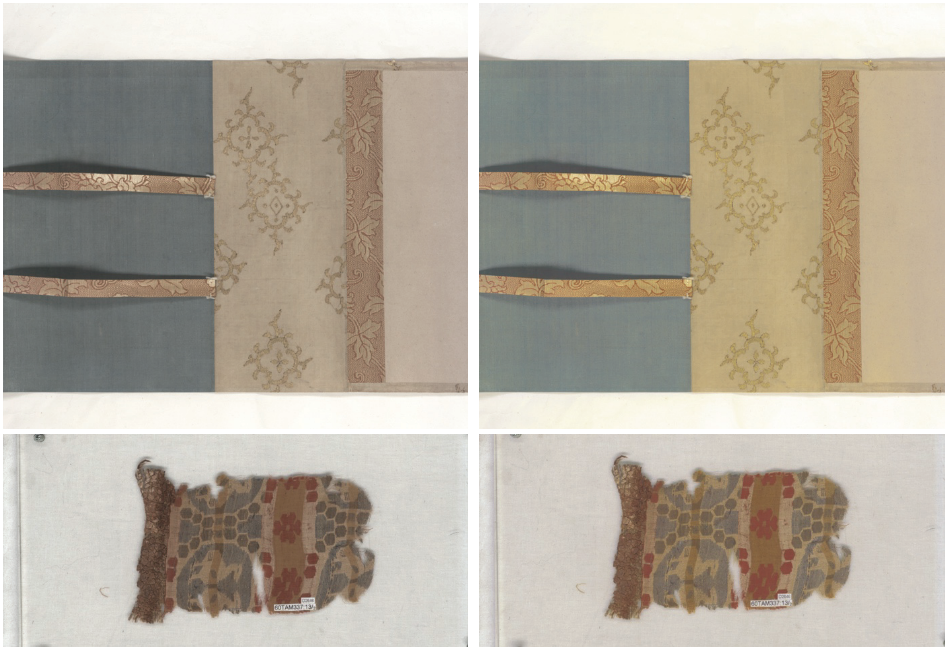

Figure 5: Comparison between original silk relic image (left) and corrected image (right).

CONCLUSION

The conventional color correction method left error when processing individual image. However, the digitization of cultural heritage requires the most color accuracy. It is necessary to popularize specialized color correction techniques in the field of cultural heritage digitization, to help achieving reliable results.

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