The Research on Color Space Transfer Model Based on Dynamic Subspace Divided BP Neural Network

Zhi Chuan, Zhou Shi-Sheng, Shi Yi

Abstract—**BP neural network not only has the ability of strong nonlinear information processing, but also has the advantage of transform quickly. Because the process of different color space conversion shows high nonlinear, it is reasonable to research color space conversion model by BP neural network. But the color space conversion is complicated, adding that it is easy for BP neural model to appear local optimum phenomenon during the transformation process, so it affects the model transformation precision. In order to improve the precision for BP neural network model color space conversion, this paper takes RGB color space and CIE L*a*b* color space as an example. Based on the input value, the color space is dynamically divided into many subspaces. To adopt the BP neural network in the subspace can effectively avoiding the local optimum of BP neural network in the whole color space and greatly improving the color space conversion precision.**

Index Terms—**Dynamic space divided; BP neural network; transition of color space; color error**

I. Introduction

Due to different color reappearance devices have different color rendering principles, when color transforms among different color reappearance device, color cast phenomenon appears. The technology of color management emerges to solve this problem. One of the core technologies of color management is the mutual conversion of color space model, namely, from the device-depend color space to the device-independent color space, and then from the device-independent color space to the device-depend color space, so as to make the accurate reappearance of colors on different devices.

At present, the frequently-used methods in color space conversion are Neugebauer equation, 3D_LUT (3-dimensions Look-up table) and polynomial regression and artificial intelligence method (such as neural network), ect[1]. Neugebauer equation is mainly used in printing industry. It transforms color measured value of manuscript to CMYK color space for the correct reproduction of printing color. The advantage of the Neugebauer equation lies in its simple and clear theories. It only needs to measure few types of ink color samples to achieve the answer. However in reality, there are many color deviation errors when directly applying the output value of Neugebauer equation to printing. So many researchers come to study this equation deeply, and have provided their own correct methods to prove the precision of this kind of method. But up to now, some of the methods provided make the solving process even more complicated, while others have the demerits, such as the coefficients difficult to decide, and the method with poor universal property[2]. For the 3D_LUT, the method has been highly developed, but the choosing of model data is difficult. If the data has large quantities, the complicacy of color matching algorithms will be increased, and the matching velocities will be very slow; if the data quantities are small, the model will not represent the essential character of primary color space[3]. The method of polynomial regression is based on the theory of the additivity of tristimulus values. Based on establishing the proper regression model, and system identified the parameters with the input and output data, the reversion calculation between the different color spaces can be realized. But the deviations between the different models in different devices are very significance, and the nonlinear character is very obvious. Thus the models are very complex with some hypothetic conditions, and it causes the poor universalities and low precision with this polynomial regression method[4].

The color space conversion belongs to non-linear mapping problem of three-dimensional space. There are some limitations in the traditional mathematic model method, and it is difficult to apply in automatic adjustment[5]. So many scholars have transferred their researching focus on artificial neural network algorithm at present. So far, BP neural network is widely used for the research of color space conversion model, to analyze the output of neural network by use different layers and nodes[6][7][8]. In addition, there are some scholars to study the color space conversion model by BP neural network improved algorithm [9]. All of these neural network models study and train sampling points in the whole color space, to adjust the weight between nodes, then to build the last input/output neural network model. The reference [8] adopted 8 gradual change color in red , green, blue, yellow, pink, cyan and black，a total of 56 colors as the basic data set to construct the BP neural network model and utilized 5-layers neural network structure to reproduce accurately the basic data. The average color error is 1.4012 for the output of the model and the actual measurement value, but this model needs to be improved to the whole color space. So this paper adopts the method of dynamic programming

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RGB color space to do the conversion of RGB color space to CIE L*a*b* color space, to dynamicly divide the RGB color space to many subspaces to decrease the complicacy of input color space, and to avoid the local optimum phenomenon of neural network to some extent.

II. Selection on the Data of Modeling Color Blocks and Testing Color Blocks

A. Selection on the Data of Modeling Color Blocks

This paper uses the basic data sets (56 colors) of reference [8] to replicate accurately the basic color of printing, and increase the number of modeling sample sets for dynamic dividing RGB color space. To uniformly divide the RGB color-axis respectively to four parts, the value of R, G and B take as 0, 64, 128, 192 and 255 respectively, a total of 125(or 5^3) sets of data. Thus there are 180 sampling points in the whole RGB color space (125+56=181, one of the sampling points is same as 56 colors).

By increasing the quantity of modeling samples to uniformly divide the RGB color-axis respectively to five parts, the value of R, G and B take as 0, 52, 104, 156，208 and 255 respectively, a total of 216(or 6^3) set of data. Thus there are 216 sampling points in the whole RGB color space (216+56=272, two of the sampling points are same as 56 colors).

Finally by uniformly dividing the RGB color-axis respectively to eight parts, the value of R, G and B take as 0, 32, 64, 96，128, 160, 192, 224 and 255 respectively, a total of 729(or 9^3) sets of data. Thus there are 729 sampling points in the whole RGB color space.

The three group data will be taken respectively as the basic data set to construct the dynamic neural network model.

B. Selection on the Data of Testing Color Blocks

The RGB color space is divided into 27 subspaces (or 27 sub cube) in order to test model accuracy of the color space conversion. Selecting the center of the cube is as a verification point of the verification model, there are a total of 27. The value of R, G, and B is 43, 129 and 213 respectively.

C. Measurement of Color Blocks

To proofread the monitor, and the color temperature of the monitor is 6500k. The color temperature of the lighting is 5000k. By CorelDraw the color blocks of modeling sample points and testing sample points is design. The each of the color blocks is 10×10mm and is measured in the CIE L*a*b* value by Eye-one spectrophotometer to obtain data collection.

III. Establishment of Dynamic Sub-space BP Neural Network Model and Accuracy Analysis

A. Establishment of the Model

This paper uses the BP neural network model construction which is described in the reference [8]. That is 4 layer BP net work structure (output layer and 3 hidden layers). Each hidden layer includes 20 nodes. The nerve cell transfer-function in hidden layers was chosen as logsig ( ) of log-sigmoid function, the nerve cell transfer-function in output layers is chosen as purlin ( ), and the training function is chosen as trainrp function with elastic gradient descent methods. On the training parameters, we choose the maximum training time as 1000, the training precision as 1, and the training velocity as 0.2. To export the 27 testing color blocks by this model, the average color error is 14.85 when the total sample size is 56. The maximum color error reaches 35.66, and the minimum color error reaches 0.51. Fig.1 shows the color error histogram of model conversion value and the actual measure value of testing color blocks. It is necessary to improve the transformation accuracy of the model.

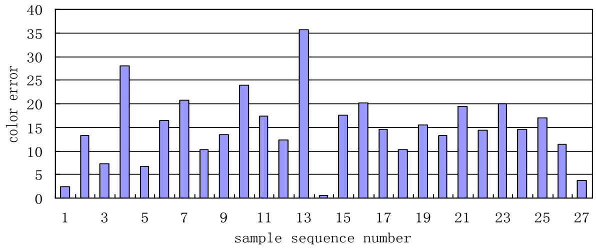

Fig.1 the total points of sample are 56, the color error schematic diagram of model output value which are directly uses BP neural network to do the conversion and measurement value

Increasing the number of training sample to 180, the model training gets more difficult, and the time of training is prolonged. Training samples are difficult to achieve the precision of output. Thus the method of automatic dynamic division of the subspace is adopted to further improve the model conversion accuracy.

To input x(r,g,b) point in the RGB color space, then calculate the distance between x and color space modeling points. Select those color space modeling points which have the smallest distance with x 15, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 points. To x point of a circle, include respectively 15， 20，30，40，50，60，70，80，90，100，110 and 120 modeling points as radius. The RGB color space is dynamically divided into many subspaces according to the input, and adopts the 4-layers BP neural network structure which is described earlier in the subspace, and establishes the BP neural network color space conversion model which is based on dynamic subspace division.

B. Analysis of the Model Precision

When the total sampling points reach 180, input the data of 27 testing color blocks. The relationship of model subspace bears with the number of model points and the average color error of testing color blocks is in fig.2(the color error formula select CIE 1976). From the fig.2 we can see that the average color error of testing color blocks decreases gradually with the increase of modeling points in the subspace.

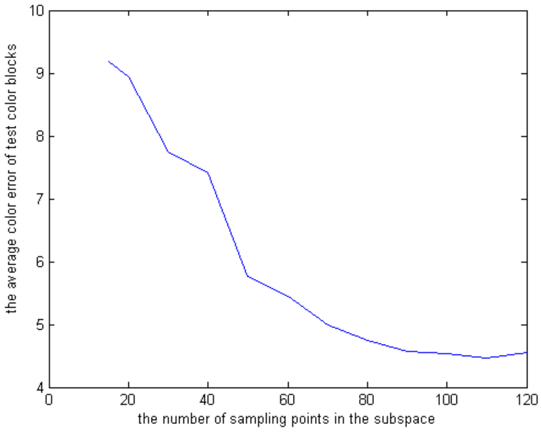

Fig.2 the relationship curves on the number of sample points in the subspace and the average color of test color blocks when the total sampling points are 180

When the number of modeling points in the subspace is up to 70, the average color error of the model output is less than 5. With the increasing of modeling data in the subspace, the change in color error of testing color blocks becomes flat. When there are 15 modeling points in the subspace, the average color error of testing color blocks is 9.19. When there are 120 modeling points in the subspace, the average color error is up to 4.56. When the number of sampling points in the subspace is up to 130, the subspace BP neural network model training is more difficult, and the time of training is prolonged. Training samples is difficult to achieve the precision of output. Fig.3 to Fig.8 show the distribution map of 27 testing color blocks when there are 20, 40, 60, 80, 100 and 120 points in the subspace respectively.

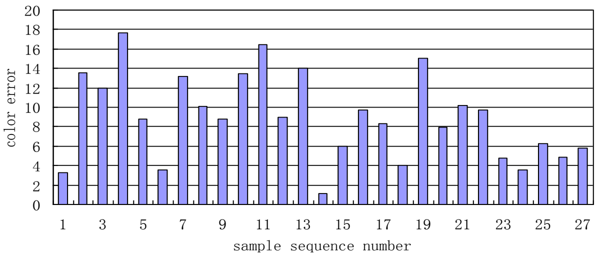

Fig.3 the total sampling points are 180 and there are 20 sample points in the subspace, the color error schematic diagram of model output value and measurement value

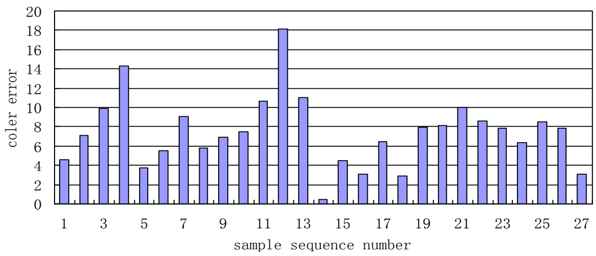

Fig.4 the total sampling points are 180 and there are 40 sample points in the subspace, the color error schematic diagram of model output value and measurement value

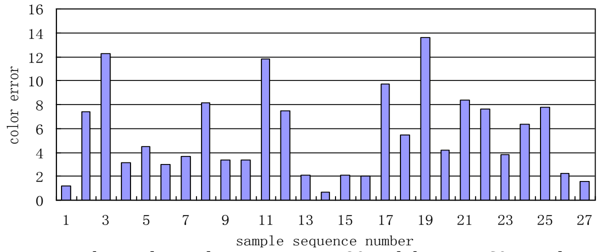

Fig.5 the total sampling points are 180 and there are 60 sample points in the subspace, the color error schematic diagram of model output value and measurement value

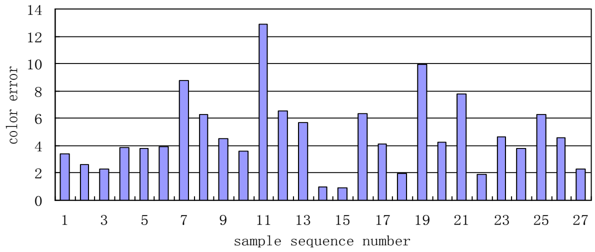

Fig.6 the total sampling points are and there are 80 sample points in the subspace, the color error schematic diagram of model output value and measurement value

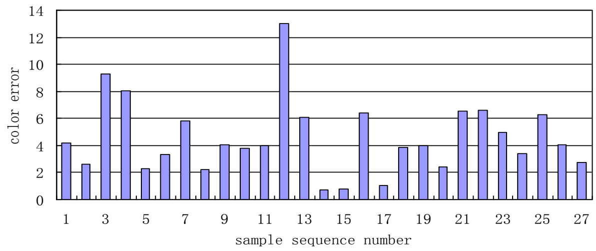

Fig.7 the total sampling points are 180 and there are 100 sample points in the subspace, the color error schematic diagram of model output value and measurement value

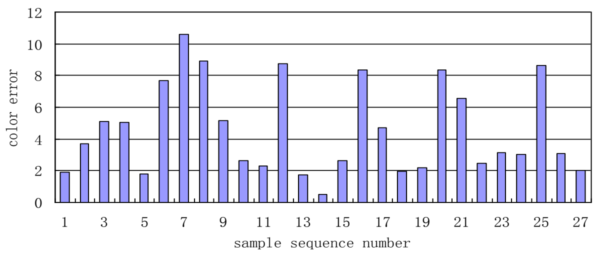

Fig.8 the total sampling points are 180 and there are 120 sample points in the subspace, the color error schematic diagram of model output value and measurement value

When the total sampling points are 270, input the data of 27 testing color blocks. The relationship between model subspace including the number of model points and the average color error of testing color blocks is in fig.9 (the color error formula select CIE 1976). From the fig.9 we can see that the average color error of testing color blocks decreases gradually with the increase of modeling points in the subspace. The conversion accuracy of the model is greatly increased when there are same sample points in the subspace compared with figure 2. When the numbers of modeling points in the subspace are up to 60, the average color error of the model output is less than 4. The change in color error of testing color blocks becomes flat with the increasing of modeling data in the subspace. When there are 120 modeling points in the subspace, the average color error is up to 3.87. The Fig.10 to Fig.15 show the distribution map of 27 testing color blocks when there are 20, 40, 60, 80, 100 and 120 points in the subspace respectively.

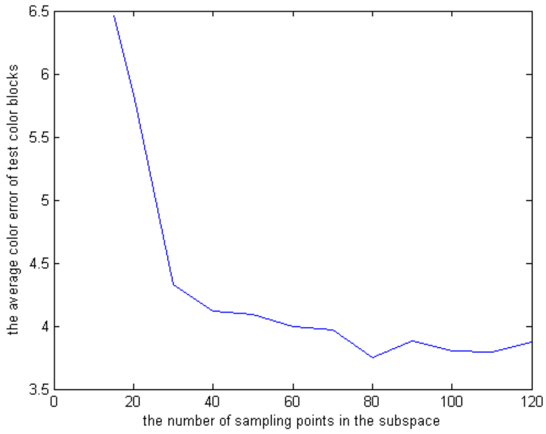

Fig.9 the relationship curves on the number of sample points in the subspace and the average color of test color blocks when the total sampling points are 270

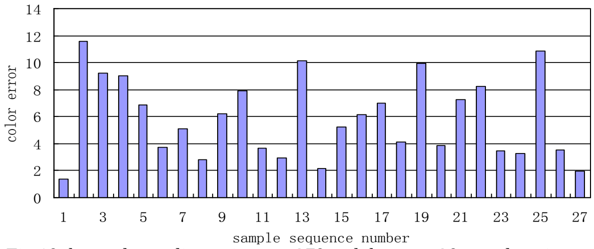

Fig.10 the total sampling points are 270 and there are 20 sample points in the subspace, the color error schematic diagram of model output value and measurement value

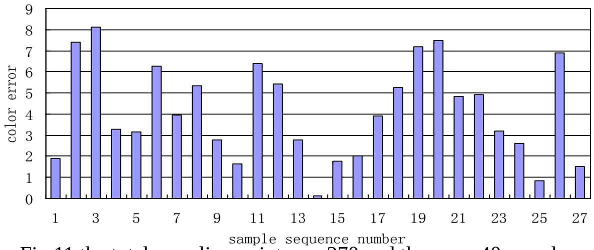

Fig.11 the total sampling points are 270 and there are 40 sample points in the subspace, the color error schematic diagram of model output value and measurement value

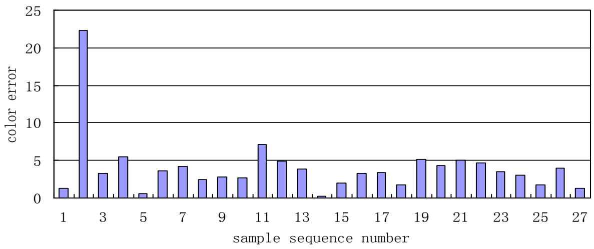

Fig.12 the total sampling points are 270 and there are 60 sample points in the subspace, the color error schematic diagram of model output value and measurement value

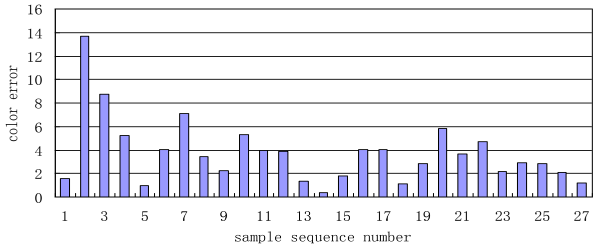

Fig.13 the total sampling points are 270 and there are 80 sample points in the subspace, the color error schematic diagram of model output value and measurement value

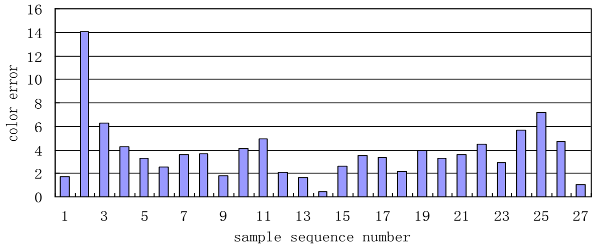

Fig.14 the total sampling points are 270 and there are 100 sample points in the subspace, the color error schematic diagram of model output value and measurement value

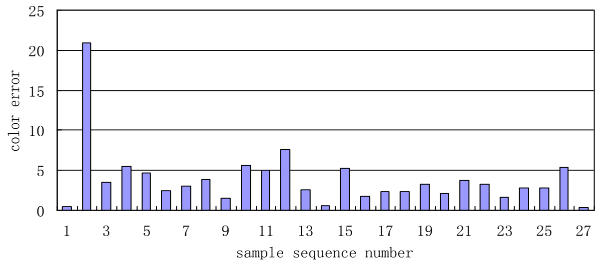

Fig.15 the total sampling points are 270 and there are 120 sample points in the subspace, the color error schematic diagram of model output value and measurement value

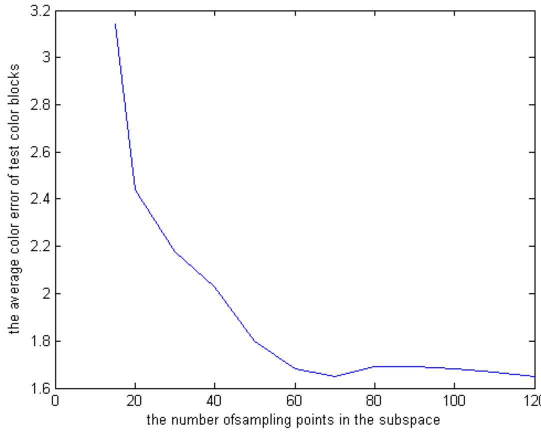

Fig.16 the relationship curves on the number of sample points in the subspace and the average color of test color blocks when the total sampling points are 729

To increase the number of modeling sample points in 729, and input the data of 27 testing color blocks. The relationship between model subspace including the number of model points and the average color error of testing color blocks is shown in fig.16 (the color error formula select CIE 1976). From the fig.16 we can see that the average color error of testing color blocks decreases gradually with the increase of modeling points in the subspace. The conversion accuracy of the model is greatly increased when there are same sample points in the subspace compared with fig.9. When the number of modeling points in the subspace is up to 50, the average color error of the model output is less than 2.

The change in color error of testing color blocks becomes flat with the increasing of modeling data in the subspace. When there are 120 modeling points in the subspace, the average color error is up to 1.65. Fig.17 to Fig.22 show the distribution map of 27 testing color blocks when there are 20, 40, 60, 80, 100 and 120 points in the subspace respectively.

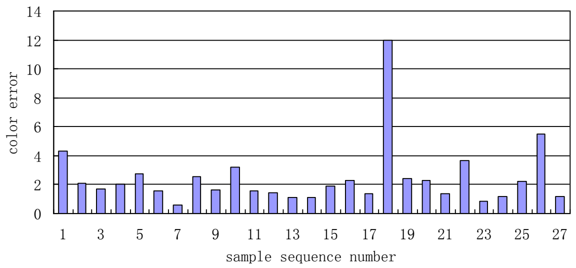

Fig.17 the total sampling points are 729 and there are 20 sample points in the subspace, the color error schematic diagram of model output value and measurement value

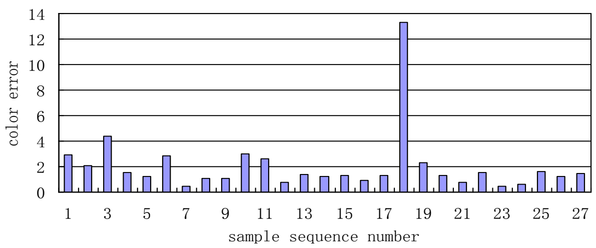

Fig.18 the total sampling points are 729 and there are 40 sample points in the subspace, the color error schematic diagram of model output value and measurement value

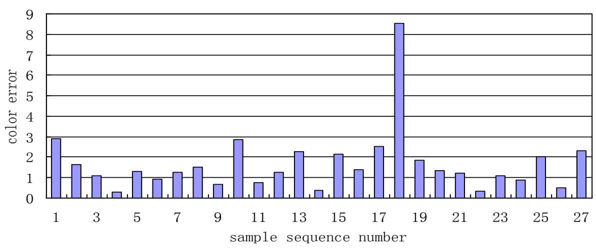

Fig.19 the total sampling points are 729 and there are 60 sample points in the subspace, the color error schematic diagram of model output value and measurement value

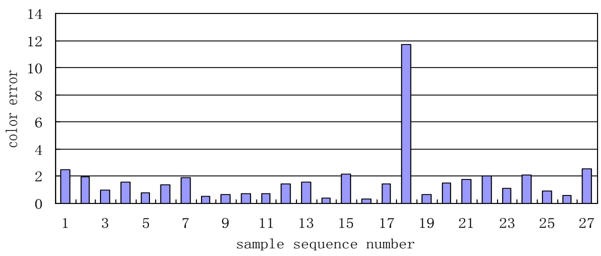

Fig.20 the total sampling points are 729 and there are 80 sample points in the subspace, the color error schematic diagram of model output value and measurement value

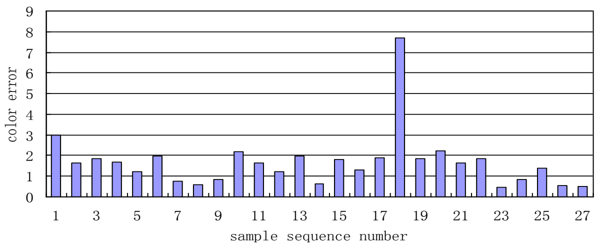

Fig. 21 the total sampling points are 729 and there are 100 sample points in the subspace, the color error schematic diagram of model output value and measurement value

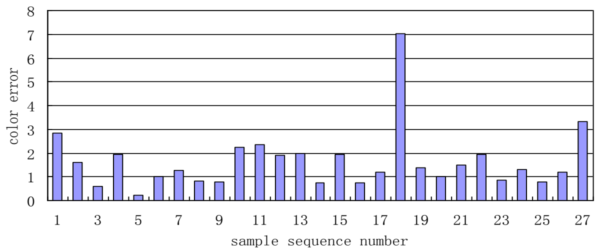

Fig. 22 the total sampling points are 729 and there are 120 sample points in the subspace, the color error schematic diagram of model output value and measurement value

Thus we can draw that with the increasing of number of sample points in subspace the accuracy of model conversion is higher and higher. When it reaches to some numerical value, the trend of modeling conversion accuracy slows, and with the increasing of sample point's number in subspace, the BP neural network model training gets more difficult. Training samples is difficult to achieve the precision of output. In addition, with the increasing of total sample points, the smaller the subspace which includes the same sample number are, the higher model conversion precision becomes.

IV. Summary

In this study the method of dynamically divided subspace is adopted to conduct the conversion of RGB color space and CIEL*a*b* color space and the number of sample points in the RGB color space is 180, 270 and 729 respectively. When the total points of the sampling are 729 and there are 120 sampling points in the subspace, the average color error is up to 1.65.

The color space conversion model which is based on dynamically divided subspace can construct expediently model structure which has different transformation accuracy according to the requirement. But the number of sampling points determines the accuracy of model transformation. In principle the number of sampling points can not be infinitely expanded. Thus there are limitations on the further improvement of the model accuracy. So the next step should be emphatically solving the problems of deficiency in the number of space sampling points for further improvement the accuracy of model conversion.

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