Influencing Factors of Color Prediction of Cellular Neugebauer Model

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Abstract. The cellular Neugebauer model at present is a research focus in the field of color reproduction. Aiming at the research of color reproduction, this paper analyzes the multiple influencing factors on the color prediction of cellular Neugebauer modelfor the parameter optimization scheme. The cellular Neugebauer models based on different cell-levels, different numbers and locations of test samples, and the different cellular correction schemes were simulated on MATLAB. The experimental result indicates that the model accuracy increases with the increase of cell-levels, but no longer changes significantly at 4 or 5cell-level. In addition, the numbers and locations of test samples and the cellular correction schemes have no effective influence on the model accuracy. This paper finally determined to use the five-level cellular division, the cell-center sampling and the uniform correction scheme (all cells share one correction index) as the optimal parameter scheme. The color prediction accuracy of the optimal cellular Neugebauer model was evaluated by comparing with the i1 Profiler software and cellular neural network model.

Keywords: Model accuracy · Cellular neugebauer model · Correction index

1 Introduction

The accurate color reproduction is significant to improve the printing quality. In digital printing process, the color conversion accuracy directly decides the color reproduction accuracy [1]. According to the principle of algorithm, the existing color conversion model can be divided intoNeugebauer model, the neural network model [2, 3] and the polynomial regression model [4]. Neugebauer model can also be divided into the model based on Tristimulus values [5] and Spectrum [6]. These models have different the number of samples, modeling algorithm and computing speed. With high color conversion accuracy, the cellular Neugebauer model at present is a research focus in the field of color reproduction.

This paper studies the multiple influencing factors on the color prediction of the cellular Neugebauer model, and provides the optimal parameter scheme. With the output device calibration software and the CMYK raster imaging processors, the cellular

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Neugebauer models based on different cell-levels, different numbers and locations of test samples and the different cellular correction schemes are simulated on MATLAB. The three influencing factors is evaluated by experiments, and the optimal parameter scheme is determined. The color prediction accuracy of the optimal cellular Neugebauer model is evaluated by comparing with the i1 Profiler software andthe neural network model.

2 Experimental Method

2.1 Experimental Principle and Method

The CMYK cellular Neugebauer equation is corrected with the Yule Nielsen Index. Within a certain range, through incremental and iterative calculation of the correction index, the color difference between the measured values and the calculated values (predicted values) of the printing samples is compared, and the index corresponding to the minimum color difference is determined as the optimal correction index of the Neugebauer equation [7].

The all color samples of the experiment include training samples, test samples and evaluating samples. The training samples refer to the vertices of each cell, and the CIEXYZ values of all the vertices of a cell are used to construct the Neugebauer equation of the cell. The test samples are mainly used to test the color prediction accuracy of the Neugebauer equation with different correction index, so as to determine the optimal correction index. Then, the optimal correction index is evaluated by test the accuracy of the corrected cellular Neugebauer equation. In this paper, the CMYK color target ECI 2002 and it8. 7–3 are used as evaluating samples. The mean color difference between the measured value and the predicted value of the evaluating samples is used to indicate the color prediction accuracy of models.

Experiment 1: Determining the optimal cell-level. In theory, the Neugebauer equation of a small cell has higher accuracy than that of big cell, but the accuracy maybe doesn't increase linearly with the cell-levels. In the experiment, all the cells share one index (uniform correction scheme), the center point of each cell is used as test sample. The accuracy of different cell-levels are tested and evaluated.

Experiment 2: Determining the numbers and locations of test samples. The best accuracy maybe can't be obtained by the cell-center sampling because each cell has only one test sample. In order to obtain higher accuracy, we design the other two sampling schemes, as shown in Fig. 1. The accuracy of the three schemes are tested and evaluated in the experiment. Since the four-dimensional CMYK space is not easy to display, the paper used the three-dimensional CMY space to show the three different test-sampling schemes.

Scheme (1): Taking the unique center point "o" of the cell as the test sample; Scheme (2): Dividing the cell into four sub-cells, the five($2^2 + 1$) center points ("o", "a", "b", "c", "d") of the cell and its sub-cells were used as the test samples, as shown in Fig. 1. (1). Scheme (3): Dividing the cell into eight sub-cells, the nine($2^3 + 1$) center points("o", "a", "b", "c", "d", "e", "f", "g", "h") of the cell and its sub-cells were used as test samples, as shown in Fig. 1. (2). It is noted that there will be seventeen samples ($2^4 + 1$)

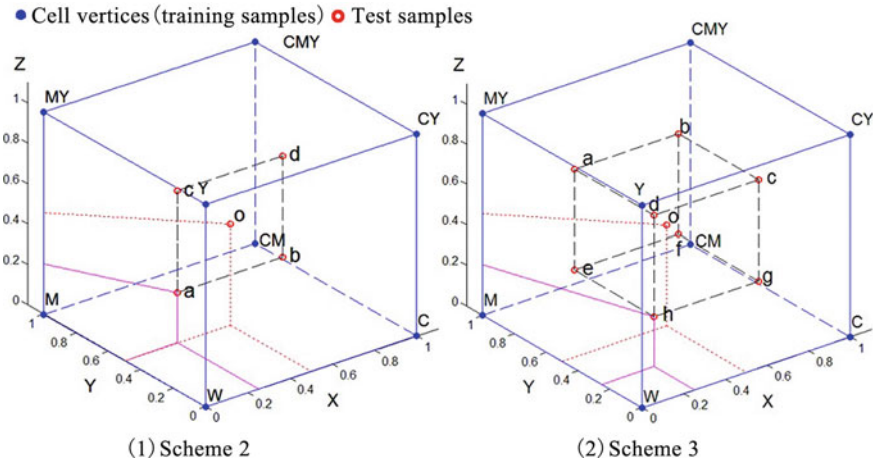

Fig. 1 The experimental schemes for test-sampling

in case of CMYK 4D cell. We can pick up nine samples (including "o") randomly from the seventeen samples.

Experiment 3: Determining the optimal cellular correction scheme. The uniform correction scheme is maybe inaccurate because all cells share only one correction index. In another correction scheme, each cell maybe has different correction index because they are individually corrected. The scheme maybe has high accuracy, but it maybe bring a large amount of calculation.

2.2 Experimental Preparation

The main devices, instruments, software and consumable material used in the paper are listed as below: ① Printing device and consumable material: EPSON Pro 7880 Digital Inkjet Printer, High-gloss paper(230g/m^2); ② Colorimeter: X-Rite i1 ISIS 2 Spectrophotometer;③ Color Management Software: X-Rite i1 Profiler; ④ Printer Correction Software: MtColor-PRO; ⑤ CMYK Rasterizing Processor (Used to control the printing device for CMYK four-color output): Mt RIP V6.0.

Before the experiment, the repetition accuracy of printing and measuring device need to be measured. According to the test results, it is necessary that all samples were placed in a closed, dark dry environment for more than 63 h and printed all at once for avoiding repeated errors and having stable and accurate measurement results.

3 Analysis and Evaluation of Experimental Results

3.1 Influencing Analysis of the Cell-Levels

Figure 2 shows that the trend of model accuracy with cell-levels. We can see that the color prediction accuracy of the model is significantly improved with the increase of cell-levels. When the cell-level is 1, 2, 3 and 4, the color difference vary considerably

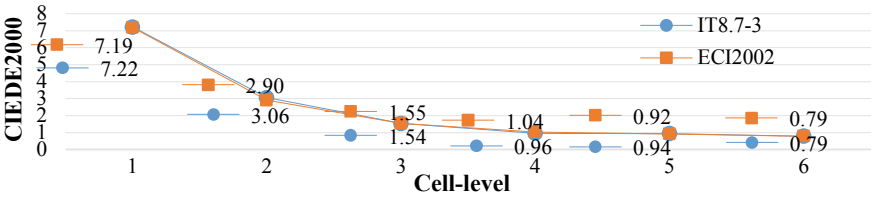

Fig. 2 The trend of model accuracy with cell-levels

(0.5 to 4). However, at 4, 5 and 6 cell-level, its variation range is less than 0.2, which is within the range of systematic error. It indicates that the color prediction accuracy has been gradually stabilized after 4 or 5 cell-level. Considering the model accuracy and the number of samples, it is more suitable to use the five-level cellular Neugebauer model to calculate the predicted color value.

3.2 Influencing Analysis of the Test-Sampling

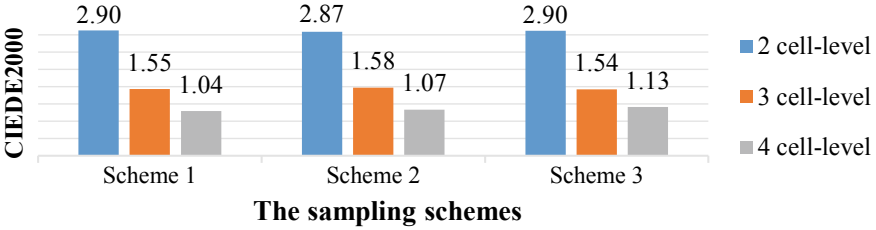

Fig. 3 The accuracy data of different sampling schemes

Figure 3 shows the accuracy data of the three sampling schemes in case of the uniform correction index. It can be seen that the color differences among the three schemes are less than 0.1 in case of the same cell-level. It indicates that the other two sampling schemes have little impact on the model accuracy, so we determine to use the center point of each cell as the optimal test samples.

3.3 Influencing Analysis of the Cellular Correction Schemes

The prediction accuracy of the two different cellular correction schemes is shown in Fig. 4. On the basis of experiment 2, the color difference between the uniform correction and individual correction is less than 0.2, which is within the system error range. It indicates that the color prediction accuracy of the cellular Neugebauer model has not been improved significantly even if each cell is corrected individually.

3.4 Evaluation of Model Accuracy

Based on the above experimental analysis, this paper determined the five cell-level, the cell-center sampling and the uniform correction index as the optimal parameters. In

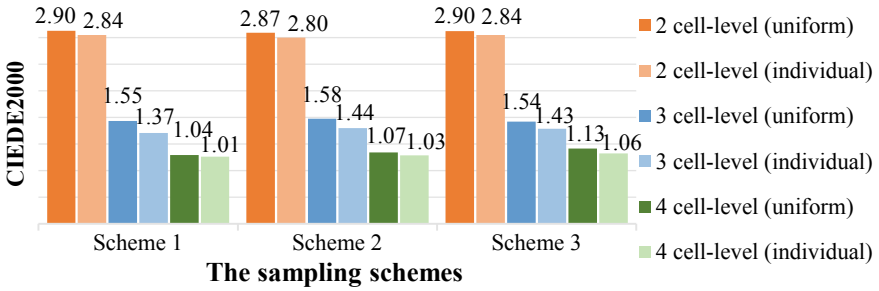

Fig. 4 The color prediction accuracy of the two cellular correction schemes

order to enhance the persuasiveness of the evaluation, under the condition of the same number of test samples, the paper simulated the ICC color conversion of "i1 Profiler" (professional color management software) and Neural Network Modelon MATLAB. On the other hand, we calculated the average value of the maximum color difference of top 4% to evaluate the stability of color prediction.

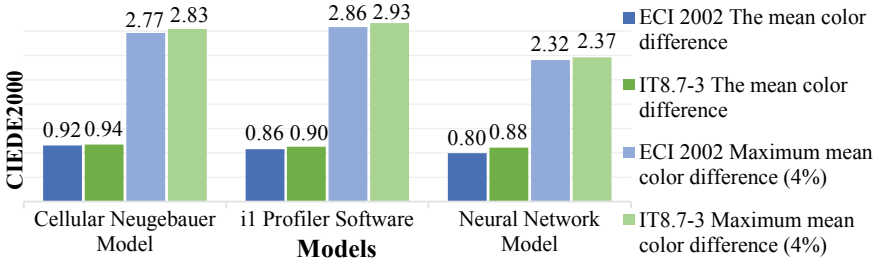

Fig. 5 The color prediction accuracy on different models

Figure 5 shows the accuracy comparison of the three different models. The mean color difference of all models are less than 1 CIEDE2000 color units, and the difference among them are less than 0.15, which is within the system error range. The models have good stability because they have the similar maximum mean color difference.

4 Conclusions

In order to study the above influencing factors on color prediction accuracy of the cellular Neugebauer model, this paper takes the CMYK ink-jet printer as an example, and simulates the cellular Neugebauer model with different parameters on MATLAB. The test results show that the model accuracy can be improved with the increase of cell-levels, but the accuracy becomes stable gradually after the 4 or 5 cell-level. Then, as the other two influencing factors, both the test samples and the cellular correction scheme have no significant effect on the model accuracy. Based on the above experimental analysis, this paper determined the five-level cellular division, the cell-center sampling and the uniform

correction index as the optimal parameters. By comparing with i1 profiler software and cellular neural network model, it can be proved the optimal cellular Neugebauer model can meet the requirements of printing color reproduction.

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