Viewed Lightness Prediction Model of Textile Compound Multifilament

Yujuan Wang[1,2], Jun Wang[2], Jiangping Yuan[1,3], Jieni Tian[1], and Guangxue Chen[1](✉)

[1] State Key Laboratory of Pulp and Paper Engineering, South China University of Technology, Guangzhou, China
chengx@scut.edu.cn

[2] College of Textiles, Donghua University, Shanghai, China

[3] Institute for Visualization and Data Analysis, Karlsruhe Institute of Technology, Karlsruhe, Germany

Abstract. To facilitate the design of the textile compound multifilament before spinning, a viewed lightness prediction model was proposed. To examine the prediction effect, 7 different color monofilaments were used to simulate 21 multifilaments according to a simplified multifilament model. Then, the mixed lightness of these multifilaments were calculated by adding the weighted tristimulus values of the surface color of a multifilament, and scaled by 12 observers in the subjective experiment. The average difference between the calculated and scaled lightness was 0.39. In order to determine the significant factors affecting the lightness difference, the Pearson's correlation analysis was conducted. The results show that the lightness difference decreased with the increase of the calculated CIE lightness (L*) or yellow-blue value (b*) of the multifilament. Finally, the optimized viewed lightness prediction model was derived by the SPSS analysis. The average lightness difference was reduced to -0.01, indicating this model can provide reliable prediction for personalized compound multifilament.

Keywords: Lightness Prediction · Textile Filament · Optical Color Mixing · Visual Assessment

1 Introduction

In order to color textiles, dyeing, color spinning or dope dyeing are usually used. However, these methods have many disadvantages, such as color difference, uneven color mixing or waste of raw materials [1]. To address this issue, our team [1, 2] suggested producing multifilament, named color compound multifilament, by dying the monofilaments directly into different colors with different proportions and arrangements. However, this new method is still limited to trial spinning at present, which is exceedingly laborious and time-consuming. On the other hand, the color is ultimately assessed by human eye. Therefore, there is a strong need to derive a prediction model of the multifilament, which can express the viewed color.

P. Zhao et al. (eds.), *Advances in Graphic Communication, Printing and Packaging Technology and Materials*, Lecture Notes in Electrical Engineering 754,
https://doi.org/10.1007/978-981-16-0503-1_17

The process of fiber color mixing includes both additive color mixing and subtractive color mixing. There have been many researches on additive color mixing and subtractive color mixingmodels [3, 4]. As for the research on the color mixing model based on the characteristics of the human eyes, there have been more and more reports in recent years. Takako et al. [5] introduced different filters to simulate the spatial filtering characteristics of human eyes, but the calculation process is too complex, and the cut-off frequency is need to be determined. Chu et al. [6] developed a model to simulate the spatial color blending process of digital camouflage. The color mixing of camouflage clothing is point-to-point color mixing, while the color of the spun filament is continuous in the length direction. Chae et al. [7] investigated many factors of individual yarn colors and their blends on the color appearance of woven fabrics and proposed several color appearance prediction models. However, these predictive models need to use the colorimetric values of physical fabric, the process of spinning filament and then weaving into cloth belongs to trial spinning. Therefore, these models do not bring great convenience to the product design before spinning.

This paper mainly studied the viewed lightness prediction model of the multifilament, and the prediction models of other colorimetric parameters can refer to the research method used in this paper. Firstly, the surface colors of the multifilament were calculated with the monofilaments. Then the mixed lightness of the surface colors was calculated, and estimated by observers in psychophysical experiment. Finally, the lightness difference between the calculated and estimated lightness was analyzed, and the viewed lightness prediction model was proposed.

2 Methodology

2.1 Simulating Multifilament

In this study, the monofilament was assumed to be an opaque cylinder (Fig. 1a), and the multifilament was composed of two different color monofilaments arranged in a fan shape (Fig. 1b). Besides, the surface overlaps between the monofilaments were ignored. So, the surface color appearance changed from Fig. 1c, d.

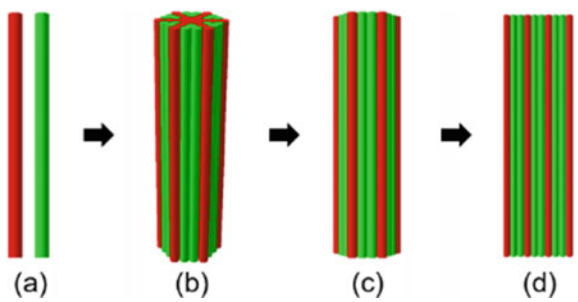

Fig. 1 The simulating multifilament: **a** the monofilaments, **b** the 3D model, **c** the surface color appearance, and **d** the simplified surface color appearance of a single multifilament

Since the monofilament was assumed to be opaque, the surface color of the multifilament was determined by the monofilaments on the surface of the multifilament. The ratio of the fan-shaped angle of the monofilament determines the distribution ratio of the monofilament on the surface. Besides, the surface color is repeated by the basic color unit. Therefore, according the ratio of the fan-shaped angle of the monofilament, this article designed 42 basic units to simulate the surface colors of the single multifilament (Table 1). The test images were formed by arranging these multifilaments in parallel.

Table 1 Designs of 42basic color appearance units

Monofilament arrangements						
RY	RRRY	RG	RRRG	RRB	RRRRB	RK
RRRK	RRW	RRRRW	RRGr	RRRRGr	YYG	YYYYG
YB	YYYB	YYK	YYYYK	YW	YYYW	YGr
YYYGr	GGB	GGGGB	GGK	GGGGK	GW	GGGW
GGr	GGGGr	BBK	BBBBK	BW	BBBW	BGr
BBBGr	KW	KKKW	KKGr	KKKKGr	WWGr	WWWWGr

Note: The letter R, G, Y, B, K, W, Gr refer to the red, green, yellow, blue, black, white and gray monofilaments, respectively

The colors of these monofilaments are often used in color spinning factories, and were measuredby the spectrophotometry (Datacolor 650 spectrophotometer, USA). The tristimulus values of these monofilaments were summarized in Table 2.

Table 2 Tristimulus values of the monofilaments

	Red	Yellow	Green	Blue	Black	White	Gray
X	23.61	57.91	5.38	6.1	2.06	76.77	9.61
Y	13.31	60.27	9.27	4.66	2.2	81.18	10.16
Z	4.32	7.25	8.59	50.19	2.59	82.75	11.63

2.2 Calculating and Estimating Mixed Lightness

Since the multifilaments were displayed on the monitor, the mixing color of the multifilament was the sum of the weighted surface colors of the multifilaments. Therefore,the tristimulus values of the mixing color can be calculated by the following formulas:

$$X_m = \sum_i (n_i * X_i) \quad (1)$$

Here, X_m represents the tristimulus values of the mixing color. The n_i and X_i refers to the tristimulus values of the primary color i, respectively. In order to facilitate data analysis, the tristimulus values were converted into CIE L*a*b* and CIE L*C*h° using the functions in MATLAB software.

In order to estimate the mixed lightness, a subjective experiment was carried out in a darkened room. A 21-inch NEC liquid crystal display monitor was used and calibrated by the X-rite Eyeone pro display calibration system. The monitor was set to a gamma of 2.2, a white point of 6500 K, and a luminance of 100 cd/m^2.A graphical user interfaces (GUI) was established and run by the MATLAB R2014a (Fig. 2). By sliding the sliders, the color of the reference image was adjusted until there was no perceivable color difference between the test and reference images. All the elements were placed on a mid-gray background with L^* of 50 [7].The wide of a single monofilament was 0.233 mm. The viewing distance was set to 2.33 m. The viewing angle was set to 0° from the normal of the display, and the size of the test image was 256 × 256 pixels.

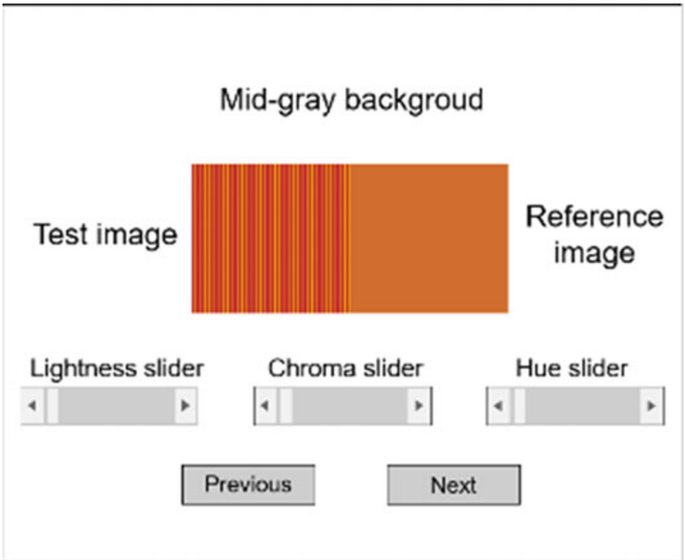

Fig. 2 The GUI display for color appearance assessment

Thirteen observers, who had normal color vision color vision according to the X-Rite color challenge and hue test, were trained for two hour before the experiment. The test image was presented in random order. The experiment was repeated within one week. The coefficient of variation (CV) of the observer accuracy and repeatability of the lightness were 1.15 and 2.14, which were satisfactory compared with that in other studies [8].

3 Results and Discussion

3.1 Comparison of Estimated and Calculated Lightness

The mean and median of ΔL* between the estimated and calculated lightness were 0.39 and −0.17, respectively, which were small. However, the distribution of the ΔL* was relatively scattered, and there were several outliers.In order to further investigate the effectson the lightness of the multifilament, the Pearson's correlation analysis between the ΔL* and the calculated CIE lightness L*, redness-greenness a*and yellowness-blueness b* was conducted. The significant factors at a significance level of 0.01 found were the mixed L* and b*.

3.2 Effects on Lightness Difference

The lightness difference ΔL^* between the estimated and calculated lightness of the multifilaments was plotted against the calculated mixed CIE lightness L_m^* in Fig. 3a and CIE yellowness-blueness b_m^* in Fig. 3b. From the Fig. 3a, b, it can be found that the relationships between the ΔL^* and L_P^*, ΔL^* and b_P^* was similar. They were both that the ΔL^* decreased with the increase of the L_P^* or b_P^* in general. This shows that for multifilament with lower lightness or bluish color, the viewed lightness was higher than the calculated lightness, while for multifilament with higher lightness or yellowish color, the viewed lightness was similar to the calculated lightness.

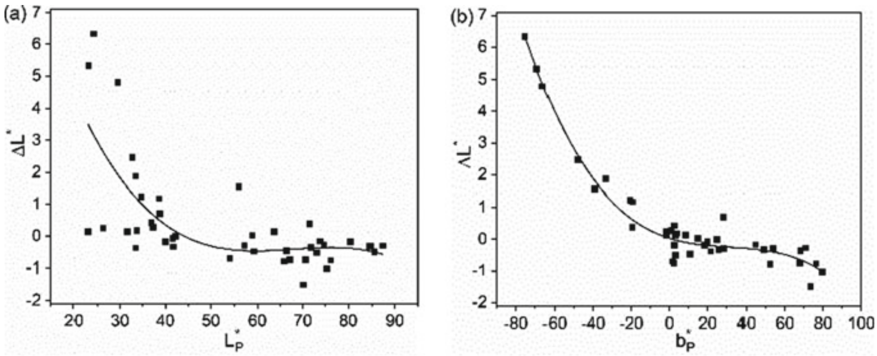

Fig. 3 The relationship between: **a** the calculatedlightness L_P^*, **b** the calculated yellow-blueness b_P^* and the lightness difference ΔL^* between the estimated and calculated lightness

4 Optimizing

In order to obtain a more accurate lightness prediction model, the mixed lightness calculated by the additive color mixing formulas was optimized with the stepwise regression analysis of the statistical product and service solutions (SPSS) software. The optimization lightness prediction model was derived, as shown in Eq. 2.

$$L_V^* = -0.611 + 1.001 \times L_P^* - 0.04 \times b_P^* + 0.036 \times c_P^* \quad (2)$$

Here, L_P^*, b_P^* and c_P^* were the CIE lightness, yellow-blue and chroma of the multifilamentconverted from the tristimulus values calculated by Eq. 1.It can be found in Fig. 4 that the mean and median of the ΔL^* from the optimization lightness prediction model were -0.01 and -0.04, respectively. Besides, the distribution of the ΔL^* was more concentrated, and there were no outliers.

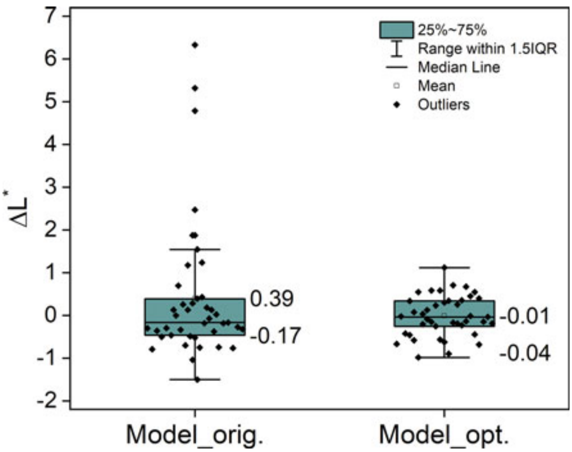

Fig. 4 Comparison of the lightness difference between the estimated and the calculated by the additive color mixing algorithm and by the optimized algorithm

5 Conclusions

In this article, aviewed lightness prediction model was proposed for the textile compound multifilament, which was the function of the colorimetric values of the mixing color of the multifilament image.

By comparing the lightness viewed and calculated, it was found that for the multi-filament with lower lightness or bluish color, the viewed lightness was higher than the calculated lightness. While for the multifilament with higher lightness or the yellowish color, the viewed lightness was similar to the calculated lightness. The average lightness difference between the lightness estimated and calculated by the prediction model was -0.01, indicating the model performs very well in predicting the viewed lightness of the multifilament.

It is worth noting that the actual distribution of the monofilaments is very complicated. This is exactly what our team is studying.

Acknowledgements. This work has been financially supported by the Natural Science Foundation of China (Grant No. 61973127), Guangdong Provincial Science and Technology Program (Grant No. 2017B090901064), and Chaozhou Science and Technology Program (Grant No. 2020ZX14).

References

1. Wang Q.H., Li W.G., Gan X.H., et al. (2019). Compound filament and its preparation technology: China, 109112655. 01.01.
2. Pi F.D., Li W.G., Liao H., et al.(2019).The collocation colored yarns of polypropylene and their key preparation techniques research. Technical Textiles, 37(3): 24–30.
3. Wang YJ, Ma C, Liu JY et al (2017) Matching color technology of color blended yarn based on modified Stearns-Noeche model. Journal of Textile Research 38(10):25–31

4. Ma C, Wang YJ, Li JL et al (2017) Theoretical and practical analysis of fiber blend model in gray spun yarn. J Eng Fibers Fabr 12(2):28–38
5. Nonaka T., Matauda M., Hase T. (2007).color mixing simulator for display surfaces based on human color vision. proceedings of the Proceedings 21st European conference on modelling and simulation, Ivan Zelinka: ECMS, F.
6. Chu M, Tian S, Yun J et al (2016) An Approach of Characterizing the Degree of Spatial Color Mixture. Acta Armamentar II 37(7):1306–1311
7. Chae Y. (2019).The color appearance shifts of woven fabrics induced by the optical blending of colored yarns. Textile Research Journal, 0(00): 1–15.
8. Luo M.R., Clarke A.A., Rhodes P.A., et al. (1991).Quantifying colour appearance. Part I. Lutchi colour appearance data. Color Research & Application, 16(3): 166–180.