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MERGING DIGITIZATION TECHNOLOGY INTO JACQUARD FABRIC CREATION

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ABSTRACT:

Traditional jacquard fabric design has very much been a mechanical reproduction of hand-paintings under plane design mode, featuring limited color expression. In this paper, an innovative design method merging digitization technology named layered-combination design mode is introduced and illustrated. Directly borrowed from layered design method of digital image and corresponding color theory, this innovative design method theoretically can be divided into colorless mode and colorful mode two parts. Following design method of all-coloring compound structure invented specially for layered-combination design mode, several colorless single-

layer structures can be combined to form a compound structure, which enables digital jacquard fabric to express an inimitable digital effect of mega-level mixed colors. The results of study are not only of tremendous benefit to developing digital jacquard fabric toward the fulfillment of ever-demanding requirement of today's fabric creation, but also the possibility of opening creative horizon and aesthetical dimension for jacquard fabric design.

Keywords: digitization, jacquard fabric, design creation

1. INTRODUCTION

For thousands of years, figured woven fabric as well as the jacquard fabric (figured woven fabric produced by jacquard machine) has been designed in a plane design mode via the employment of through warp and weft threads which differ from that of multi-colour tapestry constructed with through warp but swivel weft threads. Design process begins with the object that handled through freehand design on pattern and color, and the purpose of the structural design for jacquard fabric was but to copy the effect of patterns and colors [1]. Limited by the craftsmanship of freehand, the design of traditional jacquard has always been a passive process for mechanical imitation, and the pattern and color of jacquard fabric are easily to be pirated by others. At present, the application of jacquard CAD system has improved the efficiency of jacquard fabric design, however jacquard CAD system was devised with the main purpose to aided structural design of jacquard fabric, in which design theory and processes still remained in the traditional plane design mode [2].

Digital jacquard technology includes aided-design technology representative of the jacquard CAD system, and digital production technology represented by electronic jacquard machine and new-generation weaving looms. Design and production processes are both subject to totally digital controlling [3], which provides a technological basis to innovate traditional plane design mode of jacquard fabric. Inspired by color mode of digital image and corresponding design methods, the innovative design method invented originally in this study for digital jacquard is so-called layered-combination design mode, whose design processes consists of two parts: colorless and colorful. Colorless and colorful here does not only refer to the color effect of jacquard fabric, but also to the design method that combines the design principle of digital image into jacquard fabric. In practice, the design of colorless digital jacquard is devised on the basis of the colorless mode (achromatic theory) of digital color theory and traditional single-layer woven structure; further combining several single-layer structures, the colorful digital jacquard fabric with a compound structure can be produced. In addition, in order to meet the technical requirement of layered-combination deign mode, an innovative design method of all-coloring compound structure was invented specially for creations of digital jacquard fabric Several design creations of digital jacquard fabric are presented in this paper to highlight the superiority of such innovative breakthrough.

2. DESIGN PRINCIPLES AND METHODS

2. 1. DESIGN PRINCIPLE AND METHOD OF COLORLESS DIGITAL JACQUARD

The design concept of colorless jacquard fabric was inspired by gray color mode and digital gray image design. According to color theory, achromatic color consists of black, white, and a series of neutral gray. Similarly, in digital color mode, any corresponding colorless image could be rendered and processed with the gray mode, which contains no color information such as hue, saturation, etc., but only one certain brightness that displays white color under maximum brightness value or black color under minimum value. In addition to this, all color images can be converted to an "achromatic effect" colorless image with various gray scales controlled by bit lengths. Under normal visual conditions, human eyes can distinguish an image of 64-100 scales grayness [4], so the grayness set at scale 64-256(6-8bit) may basically meet any requirement in the design of digital jacquard with colorless digital mode.

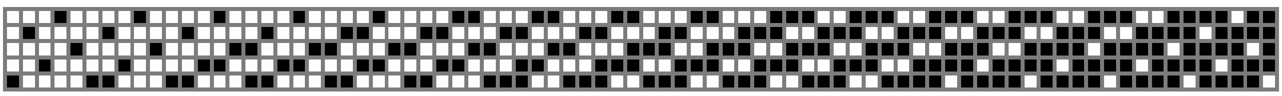


Figure 1: digital gamut weaves of five-thread satin.

Considering design of fabric construction, single-layer structure obviously shares certain common ground with gray image in terms of processing approach, that is, single-layer structure designed by shaded weaves could express the jacquard fabric in a way resembling the gray scale of gray image. As shown in Figure 1, five-thread satin can be designed into a whole series of weaves which can be further used to establish corresponding digital weave-database for structure design. This design method was defined as 'digital gamut weaves' and 'weave-database design', and designed gamut weaves have the same results as the processing method of computer gray image, In fact, the design approaches for gamut weaves might vary, but the number of weaves stays unchanged. This supplies the reference to building weave-database for colorless digital jacquard designing and also meets the requirement of intelligent matching between gray scales of digital image and weaves in weave-database. Table 1 shows data of gamut weaves that are allowed to establish under typical weave repeat.

Table 1: data of gray scales under different weave repeats.

Weave repeat	Gray scales (M=R)	Gray scales M=(1/2)R	Gray scales M=(1/4)R	Gray scales (M=1)
8×8	7	13	25	49
16×16	15	29	57	225
24×24	23	45	89	529
40×40	39	77	153	1521

Among them, R represents the number of weave repeat, M represents added value of weaving point among the weaves, the method of calculating gray scale is that when $M=R$, the formula is R-1; when $M=(1/2)N$, the formula is $2(R-1)-1$; when $M=(1/4)R$, the formula is $2[2(R-1)-1]-1$; when $M=1$, the formula is $R(R-2)+1$. This method applies to any digital weave-database established with all regular primary satins and twills. Obviously, when $M=1$, the digital weave-database will involve whole gamut weaves with all variations of a primary weave.

2. 2. DESIGN PRINCIPLE AND METHOD OF COLORFUL DIGITAL JACQUARD

The design principle of colorful digital jacquard fabric is detailed that perfectly integrating structure and color through color separation, layered design, and recombination. Design processes are shown in Figure 2, in which digital colorless image could be obtained under four methods, i.e., color separation by RGB primary colors, CMYK primary colors, designated colors and directly discoloring upon colorful image. When the gray images are designed, it can be selected for designing single-layer structure according to design requirement and characteristics of each gray scale image. After combining several colorless single-layer structures, a compound structure of jacquard fabric is taken shape, which is capable of expressing rich mixed color effect.

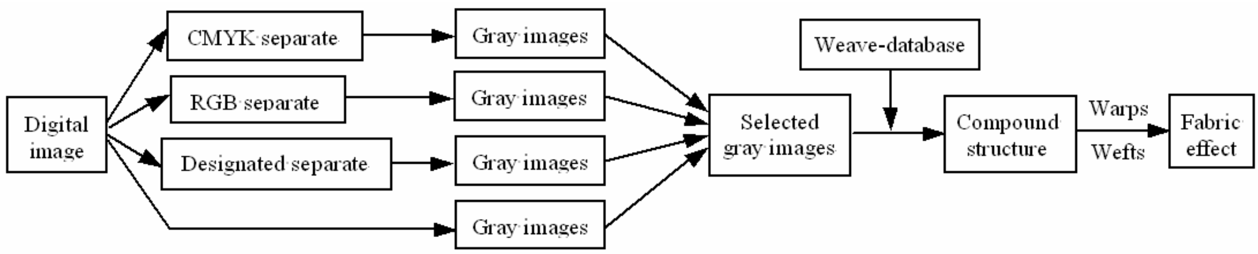


Figure 2: design processes of colorful digital jacquard fabric.

As stated above, the principle of structural design for colorful digital jacquard under-layered combination mode can be construed as the combination of colorless single-layer structure [5]. In Table 2, typical gray scales have been selected from different repeats of weaves, and combination data of mixed color has been calculated for the gray images upon two-layer, third-layer and fourth-layer, here H represents gray scale. If all layers apply the same gray scale, the multi-layer color mixture is calculated according to H^L, in which the L represents the number of layers. If the gray scales vary in any layer, the multi-layer color mixture is calculated under the product of multiplying the scales of all the gray scale layers. Table 2 utilizes the same gray scale. It is obvious that, if no covering effect of color threads caused in the process of color reproduction, the data of mixed color of the four layers of gray images all exceed mega-level, and color expression is far beyond the range identifiable by human eye [6]. It is unequaled by traditional hand drawing.

Table 2: relationship between gray scales and mixed color number under different layers.

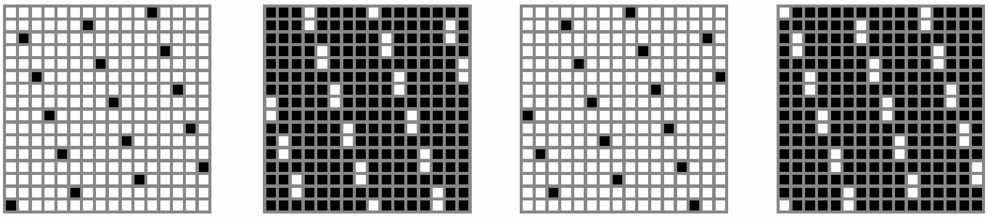
Weave repeat	Gray scale M=(1/4)R	Gray scale (M=1)	Mixed color 2-layer (H2)	Mixed color 3-layer (H3)	Mixed color 4-layer (H4)
8×8	-	49	2401	117,649	5,764,801
16×16	57	-	3,249	185,139	10,556,001
24×24	89	-	7,921	704,969	62,742,241
40×40	153	-	23,409	3,581,577	547,981,281

2. 3. DESIGN PRINCIPLE AND METHOD OF ALL-COLORING COMPOUND STRUCTURE

Jacquard fabric belongs to woven fabrics. The coloring principle of woven fabric is a kind of mixed coloring for non-transparent color, which is different from that of printing color and computer digital color [7]. If inter-covering effect is produced between warp and weft in fabric construction, and is beyond of control, the mixed color effect of fabric are undetermined because colors of warp and weft threads appearing on fabric surface will lose randomly. In order to obtain a stable coloring effect, the all-coloring compound structure is the most important for digital jacquard fabric designing in a layered-combination mode.

According to the non-transparent and mixed coloring principles of woven fabric, at a certain observation distance off side-by-side color threads, what one can see is but the mixed colors which vary with the float changing of color yarns. When the juxtaposed threads can be combined freely but no-covering effect created in the woven structure, such mixed coloring can be considered as a kind of combined threads with full color effect including all color information of the combined threads, and such fabric construction can be named as 'all-coloring structure'. On the basis of all-coloring structure, employing the limited color threads, digital jacquard fabric with accurate coloring effect that is designed in a layered-combination mode can be realized and to an extent that enables woven fabric to be designed as convenient and colorful as printing. The key technical point of all-coloring compound structure is that to set up a kind of technical all-coloring point for primary weaves in the course of gamut weaves design. If no all-coloring points are to be destroyed, any compound weave designed from primary weave will content with the no-backed structure and all-coloring effect. Similarly, shaded gamut weaves devising from primary weave and its weave-database can be built; so long as the all-coloring points exists, by the same combination method as that of compound single weave, the weaves in the different weave-databases can be combined freely and compound weaves can all content with no-backed effect. For this reason, further fixing starting points, the gamut weaves in the different weave databases obviously can be applied directly to design single-layer fabric structure. After combination of single-layer fabric structures in a way same as that of compound weave, the compound structure of digital jacquard fabric is capable of exhibiting the no-backed and all-coloring effect too.

Take 16-thread satin as an example to further explain the design method of setting all-coloring points [8]. As Figure 3 shows, there are two primary weaves with their respective all-coloring points set. First of all, select two primary weaves as I and II which have the same weave but with different starting points. Then, set the all-coloring points (similar to a kind of weave) for primary weave I in line with the feature of primary weave II, the method is to reverse the interlacing points in primary weave II and enhance it upward along warp direction, see (b) in Figure 3. Similarly, set the all-coloring point for primary weave II in line with the feature of primary weave I, the method is to reverse the interlacing points in I and enhance it downward along warp direction, see (d) in Figure 4.



(a) (b) (c) (d)

Figure 3: primary weaves and their all-coloring points.

After confirming two primary weaves and each of the all-coloring points, the gamut weaves used for structure design can be designed. Name the gamut weaves in the two weave databases respectively as 'basic weaves' and 'joint weaves'. On the basis of primary weave I shown in Figure 3, design a series of shaded weaves without destroying the all-coloring points and such weaves are named as basic weaves, see Figure 4. The enhancement direction is originated from the right to the left in order to make the interlacing points continuous and obtain the best interwoven balance. In the case of M=R, the number of basic weaves is the minimum as R-2; in the case of M=1, the number of basic weaves is the maximum as (R-2)+(R-3)×(R-1). Here, R represents weave repeat and M stands for the enhancement number of shaded interlacing points. Similarly, on the basis of the basic weave II as in Figure 3, joint weaves, a group of shaded weaves can be designed remaining the all-coloring points.

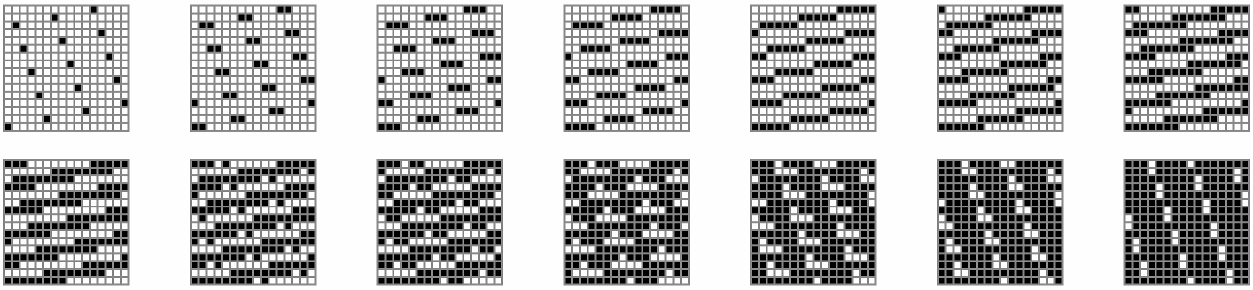


Figure 4: basic weaves design based on primary weave I.

Since all-coloring points existed in basic weaves and joint weaves, and they can content with no-backed effect after combination, such feature can be applied in structure design of digital jacquard fabric under layered combination mode. So long as the same starting point of the weave are confirmed, respectively the basic weaves and joint weaves can be used for designing single-layer structures of fabric; further combining the designed fabric structures by proper method, that is, the combination ratio in weft direction as 1:1 or 1:1 pairing (1:1:1:1 or 1:1:1:1:1:1) meanwhile the designed fabric structure of basic weaves and joint weaves is alternately ranged, the no-backed effect of interlacing points will be produced in the fabric construction after combination of single-layer structures. Such effect has no connection to the motifs of pattern, that is to say, all the patterns can be used to design all-coloring compound structure and produce digital jacquard fabric with full color effect. Moreover, in accordance with the feature of all-coloring structure, the maximum number of mixed color on the face of digital jacquard fabric with different repeat weaves can be accurately calculated by the formula $[(R\text{-}2)+(R\text{-}3)\times(R\text{-}1)]^L$, where L stands for the number of structure layers used for combination and is preferred as even numbers like 2, 4, 6, 8 and so on.

3. DESIGN CREATIONS OF DIGITAL JACQUARD FABRICS

The proposed innovation of layered-combination design mode and all-coloring compound structure design has solved essential technical issues of structure digitization designing for jacquard fabric. Also, it has laid the foundation for the digital jacquard weave fabric creation. Therefore, through developing creations of digital jacquard fabric, the application superiority of digital design technology comparing with tradition jacquard fabric can be fully manifested.

3. 1. FULL COLOR-SHADING PALETTE DESIGN

Figure 5 shows a kind of fabric effect of full color shading palette designed with four primary colors, in which the inimitable color shading effect, i.e., color varies when seen from different angles, cannot be simulated by other forms of artistic expression. In detail, the design concept is one that uses four primary colors - three primary colored threads (cyan, magenta and yellow) with one more thread in black color, coupled with the design of four layers all-coloring compound structure design, the full color-shading palette with three primary color hues can be realized, in which black color is applied for adjusting the color brightness. Corresponding design processes can be described of which, two primary weaves are designed and the all-coloring points for each of them are set up. Then, gamut weaves is designed and weave databases is built respectively on the base of two primary weaves. Last but not the least, gamut weaves are applied in two weave databases alternately to deign four single-layers fabric structures. Note that when one weave database is used for odd number fabric structural design, another one must be used for designing even number fabric structure. After combining four single-layer fabric structures in an order of 1:1:1:1, the compound fabric structure is obtained with capability of expressing four color shading effect. In this case, cyan, magenta, yellow and black colors were disposed as wefts whereas white color thread was used for warp. The completed fabric effect of full color shading palette is shown in Figure 5, even if the colors of threads vary, the color-shading effect still remain in compound fabric structure. So, conclusion is drawn that designing all-coloring compound structure under layered-combination design mode could meet the technical requirements of designing digital jacquard fabric with full color-shading effect, and also enabled digital jacquard fabric to produce printing-like color effect which was otherwise not possible to be processed by traditional plane design mode.

Figure 5: effect of full color shading palette.

3. 2. CREATIVE EFFECT DESIGN OF DIGITAL JACQUARD FABRIC

In terms of innovative design method and illustration stated above, obviously digital jacquard fabric design could process in both true effect simulation fabric design and creative effect fabric design. Comparing with the traditional design method, simulation effect design of digital jacquard fabric not only resulted in more true effect, but also greatly enhanced design efficiency. Creative design of digital jacquard fabric can fully embody the advantages/charisma of layered combination design mode, and can produce the picturesque effect fabric which is otherwise not possible to be produced by traditional way of designing.

Undoubtedly, jacquard fabric represents its artistic effect through woven texture. Based on the design change of digitization fabric structure, the unique art effect of digital jacquard fabric was created. Since layer-combination fabric structure is a kind of compound structure featuring no-backed all-coloring effect, if takes simulation design effect as the foundation, through changing disposition structure of each layer, the various artistic creations of digital jacquard fabric showing unique woven shot-effect were produced. Figure 6 shows real creative fabric effect of digital jacquard designed on the base of simulation design which was processed with disposition of CMYK primary colors. In this particular example, the applied design method was one by reducing coloring layer gradually from CMYK four layers (true color effect) to none (no coloring layer). A total of 16 color effects were taken shape within one layout; Similarly, Figure 7 shows another creative effect design case on the base of simulation design, the design method changes to one where the CMYK four coloring layers were gradually reversed from one layer to four layers (reversed effect). There are a total of 16 color effects within one layout. In addition, integrating 32 creative fabric effects of the above two designs may further generate other innovative effects design of digital jacquard fabric, for instance, by selecting all or partial effects freely from above 32 kinds of effects to carry out the combination effect design. The fabric effect designed following this design method is shown in Figure 8.

MYK	MY	Y	YK
MK	M	None	K
CMK	CM	C	CK
CMYK	CMY	CY	CYK

Figure 6: creative fabric effect designed by reducing coloring layers gradually

CMYK	CMYK	CMYK	CMYK
CMYK	CMYK	Reversed	CMYK
CMYK	CMYK	CMYK	CMYK
CMYK	CMYK	CMYK	CMYK

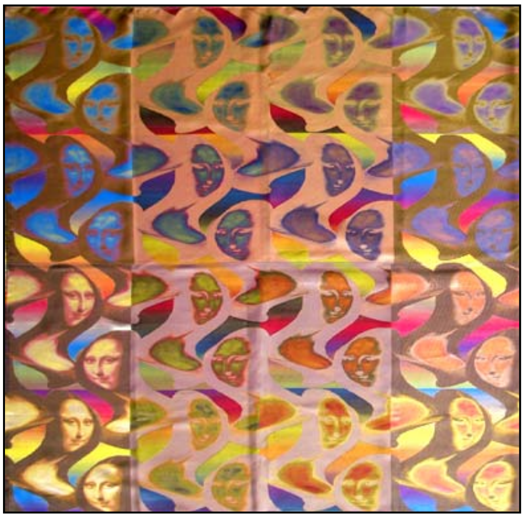


Figure 7: creative fabric effect designed by reversing coloring layers in turn.

Figure 8: digital jacquard fabric design by integrating partial creative effects.

4. CONCLUSION

Merging digitization technology into jacquard fabric creation and designing jacquard fabric in a layered-combination mode that integrated the basic principles of woven fabric structure, color science and computer science, was carried out to replace traditional plane design mode. In this study, the key techniques as well as the fabric creations by these techniques have been proposed and illustrated to exemplify the superiority of the innovative breakthrough in jacquard fabric design. Since digital jacquard fabric designed with digitization all-coloring compound structure has the capability of raising the valid mixed color number on surface up to mega level without any restriction for motif selection of digital images, digital jacquard fabric design both in simulative design and creative design can now be processed as conveniently as that of digital image printing. In addition, picturesque fabric effects featuring shot-effect color shading can also be produced. Therefore, the results of this study provide a glimpse of one of the latest developments of jacquard fabric design in the digital era and are of tremendous applications and commercial values.

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