

**Weave Structure and Image Pattern Exploration for Modern Double-cloth Design  
Development by Deploying Digital Technology**

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**ABSTRACT**

*The use of digital technology can open up new opportunities for Jacquard fabric to provide novel forms of decorative fabrics. In addition to color, texture and material, multiple layer format such as double-cloth is considered a crucial design element. In using the traditional weaving method, double-cloth design features are limited to abstract styles (i.e., stripes and color blocks). However, by deploying digital technology it is possible to depict much complicated fashion on both sides of a fabric. Two distinguished images are realized through weft yarn colors of which face, and back layer equally offer unique design novelty that was not possible with existing weaving methods. Therefore, this study firstly explored on a weave structure development which is capable of presenting pictorial images on both sides of a fabric. Once the weave structure format is finalized, further experiment is carried out with the CMYK color threads to explore the possibility of expanding a weave color scope for double-cloth. Based on the two experiments results, the details of weave structure and the image pattern design are explained to propose new types of modern double-cloth.*

*Keywords: Double-cloth, Weave structure design, Pictorial image, Weave color expansion*

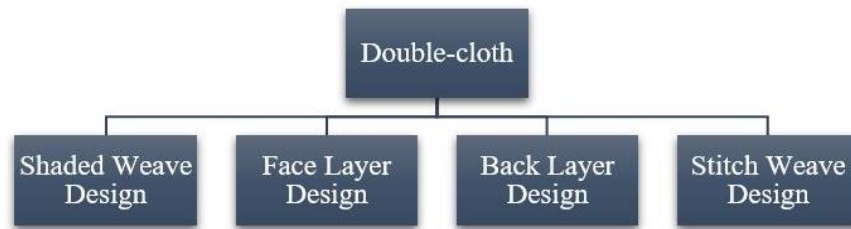
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**1. Introduction**

Double cloth possesses at least two sets of warp and weft yarns primarily engaged in generating its own layer of fabric to form separate face and back cloths (Watson & Grosicki, 1977). Two distinctive design figures independently exist in a piece of fabric by interchanging two groups of warp and weft threads; however, traditional weaving limits design, figures of double-cloth to abstract styles such as stripes, geometric shapes and color blocks (Shenton, 2014). As warp threads are grouped through shafts, shedding is limited to correspond to designs in diversity on a traditional loom. In

contrast, in modern digital weaving as each warp thread is threaded into individual hooks, higher capability and flexibility results from the loom setting (Ishida, 1994). Therefore, interweaving figurative motifs become possible for double-cloth. Digital weaving shares the same core principle (i.e. warp partition, weft float arrangement) as traditional weaving; however as image pattern and weave structure are designed through textile CAD (Computer-aided Design) system, understanding of the digital design processes become critical to utilize and explore for new possibilities.



**Figure 1. Weave structure design for modern double-cloth**

Conditions of an image pattern such as colors, shades and textures are considered in line with weave structures as they are the key to realizing the applied designs through organizing warp and weft threads (Kim, 2014; Kim, Ng, Zhou & Hu, 2016b). In this study, a shaded weave structure format is focused as its format is optimal to reproduce figurative image patterns in a natural shading effect (Ng & Zhou, 2009a; Kim, Ng, Zhou & Hu, 2016a). Based on a basic sateen weave format the weave structure is converted through four processes for digital double-cloth: 1) shaded weave design; 2) face weave design; 3) backing weave design; and 4) stitch weave design (Figure 1). Once a size of sateen weave is decided, it is developed into a shaded weave series (Zhou, 2011) and the individual shaded weaves are transformed into face and backing weaves by modifying the lifting plan of the warp. The two sets of warp and weft threads are interlaced to display two distinctive figures on face and back sides. For instance, face picks only interlace face ends according to the face weave arrangement, and back picks only interlace back ends according to the back weave. Lastly, in order to bind two layers together, stitching points are added to both face and backing weaves (Ng & Zhou, 2009b).

In this study, two experiments are explained to introduce novel double-cloth designs that approached by using an electronic Jacquard loom equipped with a single-color warp (off-white) set in continuous style. Firstly, the experiment focuses on weave structure development to realize two distinctive images on both sides of a fabric in which two weft threads are

individually assigned to face and back layers to create two patterns in different colors presented in natural shading effect. Unique aesthetic values of interwoven thread colors are equally distributed on both sides of a fabric. Testifying the possibility of depicting complex images on each side of a fabric is the key in the first trial. Once the weaving method is confirmed for the double-cloth creation, another investigation is carried out to explore the potential of enlarging a weave color scope for double-cloth design development. By deploying CMYK color theory, weft colors are selected based on the four primary colors (i.e. cyan, magenta, yellow and black) (Kim, Ng, Zhou & Hu, 2014; Kim, Ng, Zhou & Hu, 2017). The colors of the weft are paired (e.g. [M]+[Y] and [C]+[K]) and applied to each side of a fabric to display a natural shading effect accomplished by two thread color combinations. The fundamental principle of weave structure design stays the same as the first experiment, but another set of shaded weave series is created to align with the additional weft threads (Ng & Zhou, 2009a; Ng, Kim, Zhou & Hu, 2014). In this study, the digital image patterns and weave structure designs are explained in details based on the experiment results.

## 2. Methodology

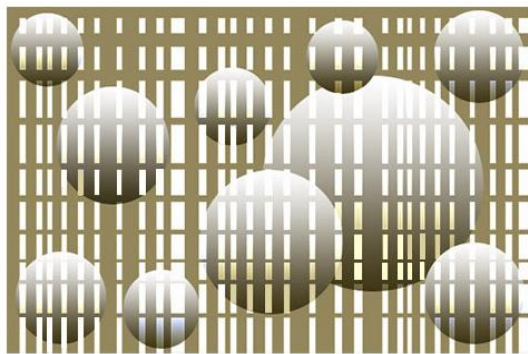
In using graphic editor software such as textile CAD and Photoshop, both image pattern and weave structure are designed in digital formats by which great efficiency and convenience are received in support of the digital technology. There are numerous adoptions that can be utilized and applied in the procedure of image modification, color

management and weave structure design by which laborious and time-consuming Jacquard design process are abridged. Colors, motifs and textures of woven Jacquard fabrics are relied on the mutual interaction between image patterns and weave structures and therefore, understanding the two core fields in conjunction with digital technology is imperative in this study.

### 2.1 Pattern design for double-cloth

A digital image in 8-bit color is considered sufficient for pattern design in which the colors of an image are displayed within 256 colors (Zhou, Tang, & Hu, 2011; Kim, Ng, Zhou & Hu, 2016a). In using textile CAD systems, double-cloth pattern designs are suggested in diverse ways. For example, hand painted images are scanned and uploaded to the CAD system or patterns can be designed by using graphic editor software or photographs directly taken from digital cameras.

In traditional weaving, the design figures of double-cloth are often realized with geometric shapes and color blocks. By interchanging the warp and weft groups of face and back layers, colors or material differences appear as designs on each surface. Therefore, this study is aimed to expand the applicable scope of double-cloth design by employing a digital technology. As Figure 2 shows the patterns assigned to a face and back layer, they are designed in a much complicated fashion to experiment with two groups of warps and wefts through unlimited shedding. In order to correspond to the details of patterns and color shades, weave structures are precisely designed. Based on shaded weave series, face and backing weave structures are developed by organizing two groups of warps with which two weft threads are applied to create the individual layers. In the first experiment, developing double-cloth weave structures are focused to testify the possibility of depicting picturesque image patterns.



<Pattern for Face>

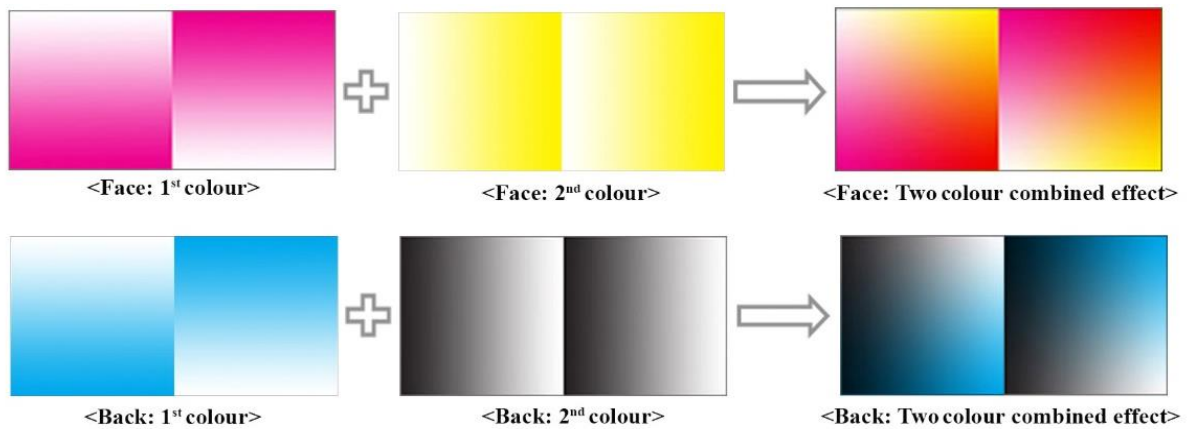


<Pattern for Back>

**Figure 2. Pattern design for single color double-cloth**

Creating a wide scope of weave colors is always challenging as a limited number of weft yarns is applicable to digital Jacquard loom. Therefore, further investigation is carried out to explore the potential of enlarging a feasible weave color scope by using the primary color threads of the CMYK system. As the color group is highly recommended for reproducing multiple color images in woven form, patterns are designed based on the CMYK color theory in line with

a single-colored (off-white) warp setting (Kim, Ng, Zhou & Hu, 2017). For the thread color combination effect, magenta and yellow are assigned to the face while cyan and black are to the back layer. This prototype of the two-color double-cloth is intended to employ more than one weft color on each side as it suggests considerable development in weave color reproduction for modern double-cloth design.

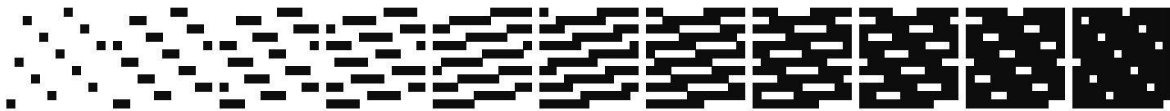


**Figure 3. Image pattern design for two color double-cloth**

Before applying weave structures to patterns, the weave pattern images are converted into greyscale mode as the format recognizes shade levels more precisely. Each greyscale level in an image is considered as a standard when selecting a proper weave structure to align with each other. Additionally, the pattern for the back layer should be flipped horizontally to secure the pattern in place when it is fabricated on the back side (Ng & Zhou, 2009b).

## 2.2 Weave structure design for double-cloth

Double-cloth weave structure is developed through four phases (i.e. 1) shaded weave, 2) face weave, 3) backing weave and 4) stitching weave). Firstly, when the weave repeat of sateen is decided, it is created into a shaded weave series by adding regular interlacing points. The interlacement addition repeats until total interlacement is left with minimum stitching points in a weave repeat (Kim, 2016). As Figure 4 shows one of the examples, a 12-thread sateen weave is created into a series by adding 12 interlacements each time in which 11 individual shaded weave structures are obtained in a series.



**Figure 4. 12-thread shaded weave structure series**

The attainable shaded weaves in a series are anticipated once weave repeat and interlacement increase are decided. As the total number of interlacements is gradually and regularly occupied, the following formulation (1) is used for the prediction of

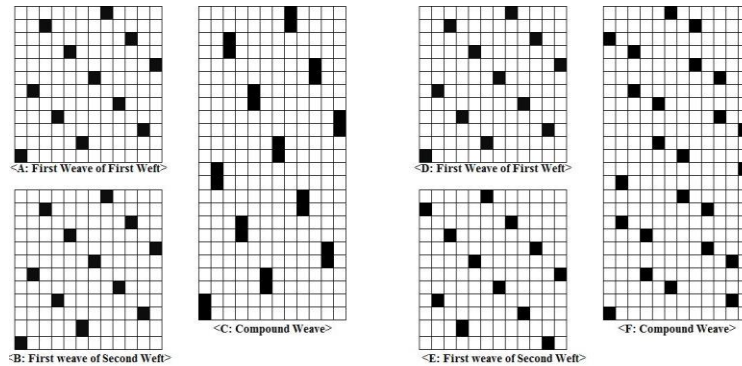
$$T = (W^2 - 2 \cdot W) \div E - \{(W \div E) - 1\} \quad (1)$$

In single color double-cloth fabrication, when the same size of a weave is

used to both fabric layers and thread interlacements are arranged in an equal

manner, favorable conditions are obtained for binding individual layers. As commencing the weave at the same relative point is maintained in weaving, stitching points are applied at the regular basis (Watson & Grosicki, 1977). In reflection of the theory,

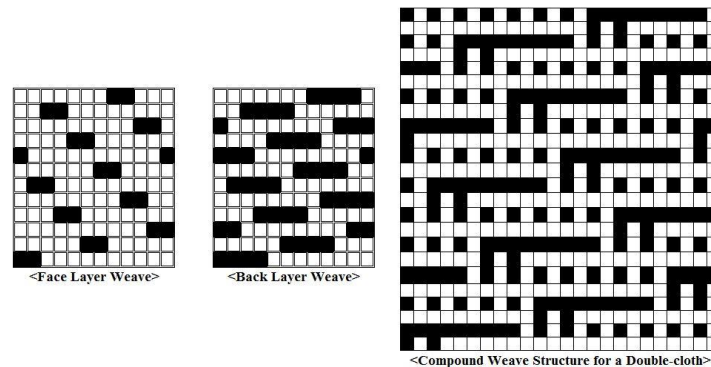
face and backing weaves for a single color double-cloth are not only designed in the same repeat size (e.g., (A) and (B)) but also the starting point applied to both layers are identical in this study as Figure 5 shows an example of shaded weave structures.



**Figure 5. Comparison of two different interlacement designs in compound structures**

In contrast, when designing the two-color double-cloth, applying two different sets of shaded weaves are suggested with different starting points (D) and movement numbers (E). In the comparison of the two cases (e.g., (C) and (F)) of shaded weave combinations (Figure 5), when two identical (A) and (B) weaves are combined for creating one layer, their interlacing points (C) appear in an identical place. In this case, when high density is applied in production, broken streaks easily result. Furthermore, thread colors exhibited on the surface assemble in

one place in which the combination of thread colors is perceived in a less favorable condition (Kim, Ng, Zhou & Hu, 2016). As a result, for two color double-cloth two different (D) and (E) weaves are designed and combined together as the interlacing points (F) do not occur at same points, nor do thread colors exhibit. Consequently, creating two sets of shaded weave series are suggested for maintaining a weave structure balance and distributing interlacing points for two-color double-cloth.



**Figure 6. Double-cloth weave structure for two layer separation**

Once shaded weave series are created, the individual weaves are transformed into face and backing weaves by modifying the

lifting plan of warp. In the weave structure modification, the warp is divided into two groups and two weft threads pair up with each

warp group. When face weaves are interwoven, face picks cross over the entire warp group assigned to the back layer while back picks are floated by lifting the face warp group. Figure 6 shows an example of weave

structure design in which face and backing weaves are combined without stitching points. In this case, two separate layers are created when the fabric is removed from the loom (Figure 6).

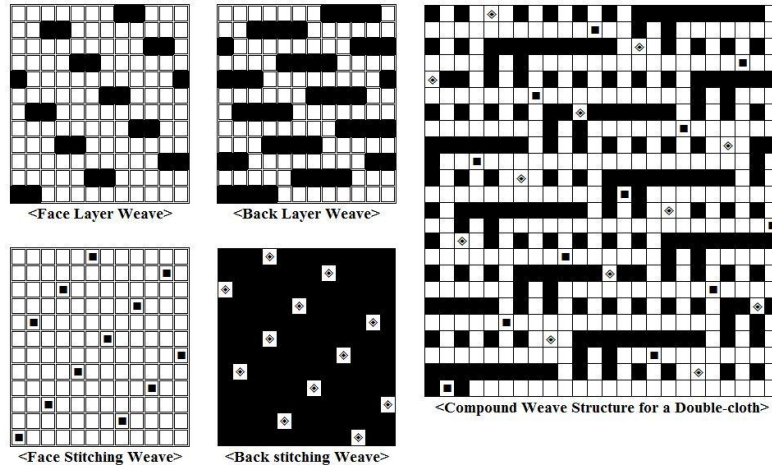


Figure 7. Double-cloth weave structure design with stitching points

There are different ways of tying two layers together (i.e., adding stitching points or stitching threads). In this study, a self-stitching method is applied to both experiments in which any additional thread is required except for the face and back layers as stitching points are made by intersecting face and back interlacements. For instance, while face picks are interweaving, most of the ends assigned to back layers are lowered for separation, leaving several picks of the back layer to interweave with face picks. When adding stitching points, their placement should be as regular as possible to prevent uneven tension and reduce warp breakage during production. Figure 7 shows one of the compound weave structures with stitching points added to face and back layers. When stitching points are correctly placed, the points have no influence on the appearance of either the face or back of the cloth (Watson & Grosicki, 1977).

### 3. Experiments

Based on the image pattern and weave structure design, two experiments are conducted to test the weave structure and weave color expansion for modern digital double-cloth. The face and back layers of images are decolorized to classify each shade level of an image while a 12-thread sateen weave is developed into a shaded weave series by adding 3 interlacements each time from which 37 shaded weaves are attained in each series. All the shaded weaves are modified for the double-cloth weave format whereas the greyscales of each image are reduced from 256 to 37 to align with individual shaded weave structures (Kim, Ng, Zhou & Hu, 2016a). In this study, 3 self-stitching points are applied to each face or backing weave to tie the two layers together.

**Table 1. Technical setting for double-cloth experiments**

Composition	Weft (experiment 1)	Weft (experiment 2)	Warp
Material	100% cotton	100% polyester	100% cotton
Thread color	Brown/blue	Cyan/ magenta/yellow and black (K)	Off-white
Yarn count	150 denier	150 denier	150 denier
Color filling density	120 picks/inch	120 picks/inch	96 ends/inch
Pattern repeat	12 inch (w) x 7.8 inch (h)	12 inch (w) x 7.5 inch (h)	N/A
Jacquard machine	Bonas electronic Jacquard		
Total hooks	3456		
Hooks/inch	96		
Total hooks/design	1152		
Weave repeat	12-thread sateen		
Shaded weave variety	37 derivatives		
Software applied	Photoshop CS6/Scotweave		

The first experiment features two weft threads for depicting pictorial images in a natural shading effect on both sides of a fabric. The face layer is created by pairing a brown thread and an odd number of warp threads while a blue thread is interwoven with an even number of warp threads for creation of the back layer. In contrast, the second experiment combines two colors of weft threads in a natural shading effect with the aim of testing the possibility of expanding a weave color scope for double-cloth design. The primary colors of the CMYK system are paired and applied to each side. Magenta and yellow threads are coupled for the face whereas cyan and black are grouped for the back layer. Table 1 shows the weaving specifications applied to both experiments. For creation of digital weaving files, Scotweave, the textile CAD software, is used,

T and for the sample production, the Bonas  
A electronic Jacquard machine is utilized.  
T Based on the weave structures developed  
M from the 12-thread sateen, the maximized  
weft density (120 picks/inch) is applied to  
both experiments to attain proper firmness.

#### 4. Result and discussion

The first experiment features two weft threads to examine the possibility of creating pictorial images in the double-cloth format. The 12-thread sateen is developed into face and backing weaves and aligned with image patterns. As shown in Figure 8, weave structure and pattern design are successfully incorporated to generate patterns in woven form while natural shading effect is effectively accomplished through the shaded weave structure layout.



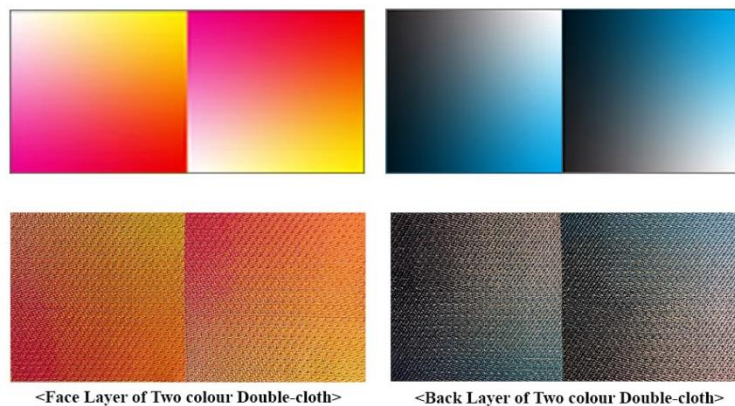
**Figure 8. Single color double-cloth fabrication in natural shading effect.**

When designing the image pattern and weave structure, the configuration of the Jacquard loom is considered as there are limitations on both aspects. In this experiment, the warp is set with 96 ends/inch and therefore a weave repeat should be selected as one of the common multiples of the warp set (96 ends/inch). For that reason, the 12-thread weave repeat is selected and developed for the double-cloth fabrication to dispose thread floats in a stabilized condition. On the other hand, when designing the image pattern, as the harness of the 36-inch wide Jacquard loom is set to give three pattern repeats with 3465 hooks in total, the width of the image pattern is limited to 12 inches (34 inch/3) with 1152 hooks (3456 hooks/3) (Table 1).

Based on the first experiment's results, further experiment is carried out to enhance the capability of embracing wider colors and

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motifs for double-cloth design. The weft threads feature the CMYK primary group as the four colors have shown great potential to enlarge a weave color scope for reproduction of pictorial images in digital weaving (Kim, Ng, Zhou & Hu, 2017). As Figure 9 shows the details of the face and back sides of the two-color double-cloth fabric, the combination of two weft threads is successfully presented in a natural shading effect by making a clear division between face and back layers (Figure 10). The fundamental principle of weave structure design is derived from the initial experiment of single-color double cloth, but two different sets of shaded weave series are applied to each weft thread of the face and back layers. Compared with single-color double-cloth, weave structure design becomes much more intricate when face and back weaves are combined.



**Figure 9. Two-color double-cloth fabrication in natural shading effect.**





**Figure 10. Prototype color experiment for two-color double-cloth**

The applied theories of image pattern and weave structure are proved through two experiments for modern double-cloth design development. Judging from the motifs and colors tested in this study, modern double-cloth has great potential to be developed into wider ornamental contexts (Figure 10).

### 5. Conclusion

Two experiments are conducted for modern double-cloth design development and many aspects have been validated in which the unique double-faced fabrics carrying an equal aesthetic value on face and back layers are demonstrated and introduced as a result of the experiments. Firstly, weave structure design is attested through single-color double-cloth in which two separate pictorial images are successfully shaped in a natural shading effect. Based on the weave structure development, further experiment is carried out with CMYK threads to enlarge a weave color scope for modern double-cloth design development. The prototype of the two-color double-cloth experiment is positively certified when combining two color threads in a natural shading effect. As double-cloth design with a wider weave color scope suggests varied ranges of ornamental fabrics in different patterns and colors, further development on two-color double-cloth is advisable with image patterns displayed in a wider range of colors for divergent uses such as fancy garment fabrics, furnishing fabrics and decorative materials.

### Declaration of conflicting interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

### References

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- [1] Grosicki, Z. (Ed.). (2014). *Watson's advanced textile design: Compound woven structures*. Woodhead Publishing., pp.108-189.
  - [2] Ishida, T. (1994). *Innovations in weaving machinery: the course of loom development*. Osaka Senken Ltd..
  - [3] Kim, K. R. (2014). *A study on structural optimization and color mixing systems of digital jacquard textile based on full-color compound structure* (Doctoral dissertation, The Hong Kong Polytechnic University), pp. 74-110.
  - [4] Kim, K. R., Ng, F., Zhou, J., & Hu, J. (2016a). Gradient color deviation in woven textiles to correspond to pictorial images in diversity. *International Journal of Fashion Design, Technology and Education*, 9(1), 32-40.
  - [5] Kim, K. R., Ng, F., Zhou, J., & Hu, J. (2016b). Diamond-shaped shaded weave series created by transforming small twills to enrich the surface texture of woven Jacquards. *Textile Research Journal*, 86(10), 1032-1040.
  - [6] Kim, K. R., Ng, F., Zhou, J., & Hu, J. (2017). Pigment mixing effect realized with pre-dyed opaque yarns for Jacquard textile design development. *Textile Research Journal*, 0040517517741153.

- [7] Ng, M. C. F., & Zhou, J. (2009a). Innovative layered-combination mode for digital jacquard fabric design. *Textile Research Journal*, 79(8), 737-743.
- [8] Ng, M. C. F., & Zhou, J. (2009b). A study on figured double-face jacquard fabric with full-color effect. *Textile Research Journal*, 79(10), 930-936.
- [9] Ng, M. C. F., & Zhou, J. (2010). Full-color compound structure for digital jacquard fabric design. *Journal of the Textile Institute*, 101(1), 52-57.
- [10] Ng, F., Kim, K. R., Hu, J., & Zhou, J. (2014). Patterning technique for expanding color variety of Jacquard fabrics in alignment with shaded weave structures. *Textile Research Journal*, 84(17), 1820-1828.
- [11] Shenton, J. (2014). *Woven Textile Design*. Laurence King, pp. 182-189.
- [12] Zhou, J. (2011). Research and creation of printing-like effect digital jacquard fabric. In *Advanced Materials Research* (Vol. 295, pp. 2568-2571). Trans Tech Publications.
- [13] Zhou, J., Tang, L. Q., & Hu, D. T. (2011). Grey Simulative Effect Digital Jacquard Fabric Design with Full-Color Compound Structure. In *Advanced Materials Research* (Vol. 332, pp. 663-666). Trans Tech Publications.

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