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Multicoloured Jacquard Artworks Reproduction with C, M, Y, and K Channels Modification to Improve Weave Colour Accuracy

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Abstract

Multi-coloured Jacquard artwork reproduction has been restricted by the modern setting of weaving machinery. To resolve the current limitations, innovative weaving applications have been introduced. The subtractive CMYK system used for colour printing has been employed for multi weave colour reproduction as a wide scope of a weave colour creation is possible by utilizing a small number of weft yarn colours. In use of cyan [C], magenta [M] and yellow [Y] coloured yarns, a range of CMYK secondary colours (red [R], green [G] and blue [B]) production is feasible by juxtaposing a pair of the three yarn colours. In addition, controlling chroma levels of the primary colours is viable by mixing with a black yarn. However, there are variations between CMYK colour mixing and optical yarn colour mixing due to the material differences. Therefore, modifications of the [C], [M], and [Y] colour channels are required to reproduce tertiary colours such as a black colour. This is because opaque and non-blendable yarns are used to create weave colours and therefore, exhibited yarn colours are all perceived together. In use of image processing tools offered by Adobe Photoshop, a pair of the [C], [M], [Y], and [K] colour channels are merged to individually generate the primary ([C], [M], [Y]) and secondary ([R], [G] and [B]) colour channels. In the process, a pair of C, M, Y and K channels is combined based on mathematical functions. As a result, new six colour channels ([C], [M], [Y], [R], [G], and [B]) are created to improve weave colour reproduction accuracy. This study introduces details of the colours segmentation processes and weaving experiment results that examines the significance of the newly developed the colour channels for multi-coloured artwork reproduction.

Keywords: Jacquard, woven textile coloration, CMYK, Multi weave colour reproduction

Introduction

Modern digital weaving has been evolving to improve production efficiency and convenience. The warp is generally set in a continuous style and the application of filling yarn is restricted to electronic Jacquard machinery (Seyam, 2016; Seyam, 2019). In order to expand a weave colour gamut with a small weft variety, the CMYK colour system is used to define artwork colours and its four primary colour data (i.e., cyan [C], magenta [M], yellow [Y] and black [K]) are used for multi weave colour reproduction (Kaiser, 1996). To apply the colour printing mixing principles, weft yarn colours are selected in alignment with the four primaries (C, M, Y, and K) and their floats are organised via shaded weave structures to reproduce artwork colours (Watson & Grosicki, 1975; Ng & Zhou, 2013). In order to discover a feasible weave colour scope using the four primaries, weaving experiments are conducted via employing 16-thread shaded weaves. First, a pair of [C], [M], and [Y] colour yarns is interwoven using 15 different shaded weaves. Second the three primary-coloured yarns (i.e., [C], [M], and [Y]) are juxtaposed with a black [K] yarn. As a result, the prototypes of 15 weave colour samples are produced in each pair combination (Kim et al., 2019). Their colours are all measured by a Macbath colour-eye 7000A spectrophotometer and the measurement data is analysed by CIELAB (i.e., Commission Internationale de l'Eclairage L*a*b*) space of which colour space depicts all colours that a human visual system can recognizes. Colours are defined by L*, a* and b* coordinates of CIELAB data, where L* indicates a visual correlation of brightness from 0 (i.e. black) to 100 (i.e. pure white) and a* and b* imply positive (+) and negative (-) values (e.g. +a* (redness), -a* (greenness), +b* (yellowness) and -b* (blueness)) to indicate to hue and chroma. When the a* b* values of the pair combinations illustrate an arch line along with the ± a*b* spaces, hue changes are indicated. Whilst a straight line is drawn from centre to outward of the a* or b* axis, chroma variations are indicated (Berns et al., 2000).

The result is shown that the three groups (i.e. [C]+[Y], [C]+[M] and [M]+[Y]) of the yarn juxtapositions demonstrate valid results to create the secondary colour ranges of CMYK colour. For instance, when [C] and [M] yarns are put side by side with different cover factors of the warp and weft, the two juxtaposed opaque yarn colours create a range of blue colours through delicately managed interlacements. The Figure 1 shows the actual weave colours produced with the pair combinations and measured a*b* colour values (Kim et al., 2019).

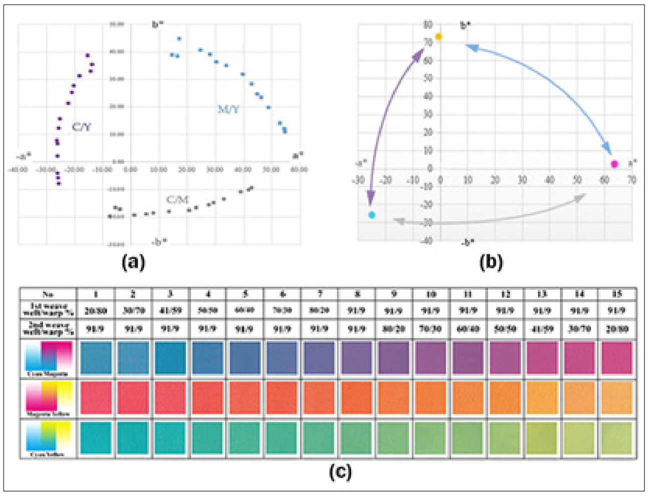


Figure 1: Actual weave colour samples of C/M, M/Y and C/Y (c) and the measured a*b* colour values of C/Y, C/M and M/Y (a) created from the C, M, Y yarns (b) (Kim et al., 2019).

In contrast, when the C, M, and Y yarns are mixed with a black [K] yarn (e.g. [C]+[K], [M]+[K] and [Y]+[K]), their chroma levels are changed and controlled. The Figure 2 shows the three pair combinations of the weave colours and their measurement results. The amount of the [C], [M] and [Y] yarns exhibited on the surface are gradually reduced from the sample 1 to 15 and their chroma changes are clearly presented in the a*b* colour space through drawing straight lines (Kim et al., 2019).

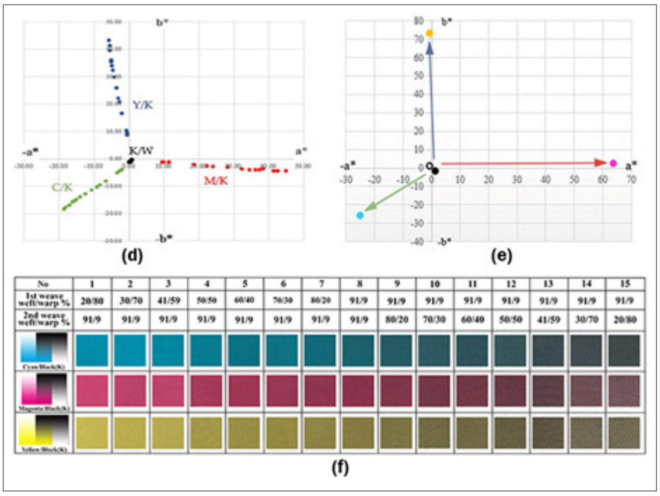


Figure 2: Actual weave colour samples of C/K, M/K and Y/K and the (f) measured a*b* colour values of C/K, M/K and Y/K (d) created from the CMYK yarns (e) (Kim et al., 2019).

The results of the two weave colour examinations shows that there are great similarities between the [C], [M], [Y], and [K] pigments and yarn colours mixing. When [C], [M], [Y], and [K] yarn colours are juxtaposed via shaded weaves, it was possible to conceive consistent hue and chroma alternations (Kim et al., 2019).

However, materials used between CMYK colour printing and weave colour creation are different. Therefore, [C], [M], [Y] and [K] yarns are further tested with a digital image (Figure 3) designed based on a RGB colour model. The C, M, Y, and K colour channels of the digital image are used to examine the multicolour reproduction quality. When creating the image, it is vital to visibly present and define primary (C, M, Y and K) and secondary (R, G, and B) colour regions of the CMYK colour system. This is because to clearly identify the different colour regions and the changes made in the segmentation processes. In addition, the black colour is applied to the background with a gradient manner to examine the secondary colour ranges realised in different chroma levels (Ng et al., 2014).

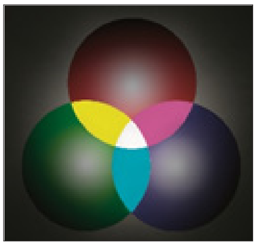


Figure 3: RGB colour model designed for testing C, M, Y, and K colour channels (Ng et al., 2014).

In the weaving experiment, the four primary colours of the CMYK system are selected for weft. The C, M, Y, and K colour channels (Figure 4) of the digital image are used for shaded weave structure inputs. As a result, the CMYK colour mixing principles are directly applied to the image reproduction. The weaving experiment result is shown in the Figure 4 (Ng et al., 2014; Kim, 2014). Using the C, M, Y, and K colour channels is appropriate to generate primary and secondary colour ranges. However, the restriction is shown in producing black colours and generating smooth colour deviances in the secondary colour zones. In CMYK colour printing, cyan, magenta, yellow pigments are all mixed and blended to produce black colours (Ng et al., 2014; Kim et al., 2022). In contrast, when the ink mixing principle is applied to opaque yarn colour mixing, the three colours of yarns are individually juxtaposed and observed together. Therefore, there is a discrepancy to reproduce saturated black colours in the yarn colour mixing. To resolve this limitation, it is suggested to individually segment [C], [M], [Y], [R], [G] and [B] colours from the [C], [M], [Y], [K] channels used for the colour printing. Based on the mathematical morphology theory, the segmentations are conducted to cluster the individual colours (Kim et al., 2019; Kim et al., 2022; Kim, 2014).

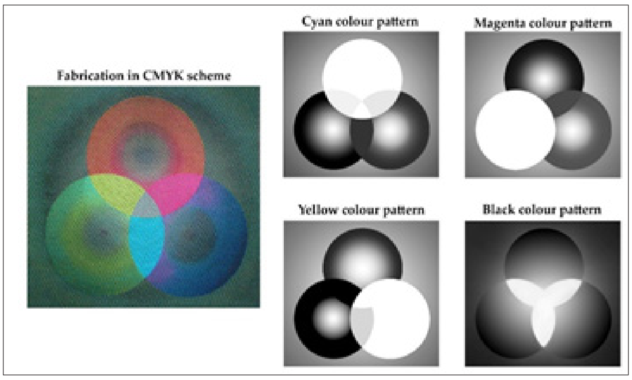


Figure 4: Fabrication with computed C, M, Y, and K colour channels (Kim, 2014).

Image processing tools offered in the Photoshop CS6 are used to segment the six colours. The significance of the six colour segmentations is examined via conducting weaving experiments. In this study, the details of the colour segmentation process and weaving experiments are explained to improve the current Jacquard design reproduction capability.

Material Selection and filling yarn colours measurement

The Arahne Jacquard CAD system is used to create digital weaving cards and the Stäubli JC6 Jacquard machine is employed for conducting weaving experiments. The warp is set with off-white 100 denier polyester yarns in continuous styles. In the preparation of weft yarns, a multifilament polyester yarn is selected to align with the warp property. When choosing pre-dyed weft yarns, highly saturated C, M, Y, K, R, G, and B colours are created in a CMYK colour mode in the Photoshop CS6 programme. The screen colours are referenced when choosing the seven yarn colours of the weft yans. Using fine yarns in the weft is advantageous to create natural gradient effects. Therefore, 50-denier polyester yarns are chosen for weft to interweave with the 100-denier polyester warp.

Result and Conclusion

Image processing tools offered in the Photoshop provides with different formulas when merging two layers. In this study, dodging and screening tools are used to segment the seven colours using [C], [M], [Y], and [K] colour channels. The segmentation processes applied to dodging and screening are the same, but the formulas applied to the two effects are different. As a result, the colour segmentation results are dissimilar to cluster the six colours. In the segmentation process, each C, M, and Y layer is obtained by subtracting one-colour arrays of the RGB model and the secondary colours of CMYK colour system (i.e., red, green and blue) are firstly clustered and then the primaries (i.e., cyan, magenta and yellow) (Kim et al., 2022). The formula applied to dodging effect is presented in (1) and the screening effect is in (2) where U_g is the upper layer of the grey value, L_g is the lower layer. The component greys range from zero to one (Sangwine & Horne, 1998; Ma, 2011).

$$(U_g, L_g) = U_g + L_g \tag{1}$$

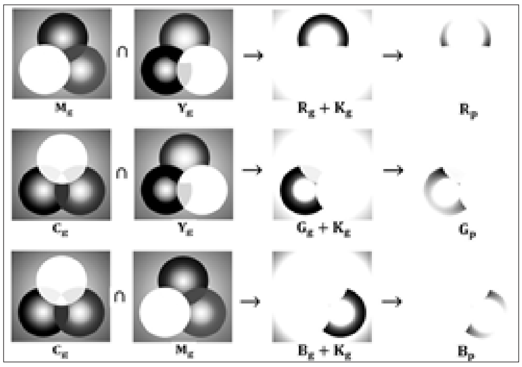
$$f(U_g, L_g) = 1-(1-U_g)\cdot(1-L_g) \tag{2}$$

Pattern rendering of red, green and blue

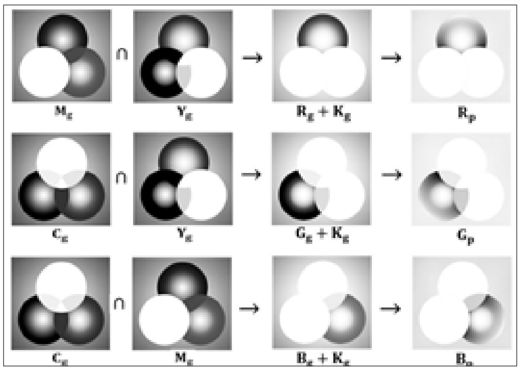
The colour values where the coupled primaries are commonly possessed indicate [R], [G] and [B] colours. According to CMYK morphology and greyscale substrates, when an upper and lower layer are merged, secondary-colour regions are clearly appeared. However, as the regions also include black colour values, the removal process is further required. The subtraction process is presented in formula (3). Where R_p, G_p and B_p are the final weave patterns of [R], [G] and [B] colours, and C_g, M_g, Y_g and K_g are the colour channels gained from computed separation (Kim et al., 2022).

$$\begin{bmatrix} R_p \\ G_p \\ B_p \end{bmatrix} = \begin{bmatrix} M_g & \cap & Y_g \\ C_g & \cap & Y_g \\ C_g & \cap & M_g \end{bmatrix} - \begin{bmatrix} 1 & - & K_g \\ 1 & - & K_g \\ 1 & - & K_g \end{bmatrix} \tag{3}$$

The Figure 5 shows each segmentation process of secondary colours in detail. Due to the formula differences between dodging and screening, the segmentation results are different. First, merging a pair of C_g, M_g, Y_g and K_g are combined to recognise their common colour values and then the reversed K_g colour channel is merged to erode the colour values. Compared with dodging and screening, the formula applied to the dodging effect has small tolerances than the screening effect to cluster colours. Those three colour channels (i.e., R_p, G_p and B_p) are used to locate individual yarn colours of [R], [G], and [B] yarns in weaving (Kim et al., 2022).



(A)



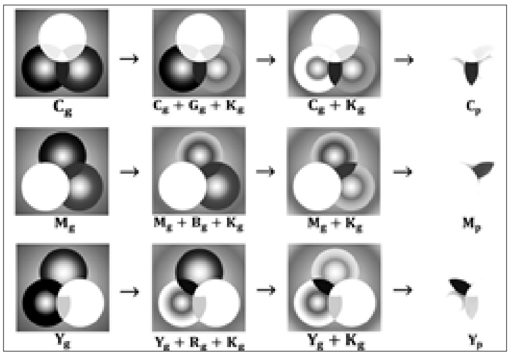
(B)

Figure 5: [R], [G] and [B] colour pattern rendering processes under dodging (A) and screening (B) effect (Kim et al., 2022).

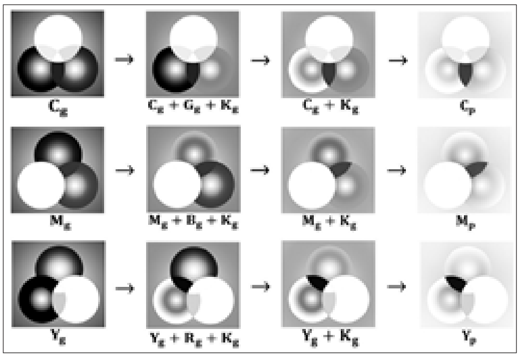
Pattern rendering of cyan, magenta and yellow

As the C_g, M_g and Y_g colour channels have colour values of primary, secondary, and black colours, erosion processes are progressively carried out to segment the three primary colours respectively. Figure 6 shows the details of C_g, M_g and Y_g colour pattern modifications. Frist, the grey values of two secondary colours are eliminated from each C_g, M_g and Y_g and then black colour values are lastly uninvolved through merging. The modifying process is defined as formula (4) to obtain the inherent values of [C], [M], and [Y] colours where C_p,M_p and Y_p are the final patterns for weave structure inputs (Kim et al., 2022).

$$\begin{bmatrix} C_p \\ M_p \\ Y_p \end{bmatrix} = \begin{bmatrix} C_g \\ M_g \\ Y_g \end{bmatrix} - \begin{bmatrix} C_g & \cap & M_g \\ M_g & \cap & Y_g \\ Y_g & \cap & C_g \end{bmatrix} - \begin{bmatrix} C_g & \cap & Y_g \\ M_g & \cap & C_g \\ Y_g & \cap & M_g \end{bmatrix} - \begin{bmatrix} 1 & - & K_g \\ 1 & - & K_g \\ 1 & - & K_g \end{bmatrix} \quad (4)$$



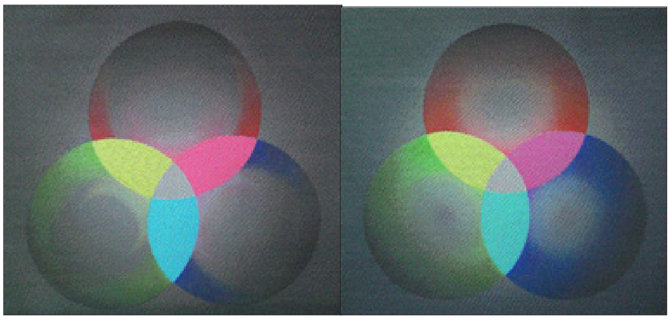
(C)



(D)

Figure 6: [C], [M] and [Y] pattern rendering processes under dodging (C) and screening (D) effect (Kim et al., 2022).

The seven colour patterns obtained from the segmentation are used to reproduce the digital image (Figure 3). Two weaving experiments are conducted to examine the two different approaches (i.e., dodging and screening) made for multi-weave colour reproduction. The results are shown in the Figure 7. In the segmentation process, the formula applied to the dodging effect clustered the seven colours with less tolerances. As a result, it could not preserve the individual regions sufficiently to reproduction the image. However, the screening effect is successfully maintained the colour regions of primary, secondary and black colour ranges and the artwork reproduction is much more effective than the dodging effect for multi-weave colour reproduction (Kim et al., 2022).



(E) (F)

Figure 7: Fabrication of C, M, Y, K, R, G, and B patterns rendered under dodging (E) and screening (F) effects (Kim et al., 2022).

Discussion

There are similarities between CMYK colour printing and weave colour creation in producing secondary colours and controlling chroma levels of primary colours. However, due to the material differences, optimisation of colour patterns is required to properly embrace black colour reproduction. Compared with C, M, Y, and K colour channel reproduction, having individual C, M, Y, K, R, G, and B colour information is much more successful to increase weave colour accuracy. As each colour pattern clearly defines individual colour regions, allocating appropriate yarn colours at the delegated places are possible. As a result, the new weaving application is a valuable reference for a range of multi-coloured artwork reproductions to improve weave colour accuracy and to embrace more di verse rages of artwork designs for Jacquard textile designs.

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