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Advancements in Pattern Coloration for Jacquard Woven Tapestry Fabrics

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ABSTRACT

Designing Jacquard fabrics is a very creative and technical process that is dependent upon the ability of the textile designer to be able to combine aesthetic sensibility with a strong knowledge of the technology of materials, textile design, color and fabric production machinery. Jacquard weaving provides the opportunity for designing an enormous number of complex pictorial and other patterning effects using combinations of warp colors, filling colors and integrated weaves. In Jacquard woven fabrics, the structural creation of shapes and images is relatively easy, but accurate control of color rendering of intimately blended pre-colored yarns is a critical and difficult-to-control attribute. Multiple trials are often required for successful color reproduction in order to match the original artwork. This is a very time consuming and costly process.

Integration of CAD systems with Jacquard weaving technologies over the years has revolutionized the entire design process. Computer simulation has definitely aid in designating particular structural colorations, but accurate color rendering using CAD systems is still challenging. The use of colorimetry has helped to achieve better reproducibility and accuracy in the shade matching of the textile products. However, no commercial system is available for accurate color imaging of Jacquard weave designs without first making the structural color effect in prototype form.

In this paper, a review is done on the available CAD systems used in woven fabric industry, and research to-date related to automation in jacquard designing and coloration. Based on the review, a systematic approach to integrate the most suitable geometric and color model is proposed as an add-on feature/tool for any CAD system. This add-on feature/tool will assist the designers to accurately predict the final color for these complex woven Jacquard woven structure without creating any samples, and there-by help in reducing the sampling cost, increase the accuracy and productivity.

Keywords: Jacquard fabrics, weaving, pattern coloration

Introduction

Color is an integral part of design. Whether it is textiles, fashion, design, graphic printing, desktop publishing, dyestuff, paint, ink, plastics, cosmetics, food and beverages, color remains the important aspect in the life cycle of product development. In most cases, color is the most important factor in the commercial success of a product. Color is also often used as quality assessment of a

material. In almost all applications, it is difficult to reproduce exact color as specified from batch to batch. Therefore, color management plays an important role in supply chain. With the help of latest objective measurements in combination with standardized subjective evaluation, it has become easier to manage color throughout the product life cycle. Although these sophisticated color measurement system enable to quantify color for consistency and reproducibility, but the process still involves visual assessment and comparisons due to the subjective nature of the color.

In case of textiles, the complexity of color measurements and assessments is more due to the three-dimensional nature of the material in combination with surface geometry and texture effects from fibers and yarns such as hairiness, gloss, luster and translucency. Although color measurements are widely used in textile industry, visual assessment is still required for final quality assurance to provide a correlation between visual and the instrumental measurements. The color measurement system and associated software are widely used in areas of textile dyeing and printing and have proved to be a reliable source of color measurement, quality assessment and communication. However, in woven fabrics, color communication is still a subjective process, as stated above.

Many measuring and imaging analysis systems are available to measure and record color data and simulate the color image from the data (Rich 1986 and Osaki 2002). Recent advancements in this area have provided great improvements in color development, color assessment, and color prediction as a part of dyeing and printing process. However, during the different stages of producing fabric (spinning, weaving, knitting, etc.), color change evolves due to different surface textures and designs (Lambart 1986, Menz 1998, Dupont et. al. 2001, Dimitrovski & Gabrijelcic 2001, Sijie 2006). In case of woven and knitted designs, existing CAD systems are equipped with these color systems but their functionality is limited in developing artwork, editing, and color palette for yarns (Osaki 2002, Bojic 1999, Doctor, 1997, Dolezal and Mateja 1995, Ross 2005, Gabrijelcic 2004, Clothing Industry 2017). In the case of woven and knitted fabrics, the final visualized color of a pattern is a contribution of each color component present on the surface of the structure. The colors present on the surface appear as a homogenized color and are perceived as one overall color.

In a typical Jacquard woven design process, for a given artwork, a designer would create a weave blanket with specified pre-colored yarns, where each weave design specifies a single homogeneous color (Figure 1). The designer then picks the color (weave design) from the pre-woven blanket for each area of the pattern. Once all the colors in the pattern are specified with a weave design from the pre-woven blanket, then the designer does the first weaving trial. After weaving the first trial, the sample is compared to the artwork. Multiple weaving trials often are required for successful production in order to match the original target artwork (Figure 2).

Figure 1: An example of Weave Blanket showing tapestry weave/color combinations woven from four warp colors (green, red, yellow, blue) and black and white in weft (Mathur 2007)

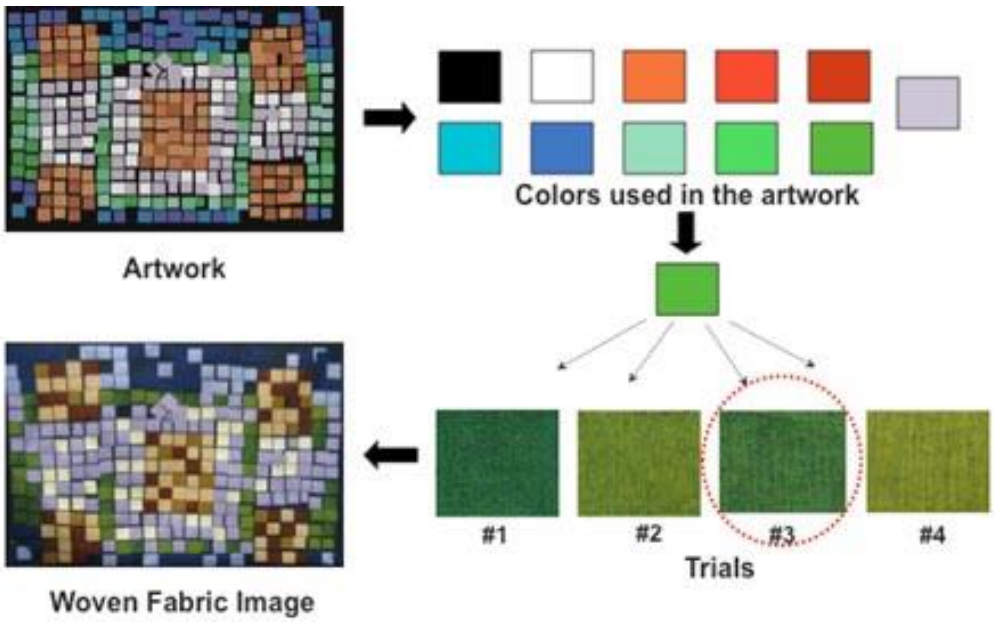

Figure 2: Color selection process in Jacquard Tapestry fabric designing (Mathur 2005)

There are numerous studies that reports automating the design process for Jacquard woven fabrics, but they do not address the issue of sample preparation before final production (Osaki 2002, 2003, Takatera and Shinohara 1988, Dawson 2002, Dimitrovski and Gabrijelcic 1999, 2001, 2004). There is no color methodology yet available to assist designers in developing fabrics without the need of developing a woven color blanket,

accurate matching of appropriate weaves to the color of the target artwork and producing samples. Therefore, Jacquard fabric producers require an automated process to assist with weave color generation and selection.

Current CAD systems used for Jacquard fabric designing

The impetus for use of CAD in the textile industry was to improve efficiency in the production process. Initial textile designing software packages were mainly derived from graphic design software, without putting much emphasis upon the underlying fabric structures. CAD systems have evolved, however, by considering the designing process and technical limitations. These systems are now extensions of creative expression, which comply with technical requirements (Doctor 1997). Numerous descriptions of this process exist within the computer environment (Lourie 1973, 1969, Laurie and Bonin 1968, Laurie and Lornzo 1966, Noonan 1998, Patwardhan et. al. 1984, Downes 2005) addressing, algorithmically, the problems that arise when one attempts to harmonize a visual pattern with the notational point paper diagrams of those used for warp and weft interlacing.

Prior to CAD systems, the woven fabric designing process was done in the following manner: (a) artwork was created on paper, (b) artwork was then rendered on to a scaled grid known as point paper or design paper, whose columns and rows represented warp and weft yarns, respectively, (c) weave structures were created for each unique color in the artwork, and each specific areas in the artwork was then assigned with a weave structure, and finally, (d) a technician prepared punch cards based on this technical design layout, in which each card represent one pick of the actual fabric. This conventional process for designing was very time consuming and laborious. The process would require considerable amount of skill and experience not only in designing the artwork, but also in weaving.

After the integration of CAD systems, the Jacquard-designing process now operates in a series of basic steps as shown in Figure 3. The first step is digitizing the artwork. This feature allows the designer to see the artwork on a computer monitor by scanning the original artwork or creating a freehand artwork using the CAD system drawing tools or exporting the artwork created using other graphics software (Photoshop, Corel Craw, etc.). This step is generally done in 8-bit format (256 colors), which allows the designer to modify patterns and reduce the number of colors. The color reduction is a necessary step when there are too many colors in the artwork and when the designer wishes to keep the number of weaves to a workable minimum number. The second step is fabric designing, in which the artwork image data is transformed into weaving information for fabric production (like converting the design into point paper format). The third step is weave allocation, which allows converting the artwork image into the weave information. This step is very important as the designer makes a choice of right color, texture and shape to match the artwork. The designer either creates the appropriate weave structure or chooses one from a weave database (either from weave blanket developed by the designer or from the CAD database) to match the desired color, shape or texture in the artwork. This is the step where different CAD system features really come into play. In the next step, the designer can see a simulation of the final fabric on the display monitor. By looking at the preview, the designer can make modifications to the design and color, if needed. Multiple trials are often required for successful color reproduction in order to match the original artwork. These CAD systems also offer a feature to transfer ready-to-weave file directly to the Jacquard controller for weaving.

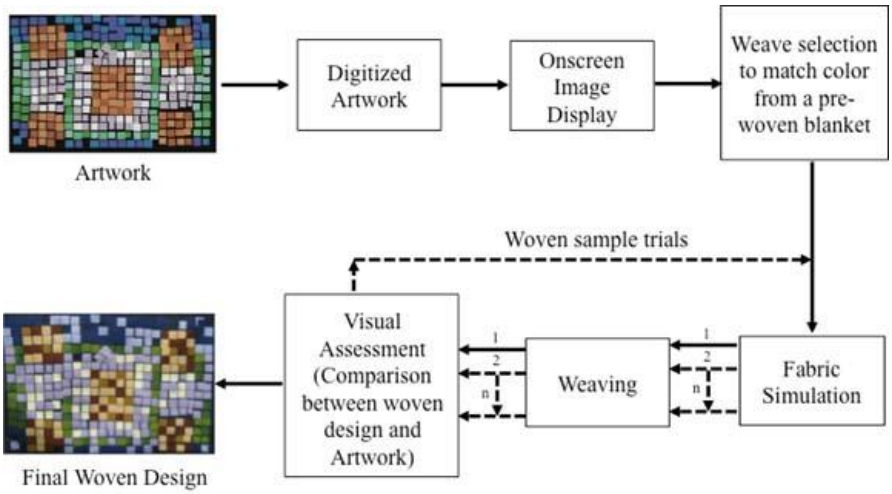

Figure 3: Current/Traditional Design Process using current CAD systems (Mathur 2012)

These latest textile CAD systems are an integrated solution, starting from creating the design to converting into weaving format, to 3D simulations, and finally transferring the design and production data in a suitable format. This evolution in CAD technology has, in turn resulted in an increase in competition among manufacturers and CAD system designers and therefore provided a quick market response. There are numerous CAD systems available that support the woven textile industry, and some of them are listed in Table 1. The CAD systems are mainly used to develop jacquard designs in any repeat size taking care of all aspects: from the designing stage to on-loom production.

Table 1: Few global CAD Software Packages for Woven Fabrics (Source – referenced CAD websites)

CAD system	Design Modules/Tools
Nedgraphics	Texcelle, Jacquard, Dobby Pro, Easy Weave
LECTRA	PrimaVision Weave
Pointcarré	Pro Weave, Pro Design
Scotweave/ScotCad Textiles	Dobby and Jacquard Designer, Technical Weaver
Booria CAD/CAM Systems	Carpet Weave
WeaveMaker	Dobby
Weave Point	Dobby
YXENDIS	Dobby, Jacquard
Arhane (Arah Weave)	Dobby, Jacquard
PENELOPE	Dobby, Jacquard, Terry
Textronics	Dobby, Jacquard
Texgen	2D, Multilayer, 3D geometry
DB weave	Dobby
EAT (Design Scope Company)	Dobby, Jacquard, 3D Weave
WiseTex	Geometrical model of fabrics (woven, knitted, laminates, braided)
CadVantage Win	Dobby, Jacquard
Viable Systems Inc. (ViaCad)	Jacquard
TEX-Style/Jac-Art – Wonder Weaves System	Dobby, Jacquard
Tukatech (TukaStudio)	Dobby

These latest CAD/CAM systems come with lots of tools and utilities to enable most of the main aspects in the Jacquard Textile Industry such as: creation of design -- from simple to intricate, editing/retouching a scanned artwork, easy conversion of artwork to weave file, developing weave designs, input yarn and color information for 3D simulations, and transfer of the design information to electronic jacquard head. The Jacquard industry is one among the other textile industries where CAD/CAM are extensively used not only for design solutions, but also as it offers a great deal of manufacturing solutions. Developments of powerful modem systems and electronic Jacquard controls, along with new automated design systems have brought the weaving machine into the design studio. The innovation in CAD/CAM systems has revolutionized the entire Jacquard industry (powerloom and handloom) both in terms of designing and manufacturing by increasing the precision, efficiency and productivity.

Innovation in the field of textile design CAD systems for woven fabrics has provided the opportunity to design intricate fabrics with the use of a variety of tools. There is also the possibility of seeing the resultant fabric on a computer monitor that gives the visualization of a real fabric prior to weaving. There is constant improvement and development in the CAD system to develop several design features (CAD tools) to keep pace with new market demands.

Main Features of CAD systems for Jacquard Design and coloration

Woven textiles are structurally complex and therefore require a lot of components and tools for design and simulation. The component selection involves selection of fiber, yarn type, yarn color, fabric weave and construction parameters. Within each component, there are numerous tools available to add more intricacy to the design. These tools help to manipulate with different yarn linear densities, thread densities, weave and yarn color combinations to get a particular appearance in the form of 3D simulation (Figure 4).

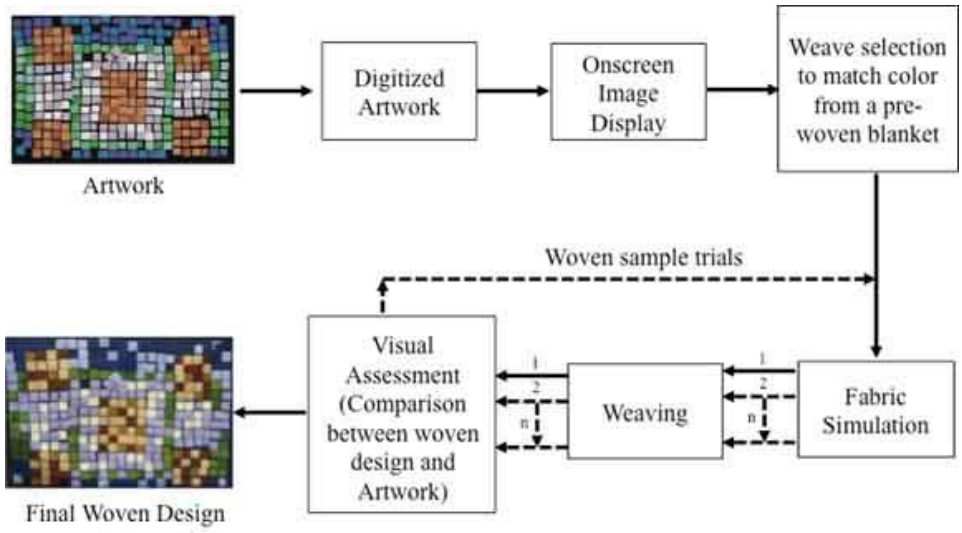

Figure 4: CAD simulation (Source: ScotWeave CAD systems)

Some of the important modules for simulation are:

Yarn library

The yarn library feature in the CAD system allows to store yarn information in two ways: 1) using scanned yarns pictures (regular or fancy yarns), and 2) creating yarns by using technical information of a yarn such as fiber type, yarn type, linear density, twist level and direction (S or Z), and color. This information is used to create regular and/or fancy yarns effects for simulation.

Color library

Color Library enables the designer to create a database of colors, which can be used for viewing colors and color combinations during fabric simulation. This feature also helps in creating, saving and loading color palettes when required. It also assists in making custom color pallets, creating/editing shade number, shade specifications, saving pallets, loading/retrieving of pallets, and searching of a particular color. In addition, color specifications are also available which allows user to manage color information between designer and customer. Color libraries vary between different CAD systems, depending on the module and area of application.

Weave library

The weave library aids in creating virtually any kind of weave. The weave library tool is designed to create and store weaves, edit weave structures, combine/blend multiple weaves, and create a weave database from importing images. All of this can be achieved by either click/unclick or drag & drop features.

Fabric simulation

This feature in CAD system allows one to see the fabric simulation in the virtual fabric form before the production of actual the fabric. All the settings such as yarns type and linear densities, yarn color, warp and weft pattern are predetermined in the simulation window. This feature also allows the designer to make changes in terms of color, yarn and weave. This tool is widely used as a communication between designer and the customer for preapprovals. The CAD packages use different modules of fabric simulation based on the fabric appearance and properties.

The design modules in the CAD systems provide a wide range of possibilities such as designing tools, image compression, color reduction, weave repeats, floats reduction, and weft control according to the weave design. These tools and simulations help the designer to make a decision focusing on the esthetic appearance of the fabric on-screen before it goes for final weaving. Most of the CAD systems now simulate the appearance of the woven structure, using combination of fiber and yarn attributes from the yarn pictures added in the database system. These simulations can be visualized on a high resolution monitor to visually compare with the original artwork and avoid the expense of producing fabric. Although computer simulations are highly desirable as an aid to designate particular structural coloration, the actual color rendering of the final weave design is still critical. These commercial CAD systems still require prototype (or blanket) development at the weave allocation step to match the weave structural color rendition with the final artwork color (as described in Figure 3).

Recent Advances in Color development for Jacquard Weaving

Advances in electronic imagery have helped in designating particular structural colorations, but accurate color rendering is critical. Several experimental studies in the past have revealed that the use of colorimetry has helped to achieve better reproducibility and accuracy in the shade matching of the textile products (AATCC 1997, Nihira et. al. 1980, Ohta 2005, Walowit 1987, 1988, Randall 1997, Rich 1986). Several measuring and imaging systems are now available commercially that can record colorimetric data and convert these data into visual images. Hence, the designer can generate a numerical color specification that can be visualized accurately on a suitably calibrated

monitor. Recent advances in color data generation and image processing provide opportunities for additional improvements in areas of collaborative color development, color marketing, and color prediction in multi-step processes. Some of the latest CAD systems offer possibilities for using colorimetry in weaving practice. However, based on the review, it is clear that these commercial CAD system require an add-on tool that will produce colorimetric data from the combination of the geometric information of the weave design and yarn colors to match with the colorimetric data in the artwork without first making the weave in prototype form. In other words, Jacquard fabric producers require an automated process to assist with color generation and selection. To meet such a need, a tool is required to predict the contribution of each color component present on the surface of the fabric structure in terms of warp and pick densities, warp and filling yarns sizes, weave, size of the color repeat of warp and filling yarns, and the number of yarns of different colors. Results from these geometric calculations when combined with sound existing color mixing equations could lead to the automation of the process of weaves and color selection, and thus dramatically reduces the production cycle. The focus of this section includes a review of recent research work done in this area to automate the process of assigning weaves/colors in order to reduce or even eliminate the need for physical sampling and to assist woven fabric designers in the creation of woven designs that are a very close match to the original colors in the artwork.

A lot of research has been done in the past to automate the design process for Jacquard woven fabrics, but the research does not address the issue of sample preparation before final production (Osaki 2002, 2003, Takatera and Shinohara 1988, Grundler and Rolich 2003, Dawson 2002, Dimitrovski and Gabrijelcic 2001, 2004). Very little research has been done to develop a method for predicting color values on woven fabric surfaces by calculating the color values from the yarns and the constructional parameters (Dimitrovski and Gabrijelcic 2001, 2004). Further, a geometric model was developed using the fabric's fundamental theory of geometric and optical cover principle (Peirce 1937). This model enabled calculation of color proportions on the fabric surface in terms of weave pattern and color sequence of warp and weft yarns. The geometric calculations obtained from this model were employed in the number of Kubelka-Munk based colorimetric models to predict the final colorimetric value of the woven design (Mathur et. al. 2005, 2007, 2008, 2009), to objectively define the color on the fabric surface before weaving. This method developed in this research was good for small patterns with fewer number of warp and weft yarns, colors and weaves. In the case of large patterns with numerous warp and filling yarns, colors, and weaves, this method was very tedious and cannot be programmed to enable the automatic calculations of color contribution from basic design parameters. Later, a generalized model was developed to enable the user of a computer simulation to input basic design parameters (Seyam and Mathur 2012). The basic parameters used in the generalized model are warp and filling yarns linear densities, warp and pick densities, weave, color arrangements of warp and filling yarns, and color of the background. This is most comprehensive geometric model to-date. With proper computer programming, in combination with a suitable color mixing equation (Marcus 1978, McDonald 1997, Walowit 1987, 1988, Kim 2013, Ken et. al. 2017, Chae et. al. 2014, 2016, 2018, Zhang and Zhou 2018, Youngjoo 2014, 2016, 2018), and databases (CAD libraries), the process of color/weave selection, this model can be integrated with any CAD system to automate the process of color/weave selection as shown in Figure 5.

The process flow starts from creation of the artwork and measuring color attributes (defined in CIELAB color space) for each color in the artwork. The CAD tools allow the designer to edit the artwork if needed and input all the design parameters at this stage. Next, the final color of each area in the pattern can be obtained using the add-on

feature/tool developed to calculate the geometric contribution of each color and in combination with the color mixing equation. The calculated color attributes are compared to the measured from the artwork. The difference of color attributes between the measured and calculated is verified. If the difference is within the set tolerance, then the system will report the output that will include the color attributes for calculated and actual, along with the color arrangement and specific weaves.

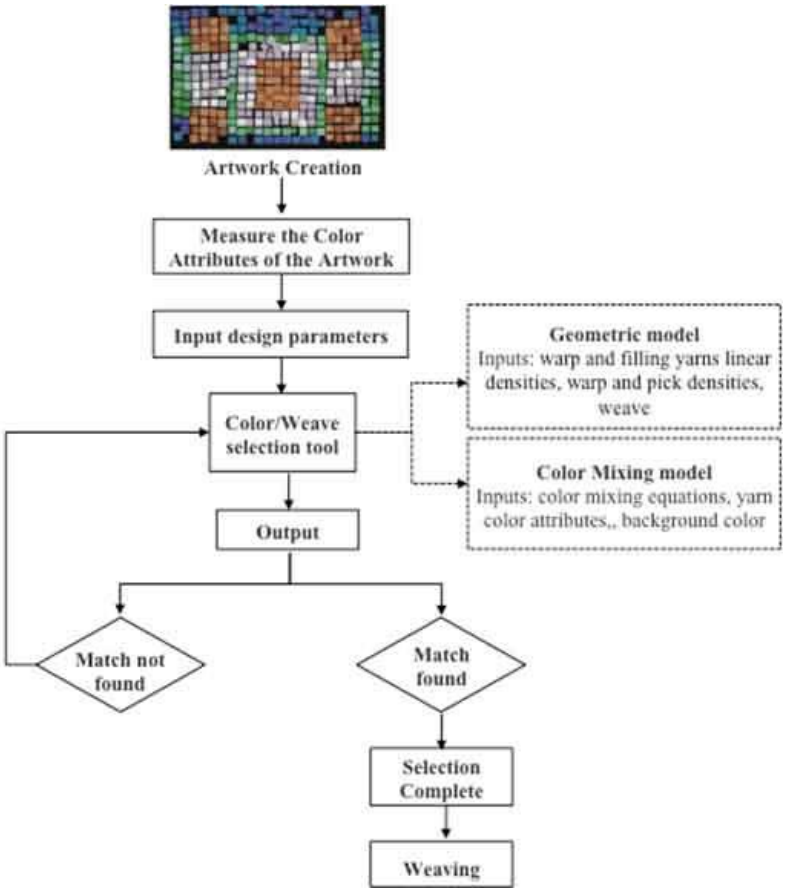

Figure 5: Flow chart showing the benefit of employing geometric and color models to automate the process of weave (color) selection

Conclusions

This paper focused on the review of latest advancements in Jacquard designing and coloration technologies. Based on the CAD system review, it was obvious that the available commercial CAD systems still require prototype development at weave allocation step to match the weave structural color rendition with the final artwork color and therefore require an automated system to assist with color generation and selection. Additionally, this paper reviewed the recent researches in the area of Jacquard designing and coloration. The review indicated a use of geometric model to predict the contribution of each color component present on the surface of the fabric structure in terms of warp and pick densities, warp and filling yarns sizes, weave, size of the color repeat of warp and filling yarns, and the number of yarns of different colors. The geometrical model combined with sound existing color mixing equations could lead to the automation of the process of weaves and color selection and thus dramatically reduces the production cycle.

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