Review Article

Journal of Textile Engineering and Fashion Technology

A Total Appearance Reproduction System for Supply Chain Colour Management

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Submitted: 25 Feb 2021; **Accepted**: 01 March 2021; **Published**: 02 March 2021

Citation: *Ming Ronnier Luo, Keith Hoover, Tingwei Huang, Candong He, Xiaoping Zhang, et al. (2021), A Total Appearance Reproduction System for Supply Chain Colour Management. J Textile Eng & Fash Tech, 3(1): 46-40.*

Abstract
Digital colour technology has long been available for use by the global supply chain in the textile industry. However, it has yet to achieve total appearance reproduction including both colour and texture. A new computer system named LED Simulator was developed to achieve this. It reduces the design cycle from months to weeks. At the same time, it assures a high degree of colour reproduction accuracy between different systems. It applies the concept of virtual samples to textured substrates by illuminating an undyed substrate with coloured light. It exhibits a larger colour gamut than conventional monitors. This results in a truthful representation of the final product.

Key words: Colour Appearance, Total Appearance

Introduction
In the apparel industry, the process to move from a garment design to the finished product takes a long time [1]. It is split into three distinct phases: 1) exploration, 2) product design and development, and 3) manufacturing. A brief account is given for each phase.

Exploration
The journey starts in exploration when designers research trends that translate into fashion concepts. A significant part of this research involves the colour and textural appearance of inspirations found in nature and the environment. Trend research is used to create a conceptual line plan – a merchandising theme used to design a collection of garments. The foundation of a conceptual line plan is the colour palette, a collection of colours used for all garments to be marketed together. Since colour palettes at this stage are created before garments are designed, various material textures identified during exploration are not yet tied to specific fabrics. As such, designers typically focus only on pure colour even though their research has a textural context.

Colours identified during colour exploration are documented by referencing physical specification systems such as Pantone, Archroma, CSI, and Coloro. These systems are presented as books or fan decks of colour patches using either coated ink on paper or textile dyes on flat fabric. These colour specification systems are designed to focus on colour appearance, excluding attributes such as texture, gloss, and translucency that make up the "Total Appearance" of a colour [2].

Product Design
During product design and development, designers and product developers use digital versions of the documented colours in CAD software to create garment designs as choices for merchandise plans. As part of an editing process, merchandisers review these images either on-screen or on paper printouts to determine which designs will be included in the final product line to be manufactured and sold in a design season. As product designs are selected, product samples (protos) are requested from the garment manufacturer to evaluate the fit and aesthetic. At this stage, protos are not colour-correct since they are typically made from available fabric.

To address colour, a product developer initiates the manufacturing stage of the process by sending requests to the fabric mills and suppliers to match the colours in the palette on the fabrics that will be used in the garments. This is called "labdipping" because the dye lab at the mill creates a small sample of the colour (although not by dipping fabric in colour) to create a production dyeing recipe. The internal process of matching a textile colour to a colour standard is a prior art practiced successfully and efficiently for decades in the textile industry. However, the process for colour matching between a mill and a product developer is not so clear cut.

Manufacturing

Many factors can confound the colour matching process. In some cases, the specified colour standard represents a "starting point" and the mill is expected to create variations for selection. In other cases, the colour standard might not be matchable for technical reasons related to the substrate or fastness requirements. However, the biggest barrier to colour matching involves "Total Appearance." Matching a colour on a fabric with significant texture to a colour standard with no texture requires subjective decisions on the part of both the product developer and the colour matcher. Several iterations between the mill and the product developer might be required before an approval is issued. And even then, the total appearance of the fabric might not be what was envisioned during the colour and textural appearance exploration process. It is highly desired to have a new tool to rectify this process.

Digital Technology

Conventional systems

Successful technology has been developed to visualize colour on screen in the design studio and expedite textile colour matching on flat substrates at the mill resulting in colour communication systems for supply chain management [3, 4]. Digital design images can be digitized via CIE colour specification data and transferred to the mill via spectral reflectance data, enabling objective and accurate colour matching. Very little has been done to bridge the gap between colour appearance and total appearance. A colour patch with no texture cannot address total appearance [3, 4]. This can be overcome by some digital imaging systems such as TAC7® from XRite and DigiEye® from VeriVide [5]. However, they also have limitations, such as colour appearance difference due to reflective and self-luminous, surround viewing conditions, or colour gamuts between the display and the dyes/substrate. Neither successfully solves the more challenging issues involving texture.

LED Simulator System

A true colour specification for textiles is needed that includes both colour and texture information. To address that need, a computer system has been developed to perform accurate total appearance reproduction. The system is called LEDSimulator supplied by Thousand Light Lighting (Changzhou) Limited. Or THOUSLITE. (www.thouslite.com) [6].

The System

A new system for surface simulation has been developed. Figure 1 shows the full system in operation.

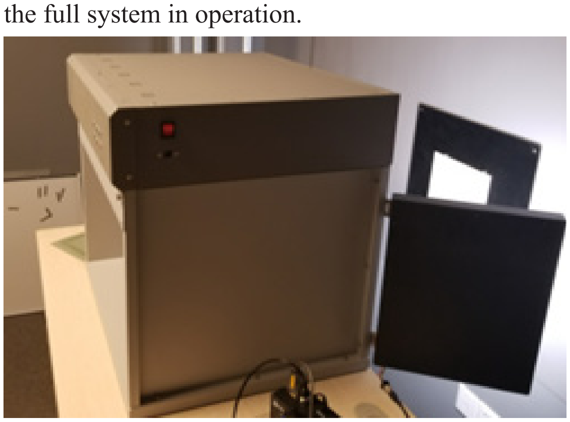

Figure 1: The system in operation

Figure 2 shows a schematic diagram of the system. It applies two light panels that are spectrum tunable 6-LEDs systems to illuminate the surface substrate, thus producing a wide colour range.

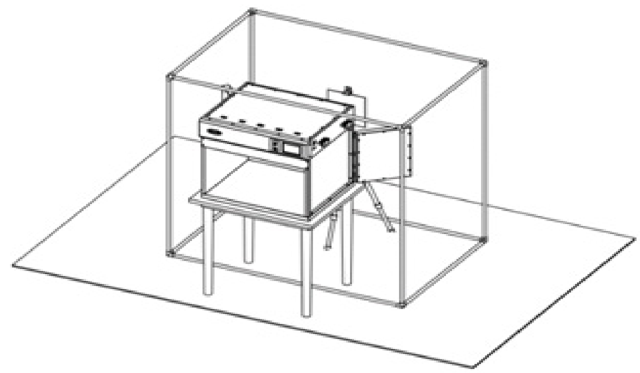

Figure 2: The schematic diagram of the system

The colour gamut of the 6 LEDs (like a 6-primary display) is larger than the typical monitor display gamut such as sRGB and DCI-P3. It also includes a viewing cabinet coated with grey ($L^*=70$) to provide a standard background and is equipped with an 11 spectral tunable lighting system [7]. The viewing cabinet includes the standard CIE illuminants corresponding to correlated colour temperatures (CCT) of 6500, 5000, 4000, 2850 K. Each illuminant has very high colour quality properties such as Rendering index (Ra) and Metamerism index (MI) [8]. There is a compartment covered by the black cloth in the back of the cabinet to prevent the interference of ambient light in the room. The back wall of the cabinet incorporates a window, or aperture, through which an undyed substrate in the dark compartment behind the cabinet can be seen. The substrate is illuminated by the two light panels as explained above. There are 10 substrates included in the system including a range of coarse to fine textures for both woven and knitted fabrics. These samples are made from different materials, such as cotton, polyester, and linen.

A designer can use LEDSimulator to create a new colour or match an existing physical sample by adjusting software settings for the three colour appearance attributes, lightness, chroma, and hue using the TL-H, TL-V and TL-C controls respectively or adjust a colour until a satisfactory shade is produced. Figure 3 shows the colour selection interface that supports either process. The sequence of colour matching in the software starts with a colour wheel (see the left diagram) to select a desired hue. Upon selection, a page of hue samples varying in lightness and chroma appears (see the middle diagram). From there, the designer uses the Colour Picker displayed on the right as a fine selection tool, to select the "perfect colour." Upon selection, the colour appears on the substrate to be viewed in the viewing booth.

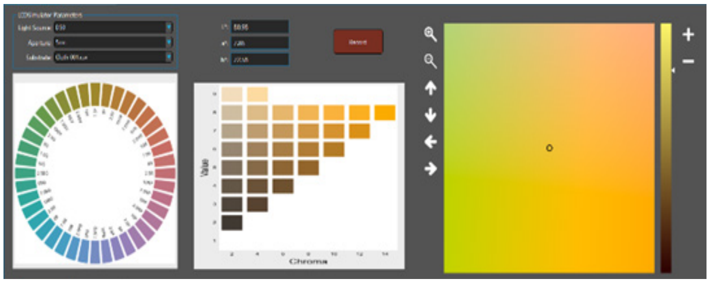

Figure 3: Colour selection Interface

Figure 4 shows an example of colour adjustment in which a user intends to match the top left patch in the physical colour chart using the system. First, s/he selects a colour from the coarse colour display and then moves to the fine colour picker to achieve the target. The coarse picker can be supplemented with a customer-specific colour library or a colour specification system.

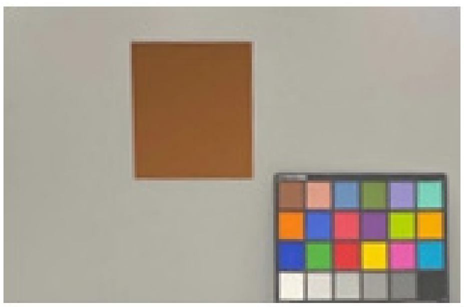

Figure 4: LED Simulator image next to physical sample

All colour information is stored in the computer, each definition including the Palette name, Product name, Substrate number, CIE XYZ, and LAB values. Note each Palette includes a number of products. The typical colour reproduction between two LED simulator systems is within 2 ΔE00, CIEDE2000 colour difference units [9].

Before the system dispatches from the manufacturer, the front viewing cabinet and two back panels are calibrated in terms of the 11- and 6- LED primaries respectively and CIE 10-degree XYZ values. This allows them to have an agreement below 2 ΔE00 units. For more accurate colour reproduction, a tele-spectroradiometer or tele-colorimeter can be used. The results of CIE XYZ and LAB can be reproduced to achieve a colour accuracy of 0.5 ΔE00.

Standard Operation Procedure (SOP)
The apparel industry is built on a fragmented supply chain and a complicated process involving three types of users: designers, merchants (retailers), and manufacturers. LED Simulator can be used by all three.

LED Simulator provides designers with a powerful tool to create colours either from their imagination or by matching physical samples from trade shows, found objects, etc. They move from the colour wheel to the hue page, to the colour picker to create the colour. Then they can see the impact of different textured fabrics on the colour "right in front of their eyes." The selected colour along with information about the substrate is digitally stored and transmitted for communication to the merchant, who can see the desired colour and appearance exactly as the designer saw it – a single source of truth for all decisions involving colour specification or matching downstream.

LEDSimulator colours sent to the mills for matching include colorimetric data (XYZ or LAB) that can be used in computer formulation systems to obtain dye recipes for both textured and non-textured fabric. Colours for non-textured fabrics can go through the digital match process using spectral data as the standard. Colours for textured fabrics go through a visual approval process using the LEDSimulator for match assessment. The colour/fabric specification created in LEDSimulator by the designer is used as the digital reference standard in the mill's LED view unit. A visual assessment is made by the mill colorist by comparing the total colour appearance of the dyed fabric to the LEDSimulator digital simulation using the brand-specified substrate.

Conclusions

A new computer system to achieve total appearance reproduction for Supply Chain Management has been achieved. It reduces the design cycle from months to weeks. At the same time, it assures a high degree of colour reproduction accuracy between different systems. It applies the concept of virtual samples to textured substrates by illuminating an undyed substrate with coloured light. It exhibits a larger colour gamut than conventional monitors. This results in a truthful representation of the final product.

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