Digital Printing for Sampling

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Abstract

Textile manufacturers spend a significant amount of effort to produce a set of samples of their collection. Digital printing offers a tool to eliminate this. Of course the samples must be representative for the real products. This means that the color and texture must look like real. For flat fabrics, systems are already available to print paper samples that can hardly be distinguished from the real ones. For pile fabrics, which have a 3-dimensional structure, the quality of the samples is not acceptable yet. This paper will describe the two factors that have to be considered to come to an acceptable solution: color and texture. As for color, three cases must be considered: printing on paper, on the actual textile material, representation on the screen (e.g. for e-commerce). Each of these cases have different problems. Texture is a complex phenomenon. At the department, research is being carried out on modeling of texture. The results of this research will be presented. As a conclusion, an overview will be made of the applications that are within reach, and of research to be carried out to solve the remaining problems.

Digital Printing for Simulating Textile Fabrics[6]

Commercial CAD/CAM systems for the textile industry allow already for simulating textile fabrics on paper by means of a digital printer. However, these systems can still be improved. Current systems still have problems simulating realistically 3 dimensional textiles (pile fabrics). The resulting design is, as a consequence, difficult to evaluate by designers and customers with regard to its realism. A good simulation (on computer screen and on paper) requires that both color and texture are accurately modeled. Both characteristics are highly dependant on the type of textile. It is relatively simple to predict the color for flat (2 dimensional) fabrics using the color of the original yarn. However, for 3 dimensional fabrics the relation between yarn and fabric is much more complicated. The microscopic structure of the fabric 'surface' will influence the amount of light which is diffused or reflected. The reflection characteristics of a fabric are furthermore also dependant on the angle light – fabric, fabric weave characteristics, the presence of oils and wax in natural fibers.

In other words: color is the major problem in textile appearance of 3 dimensional fabrics. For 2 dimensional fabrics the color corresponds with the yarn's side color, which can be accurately measured on a spectrophotometer and correctly printed. The problems of specular reflection and luster with pile fabrics also influence the color measurement by spectrophotometer. This subject has been studied by several authors:, more specifically: the characterization of fabric luster[1,5] and measuring the influence of the viewing angle on carpet color.[4] The following paragraph gives an overview and some of the results with regard to the color research done in this area.

Determining the Color for Pile Fabrics[2]

It was the intention of this research to determine if a relationship can be established between yarn color and carpet color, so that the carpet color can be predicted starting from the yarn color in the same way as for flat fabrics. First, the carpet color distribution and the corresponding yarn colors were measured. A Furthermore, the difference between yarn side color and yarn cross-sectional color was studied, because carpet color seems to correspond more to the cross-sectional color than to the side color.

In this study it was assumed that light falls perpendicularly and homogeneously on the surface of the carpet. Each point of the carpet surface receives the same amount of incident light, which can be divided in three components:

- Absorbed light (light lost between the fibers and not reflected at all)
- Reflected 'colored' light (dependant on the fiber's color)
- Directly reflected light (reflected similar to a mirror or not 'colored' light). This sort of reflection is called specular reflection. The proportion of specular reflection will depend on the tuft angle with the vertical

Modeling was done in the CIE color space,[3] which is a standardized color space where color is defined by three coordinates X, Y, Z (tristimulus values), taken from the reflection curve. These three coordinates match the pigments and the color response mechanisms in the human eye.

Experiments were restricted to two different fabric constructions (frise and flat velvet).

Because carpet, even so-called flat velvet, is not a flat surface, the carpet color is not one color, but a color distribution. A 3-CCD color camera was used to measure this color distribution. The camera's RGB coordinates were converted to XYZ coordinates. Initially, the method used to calculate the conversion matrix was as follows: first 200 calibration colors were taken as representative of the color space, and the RGB camera values of these and the XYZ values from the spectrophotometer were measured. With the least square error method, the conversion RGB to XYZ matrix was calculated, which should fit for the whole color space. This was done for each carpet separately as the conversion is completely non linear.

Yarn color is traditionally measured from the side, not the cross section. Because it is an irregular surface created by individual filaments or individual tufts, the cross section is difficult to measure. The color of the cross section was measured by pressing tuft ends into a cylinder and shaving the resulting bundle as closely as possible.

A digital printer was used to check how well the camera carpet colors images fit the original carpet samples. The printer exhibited good color quality and can reproduce CIELab colors with good precision.

A first observation was that the color distribution of the carpet is linear in the color space and that this line is passing through the yarn color. In retrospect, this observation seems obvious, but there was no theoretical proof (in advance) that carpet color distribution would be a line. It does make the characterization of carpet color distribution much easier, because it is reduced from a three-dimensional problem (entire color space) to a one-dimensional problem (line).

When comparing the yarn cross-sectional and side color measurements it was obvious that the cross-sectional color is always darker than the yarn side color. To check how well yarn measurements fit with reality, the digital printer was used for both side color and cross-sectional color, to compare those values with real samples. The yarn side color and cross-sectional color spectrophotometric measurements were each one solid color, which was printed on a 1 cm square with the digital printer. This print-out was visually compared to the real sample. Yarn side color printings fit well with original samples, but yarn cross-sectional color printings fit less well.

It was checked whether the yarn side color and cross-sectional color measured from the spectrophotometer also followed the color line. To this end, the closest color point was calculated between the carpet line color and the yarn color (side or cross-sectional). Furthermore, a color difference was determined between the closest color point and the yarn side color. Although some of these color differences are important, it can be concluded that the yarn color is part of the color line because the color difference is smaller than the error of the carpet measurement. Also, the samples with a large color difference corresponded to bad carpet printings. In general it could be concluded that yarn side color and cross-sectional color fit with the color distributions obtained from the carpet samples.

Starting with yarn colors, it is now possible to predict the 'theoretical' carpet color line. A set of equations can be generated which allow to calculate the theoretical coefficients of a carpet for each color.[2] Theoretical values have been compared to measured coefficients. The results are acceptable for most carpets, especially when considering that the camera measurements and yarn cross-sectional measurements are far from perfect.

Another important relationship which has been researched is the relationship between yarn side color and cross-sectional color or in other words: is it possible to predict the yarn cross-sectional color departing from the yarn side color? To this end, the Kubelka-Munk theory has been used. When a light beam is incident on a dyed specimen, the radiant energy interacts with colorant molecules, resulting in scattering and absorption of light. In the absorption process, the light energy is absorbed by the colorant and converted into heat. In the scattering process, the direction of the light beam is altered. The medium is characterized by empirically introduced optical parameters K and S, commonly known as K-M absorption and scattering coefficients. K-M theoretical expressions have made significant contributions to color matching in various industrial products. One valuable feature of the K-M theory is that absorption and scattering coefficients for mixtures of colorants can be built up from unit absorption and scattering coefficients of individual pigments and dyes. More details about this theory can be found in Ref. 3. Finally, the reflection curve of the yarn cross section can be obtained by using the following procedure:

Step 1: Reflection of yarn side (R)

Step 2: Conversion into K/S space (K/S curve for yarn side)

Step 3: K/S multiplied by the appropriate coefficient (K/S curve for cross section)

Step 4: Reflection curve of cross section

For each of 30 colors, the cross section was calculated starting from the reflection curve of the yarn side. These results were compared to the measured cross-sectional color. The (color) difference for all colors was rather small indicating the validity of the aforementioned procedure.

Digital Printing on Textile Fabrics[7]

Digital printing is an important research topic in textiles. Digital printing allows theoretically to print a design from computer (developed by for example a CAD system) to a textile material without the need for templates or the creation of the correct color blends. The creation of templates is a time consuming and expensive activity. Furthermore, they can only be used for one specific design (with the possibility of different colors).

The templates have to be cleaned thoroughly, which uses a lot of water, producing waste fluids. For each color a correct color blend has to be produced, resulting in remaining waste. This is ecological unfavorable. To achieve a desired design, the templates (each corresponding with a different color) have to be positioned accurately with regard to each other. Failure to do this leads irrevocable to second quality textiles. Compared to traditional printing, digital printing has several advantages. As has been mentioned, it is not necessary to use templates. This results in an important savings towards time and materials. The preferred color is obtained by blending the different printer inks which are kept in small containers. Using this method, a substantial amount of color substrate is being saved. Digital printing allows to realize a design very quickly and, if necessary, on a limited scale, personalized to the designers wishes. Flexibility is a keyword when considering digital printing. Although today, digital printing is very slow, it is expected to attain a feasible level in the near future with regard to industrial applications.

One of the largest problems with digital printing on textiles is obtaining the desired color, as there exists a strong interaction between the texture of the textiles and the ink. Fundamental research is being done to model the relationship between texture, color of the textile material, dye and the resulting color. The goal, within this part of the research, is to allow a combination between a CAD system and a digital printer that is capable of printing on textiles without to much trials.

The relationship between textile, inks and resulting color is complex. The set of textiles to print on is very large. It is therefore not realistic to suppose that a strictly mathematical model will be found to describe these relationships. Moreover, optical effects have to be taken into account. The solution will probably be found in a combination of relationships and calibration of the digital printer.

Today, CAD developers use elementary calibration procedures using thousands of colors. These colors are printed on the textile material. The results are scanned and a correction is applied depending on the difference between obtained color versus desired color. This procedure can be repeated until the results are satisfying.

As the measured (obtained) color is dependant on the equipment, the equipment has also to be calibrated. It is only after this has been done that the digital printer can be calibrated. As already mentioned, this procedure involves the analysis of thousands of colors.

This procedure has several disadvantages:

- Even with the use of thousands of colors it is not certain that these colors are the optimal choice with regard to a specific textile.
- All colors have to be scanned. This is a very time consuming activity.
- The measured color is dependant on the scanning method (equipment), which means that the scanning equipment influences directly the correction factor. Also, some scanners have serious problems if the color is to light or dark.
- The printer itself has certainly an influence on the resulting color, as a different configuration (ink, substrate, printing heads) will result in a different color space.

Research in this field concentrates on several aspects:

- Research on color space sensitivity. Color can be represented in a number of different color spaces (CIE, L*a*b*, XYZ, R'G'B', Y'IQ, etc.). The goal in this research is to find the color space which is the best suited for presentations on different media (computer display, scanner input, printer).
- Optimization of the calibration procedure. Each step of the calibration is analyzed to obtain a better understanding of the whole procedure. Especially the influence of the scanner and the development of correction algorithms are important.
- Influence of the textile material on the resulting color. Textile texture and the combination of fibers have an influence on the absorption and diffraction of light. Absorption and diffraction will also change for different wavelengths (and as a consequence also on different colors). Current research attempts to find an empirical equation (or set of equations) between the different textile parameters and the observed color difference.

Conclusion

This paper has introduced and discussed several digital printing topics with regard to textiles. First an overview was given of the use of digital printing for simulating textiles on paper. A very important element in this discussion was the simulation of the correct textile color, especially with 3 dimensional fabrics. The research done on this subject has been presented, showing the relationships between fabric color distribution, yarn side color and yarn cross-sectional color. The last part of the paper discussed the application of digital printing on textiles, including its disadvantages and the research possibilities within this field.

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Biography

Lieva Van Langenhove received her degree as textile engineer from the University Ghent in 1984 and a Ph.D. in Applied Sciences (textiles)from the same university in 1994. From 1984 to 1989 she worked as research manager at UCO NV where she received an extensive training in all departments of the company, including printing. Since 1997 she became Professor at the University Ghent. Her work has primarily focused on the following research fields: fibers, spinning, weaving, information technology in textiles, interactive textiles and medical textiles.