Colour range generation using precise on-screen colour

Colour range generation using CAD

Pag. 65

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The availability of high quality colour monitors and graphics systems leads to the possibility of a CAD system for colour. Colour is already widely used in Textile CAD systems, and is an essential component in the overall design.
Unfortunately the colour of a typical colour monitor is neither constant nor reproducible. Thus a designer may produce a pleasing colour combination on the CAD screen, but it can not be communicated easily to potential customers or to production.
The UMIST research project on 'colour systems for Textile CAD' set out to identify the key components of as CAD system for colour and develop them. This process has been successfully completed. The resulting components have been licensed to Messrs Textile Computer Systems for commercial exploitation. The resulting Shademaster system combines all the key components into a powerful design tool.
Shademaster has already been sold into a major organization that specifies and develops a series of colour ranges for each season. Use of the Shademaster will enable this company to reduce lead times and increase flexibility of response substantially.

The Umist Research Objectives

The Umist team have access to a wide range of designers, colour specifiers, and colour range managers. The process by which colour ranges are developed, balanced, tested and managed have been examined, and a set of key features of a colour CAD system has been identified. This was a prime objective of the research.
The next major objective was to develop the necessary components which would support the required features.
The third and final objective was to assemble and demonstrate an effective colour system for CAD and license it to a suitable manufacturer.
All three objectives have been successfully achieved and the benefits of the research are now available to designers.

The Key Features of a CAD System for Colour

The Umist team have identified five key features that a CAD system for colour should provide.
1. The ability to visualize a large gamut of possible colours.
2. The ability to specify and define the colours seen unambiguously and precisely.
3. The ability to communicate colour rapidly and precisely between decision makers and into production.
4. The ability to navigate rapidly and easily through all the available colours.
5. The ability to manipulate colours singly and in groups for content, balance, harmony and theme.
Several of these could not be delivered adequately with existing technology. In particular, on-screen colour required a system, giving precise control and specification.
In addition it was necessary to relate self luminous screen colour to surface colour satisfactorily and to provide tools, suitable for use by designers, for manipulating colour.

The Components Developed at Umist

1 - Colour Visualization

The Umist Adaptive Driver *is a self adapting driver system for colour graphics monitors. It uses screen measurement and feedback to adapt drive characteristics so that:*

a. Screen colour can be precisely defined in terms of CIE co-ordinates.
b. Screen colour can be maintained constant over the full gamut of colours on a given monitor.
c. Any two monitors can be calibrated to give the same colour appearance.

In effect the Adaptive Driver constructs and maintains a non-linear three dimensional mapping function between XYZ and monitor RGB inputs.
This mapping function is modified by reference to the current state of the monitor, which is fed back to the Adaptive driver from a Minolta CA100 tristrimulus colorimeter.
The result is that any given CIE XYZ colour specification can be reproduced on the screen to a tolerance of:

and $\pm$ *0.003 in x, y chromaticity*
$\pm$ *5% in Y lightness*

Thus any two systems using Adaptive Driver Calibration will have constant colour and will look exactly the same.

The UMIST Colour Context System *is a further innovation. The problem is to relate self luminous screen colour to surface colour appearance under standardized illumination conditions.*
To achieve this the UMIST colour context system uses a complex scene that simulates a standard colour matching cabinet. The scene has a number of key elements that cause the human brain to accept the simulation. These are:
a. A perspective layout with a set of coloured tiles.
b. A 'virtual illuminant' corresponding to D65 standard artificial daylight.
c. A reference white and black tile.
d. Standard neutral surroundings, keyed to those of a matching cabinet.
A large number of visual comparisons have been made between coloured tiles on the screen with a given CIE XYZ specification and textile fabrics with the same XYZ specification.
It has been shown that, provided screen co-ordinates are within $\pm$ *0.005 in x and y and* $\pm$ *10% in Y the physical samples are judged to be a good match to the screen. This is true of both dark and light shades over a wide range of hues and chroma.*

2 - Colour Specification

The colour seen on the screen can be

manipulated until it is acceptable to the user. It is however, necessary to specify precisely what colour was seen and selected.
The obvious candidate for specifying colour is the CIE system.
This expresses colour in co-ordinates which take into account the effect of illuminant and the properties of the human standard observer.
CIE 1965 10 observer D65 illuminant co-ordinates where selected as the basis for colour specification.
In a successful colour CAD system it should be possible:
a. To know and quote the CIE co-ordinates of all colours shown.
b. To ensure that the screen is maintained at or very close to those co-ordinates.

CIE 1965 10 illum D65 co-ordinates are the reference co-ordinates for all colours, but there are other colour spaces which may be profitably included in the system.

1976 CIE L*A*B* Colour Space
"CIELAB" colour space is mathematically related to XYZ space by non-linear transformation. It has a much higher degree of perceptual uniformity and is more closely related to the human experience of colour. In consequence of this CIELAB colour space was reviewed and included in the colour specification facilities.
a. As a known and valued colour specification system.
b. As a basis for natural, intuitive colour manipulation tools.

HCL Colour Co-Ordinates
The attributes of Hue Chroma and Lightness are closely related to the human experience of colour. Consequently a co-ordinate system that could express these attributes was regarded as an important objective.
Within L*a*b* space Hue may be defined as a Hue angle - derived as:
O arctan b/a
This gives a uniform circular 360 Hue scale with red = 0, yellow = 90, green = 180 and blue = 270.
Chroma may be defined as the distance from the central neutral point
$C = (a^2 + b^2)^{1/2}$

The L* co-ordinate of L*a*b* space is a suitable lightness co-ordinate which has a good perceptual uniformity of scale.

Colour appearance under other illuminants
A CIE XYZ colour specification defines colour as seen under a specific illuminant. The colour reproduced on the colour monitor reproduces this appearance, but gives no information about how the colour will appear under a different illuminant.
For any given coloured surface it is necessary to measure the spectral reflectance curve in order to calculate CIE XYZ specifications for a given illuminant.
A method has been developed at Umist by which a synthetic spectral reflectance curve can be deduced for screen colours. This synthetic refletance curve further defines the colour seen on the screen, and provides the necessary information to asses appearance under alternative illuminants.
One line of on-going research at Umist is directed towards an accurate on-screen simulation of colour appearance under a range of illuminants.

3 - Colour Communication
Much of the time needed to generate colour ranges and colourways is spent in colour communication. Rapid, accurate communication of colour is needed:

a. When gathering colour information worldwide.
b. When discussing and developing colour ideas.
c. When turning colour ideas into swatches of fabric.
d. When producing prototype garments.
e. When specifying colour for large scale production.
Given the precision of on-screen colour delivered by the Umist Adaptive Driver, and the Umist colour context system to aid colour visualization, colour communication becomes rapid and precise.
Any pair of CAD systems can be used to communicate colour electronically. All that is required is a telephone, fax or modem link to transmit the CIE co-ordinates of the colour in question.
The simulation of surface colour provided allows any group of designers and decision makers to inspect and discuss colour ideas freely.
Synthetic reflectance curves are the ideal way to communicate with fabric, paint or plastic production.
A series of trials involving Umist, colour specifiers and commercial dye houses has been conducted. In the trials colours were created on screen, and synthetic reflectance curves sent to dyers. The curves were used as input to standard recipe prediction systems and matching dyeings to DE of 1.0 or less produced. Matchings on wool, polyester, and cotton were retuned and compared with the original on-screen colour.
A close commercial colour match was achieved across the three fabric types. It was also judged a good match to the original screen colour.
In one case a garment length was produced and returned within four days allowing the production of a prototype garment within one week of original shade definition.
It is important to note that in all cases the dyers were working with synthetic reflectance curves only. No matching to physical samples was involved.

4 Colour Manipulation
In a Cad system for colour, intended for use by designers and colour range originators, an important component is a set of easy to use tools for manipulating colour. As far as possible the CAD system should allow the user to handle, move, and alter coloured samples freely. In addition it is possible to provide a wide range of computer originated tools with no equivalent in the manual process. These tools allow great control over individual colours, groups of colours, and colour relationships.
The following colour manipulation tools have been developed and incorporated in the Umist research system.
a. A set of coloured samples on screen arranged in single colours, ranges and colour ways.
b. Tools to create, delete, move, enlarge, decrease and compare the coloured samples. This reproduces the manual process of handling and comparing physi-

cal samples.
c. A facility to select and change the colour of any sample on the screen using easy to understand intuitive parameters such as Hue purity/chroma and lightness.
d. A facility to define sets of samples on the screen and operate on all of them simultaneously.
e. A facility to produce sequences of colours varying in Hue chroma and lightness in any combination.
f. A facility to name, store, inspect and retrieve files of colours.
g. A facility to alter sets of colours while maintaining their internal balance. This gives a powerful method of generating new colourways.
Most of the above colour manipulation tools have been developed from suggestions of designers who have used the system. Others are based on the psycophysics of colour relationships researched at Umist.
An important objective of on-going research at Umist is the quantification of higher order colour relationships such as colour sequence, colour balance, mood, tension and harmony.

The Shademaster System

All the features and components developed at Umist for a CAD system for colour have been built into a fully commercial product named Shademaster. This has been licensed for production and sale to Messrs Textile Computer Systems.
Shademaster has all the following key features:
- A simple to use man-machine interface using point and select operations throughout, eliminating any need for keyboard skills.
- Convincing surface colour visualization based on the Umist colour context system, with easy to manipulate coloured samples on screen.
- Precisely controlled and defined colour using the Umist Adaptive Driver screen calibration and CIE co-ordinates.
- A comprehensive set of colour selection storage, retrieval and manipulation tools for the design and colour range generation processes

Given these features Shademaster can be used in several ways to facilitate the use of colour. Its main functions are summarized as follows.

AID To The Generation of Colour Ideas.
Individual colours out of the 10 million plus possible variations can be reached within seconds. A hue bar is used to reach the appropriate hue area directly and visually. Fine tuning is done with variable sized steps. Hue, chroma and lightness can be varied independantly with a visual colour guide showing direction of change.
Point to the direction of change required, and the colour changes that way.
Balanced sets of colour varying only in hue are often used in colour ranges. They can also be used to express an overall mood or theme.
It is a natural operation to create balanced sets by holding one or more of the prime variables of colour space (Hue, chrome lightness) constant, and varying the others.
Tonal sequences and co-ordinated sets are equally easy to produce and balance visually.
A sample layout is provided representing a "colourway" with four colours. As laid out all possible contrast combinations within the colourway can be assessed. **Once a** satisfactory balance and tonal relationship has been established within a colourway, it is possible to generate new colourways by moving all four colours simultaneously through colour space.
It is important to emphasize that Shademaster does not in any way replace the flair that goes into the creation of colour ideas. It is a Computer Aided Design tool.

Colour Specifications

Shademaster automatically quantifies and defines all the colours selected by providing exact CIE co-ordinates for them. These are the basis for:
a. Communicating colour information.
b. Classifying, storing and retrieving colour information.
c. Establishing and maintaining tonal, sequence and balance relationships within sets of colours.

Colour Communication

A single Shademaster aids a group of users to explore and discuss colour ideas. Any single colour can be generated then compared and adjusted until agreement is reached. Large files of historical, seasonal, and colour intelligence data can be maintained. This allows analysis and extrapolation of colour trends and analysis of competitive production.
A pair or a network of Shademasters allows instant communication of precise colour within an organization, across continents, with suppliers, and with customers.
Important reductions in lead time have been realized by improving colour communication:
a. Electronic communication of colour specifications to dyers and printers.
b. Rapid establishment of balanced colour ranges.
c. Rapid communication of colour marketing intelligence.
d. Rapid transformation of colour ideas into fabric garment lengths.

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