SET 1

APRIL 2015

EXPERT TECHNICAL GUIDE

COLOUR MANAGEMENT

GUIDE 1: COLOUR MANAGEMENT AND REPRODUCTION

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FESPA INTRODUCTION TO

COLOUR MANAGEMENT AND REPRODUCTION

It is dark. You are standing deep in an impenetrable forest and the sky overhead is densely overcast. You cannot see anything through the darkness, not the clouds or the branches or the tall trees, not even shadows. The dark is so absolute that when you raise your hand to your wide open eyes, it is as if your hand isn't there at all.
You can only imagine what the world around you looks like. Scary? Well this is the world without light, the world without colour, the world unreal and unknowable.
Add light to the scene and everything changes.
With light you can see the trees, the shadows, the shapes of the clouds in the sky, because with light there is colour. This is why managing and controlling light is so very important for printers and for the success of their customers' jobs.

Colour perception is about the interplay of light and texture, and how a surface absorbs and reflects lightwaves. Radiated light from a light source such as the sun or the moon or a light bulb exists as electromagnetic radiation, expressed as light. We cannot see all of light's wavelengths, so what we can see is referred to as the visible spectrum. Wavelengths range from 390nm to 700nm, which we see as violet to red under normal daylight. Under the right lighting conditions, we can see infrared and ultraviolet colours as well. Under the wrong lighting conditions we may not see the same colours as are intended by the designer or print specifier. This is very risky when doing colour proofing and managing print approvals across multiple locations.

In that darkened forest the gradual addition of light reveals more and more colours as the light increases. We can differentiate the colours because our eyes capture information about the light and our brains analyse and interpret the information. Colours are a means of distinguishing between surfaces in the physical world and they help us to understand what we see, according to how much light the surfaces absorb and transmit. Colours only really exist in our brains; they are just light and physics. This is why they are so tricky to accurately reproduce in print.

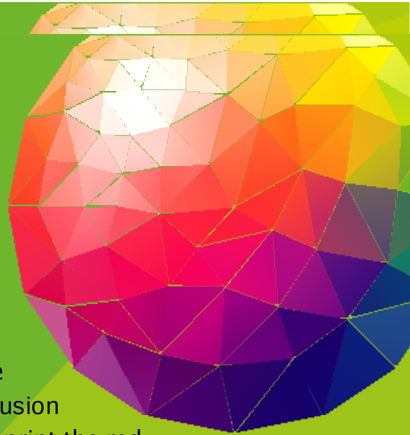
MANAGING COLOUR INFORMATION

Understanding how colour works in our heads is fundamental to understanding how to manage colour data in a print production workflow. It is also fundamental to appreciating why colour appearance can differ, particularly when print jobs are output across a range of substrates. The colour we see is analogue, which means that it is a continuum, a gradual phasing of shades and tones that make up the overall appearance of colours in a scene. In a digital production system colours are described as logical components, entities made up of binary data, bits and bytes. Without using mathematics to define colour it is impossible to have absolute commonality between the colours we think we see and the colours a computer thinks we will see when they appear in print.

THE EYE AS CAMERA

The iris in the human eye expands and contracts according to the amount of light available, so that it can control how much light enters the eye. Contraction of the iris reduces the amount of light entering the eye and expanding the iris increases the amount. The aperture on a camera uses the same idea. If there isn't much light around, a wide aperture allows you to use as much of it as possible to stimulate the red, green and blue sensors in the digital camera back to capture the scene. The iris does much the same thing to control the amount of light hitting the cone cells on the retina, which respond to red, green and blue wavelengths of light. The intensity and perceived character of this tristimulus response depends on the composition of the light, regardless of how complex it is. The human eye responds to the light as a continuum of information. A digital camera or scanner samples points in the image as a discrete series of binary data.

When all the available light is absorbed our eye perceives darkness, when all the red, green and blue light is reflected there is no differentiation of colours so we see white, the sum of all red, green and blue wavelengths. This is why RGB systems are called additive colour systems, and they are the polar opposite of the system printers use to create colour on a substrate. Printing is about transforming digital RGB images into a printed reality that mimics the appearance of the natural world.



PRINTED COLOUR

Printers use cyan, magenta, yellow and black inks to exploit the way a surface absorbs and reflects light in order to create the illusion of colour. Printed colour is quite literally a trick of the light that relies on the principles of subtractive rather than additive colour. In the subtractive model the primary colours are cyan, magenta and yellow rather than the red, green and blue of an additive system. Combining cyan and magenta produces blue, a secondary colour in the subtractive colour model. The combination of magenta and yellow produces red, and yellow and cyan produces green. Mixing all three in theory produces black.

Printing inks can appear to produce the same colours as the eye perceives in the red, green and blue world. They exploit the behaviour of light as it is reflected and absorbed by a surface printed with cyan, magenta and yellow (CMY) inks. The inks work like filters to create an illusion of colours that appear to mimic in print the red, green and blue world we see all around us. In the same way that the sum of red, green and blue light presents as white, in the subtractive CMY system the sum of all three should appear black. However CMY inks are rarely pure enough to absorb all available light, so printers add black in order to enhance contrast and ensure really deep, rich blacks and sharp black text. This makes black the key (K) colour in the CMYK process ink set. CMYK inks are not able to render low intensity and low saturation colours well, which is why nonprimary colours such as light magenta and light cyan, or orange and green are sometimes added. This enhanced gamut printing adds to process complexity, so a more usual approach to expanding the gamut of CMYK is to use inks with a specific colour, generally referred to as spot colour inks.

In theory there should be no limit to the range of colours that can be printed, however the range depends very much on the accuracy of the print process and the behaviour of inks and substrates. A designer's colour and substrate choices, how data is managed in the workflow, prepress decisions over screening, trapping and platemaking, and the press itself will all influence colour appearance. The human eye can distinguish over ten million colours, but the range of colours that can be printed with CMYK inks is around 400,000 for most offset printing processes. Screen printing by the nature of its process allows considerable flexibility in colour gamut depending on the substrate, and wide format digital printing can sometimes manage over 500,000 colours, depending on the combination of technology, inks and substrate.

DELTA BLUES

To measure colour difference quantitatively we use Delta E (ΔE), a formula for calculating colour values. A ΔE value is a single figure that expresses the difference between two colours. A ΔE of one or less is considered to be undetectable to the human eye, whereas, ΔE values of two to four are just noticeable. Colour differences of ΔE five and above are extremely easy for people with normal colour discrimination ability to detect. Around ΔE 10 and above and you get the impression that it's actually no longer the same colour, because it doesn't match at all.

There are several versions of the ΔE formula, so it is important to make sure your production workflow uses your preferred ΔE consistently, and that your customers know which one to work with. Probably the most widely used version is ΔE76 however colour scientists recommend the more recent ΔE00 which varies the luminance values depending on the actual colour itself. This is considered to give a more mathematically accurate value. But whether you work with ΔE76 or ΔE00 most important of all is to use a properly calibrated spectrophotometer and to be able to correctly interpret the results. This is especially key if you are moving colour data across different colour spaces.

COLOUR SPACES

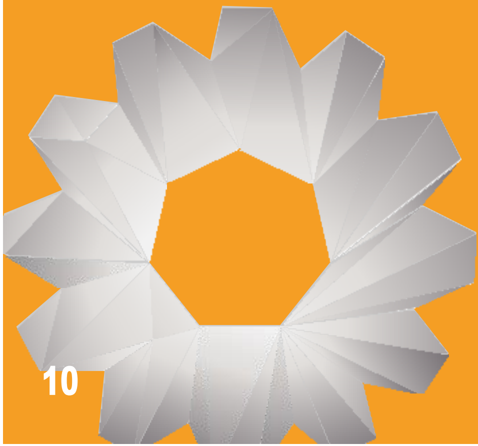
Whether it is the human visual system, a digital camera or a computer monitor, all RGB systems have a finite range of colours that can be expressed. And the same applies for CMYK systems, regardless of the method used to print the colour. A colour space is a mathematically defined reference of colours. Colour management for print output is the management of colour data from colour space to colour space, ideally ensuring that wherever colours appear – in reality, on your computer monitor or in print – they look as much the same as possible. Colour spaces share many colours in common, however at their boundaries these three dimensional spaces will differ. If you produce work for big brands it is imperative that their brand colours retain colour integrity, wherever they appear be that on shelf hangers and leaflets through to billboards and textiles. If the required brand colour is near the periphery of a colour space, you need to be especially careful in how you handle the data.

Colour spaces are abstract, mathematically defined models of colours. The RGB space, for instance, is an additive colour space that represents all the colours that could result from all possible combinations of the red, green and blue additive primaries. All RGB spaces must include a gamma correction curve for coding and decoding tristimulus values, and the coordinates within the space that define white. The most common RGB space is probably sRGB which is the default standard for web publishing. For high end photography Adobe RGB is preferred to sRGB. CMYK colour spaces are subtractive spaces that represent all colours possible by combining cyan, magenta, yellow and black. There is no standard CMYK colour space, so be careful to ensure that the CMYK colour space you work with is correctly defined. If you print the same job on several different presses, you are likely to be making colour conversions between multiple CMYK colour spaces.

Understanding that colour spaces define different collections of colours is vital for colour management, and especially for designers and content creators. RGB and CMYK spaces are not the same shapes and they describe different colour sets. It is also vital to understand that they are only models and on their own they are more or less arbitrary. In order to be useful for print production a reference colour space is required, a colour space to which colour values can be compared in a meaningful way. The most common reference colour space in the graphic arts industry is CIELab.

CIELAB

The CIELab colour space represents the entire spectrum of colours, even those beyond what most humans can perceive, using a standard illuminant such as D50 or D65 (daylight). In CIELab, colours are mathematically defined using three values. These are how light the colours are, from absolute black at 0 to complete illumination which is 100, and their a and b values. The a value indicates red to greenness and b yellow to blueness. The ICC colour management model, which is the industry standard in the graphic arts, uses the CIELab colour space as its reference colour space, calling it the ICC Profile Connection Space (PCS).



THE INTERNATIONAL COLOR CONSORTIUM (ICC) & PROFILES

In 1993 a group of eight leading manufacturers in the graphic arts industry established the International Color Consortium. They wanted to encourage open colour management, through the development of common colour descriptor technologies that all hardware and software manufacturers could use. Together they created a system based on human colour perception and CIELab, introducing the concept of a PCS that works in conjunction with ICC profiles. The ICC model makes it possible to use device profiles to translate and share colour information for images and files created on different devices and using different software. Operating systems suppliers and colour management professionals embraced the format, making colour a lot more predictable and reliable and encouraging wider use of colour in print.

Moving profiles, or characterisation data, and images with embedded ICC profiles across systems is now commonplace, with ICC profiles regularly assigned to images ensuring that they have the correct CIELab values. ICC profiles are also used to define the characteristics of hardware and how colours can be expected to appear. Device calibration and characterisation ensures that colour managed workflows perform optimally to minimise colour errors and ensure high quality prints.

Version 4.0 of the ICC specification was published as ISO 15076 in 2005. Most profiling software developers have adopted the standard and it is the foundation of all professional colour management systems. The ICC recently introduced iccMAX. This technology extends the existing ICC architecture to go beyond D50 colorimetry, which represents appearance using a D50 lightsource. The current model is easy to define mathematically and assumes a light source with a spectral power distribution equivalent to daylight. But it does not provide as much flexibility as a spectral colour model, which is increasingly of interest in packaging and other high gamut applications.

iccMAX is still under development, but the ICC has released some details about how what is essentially version 5 differs from version 4. The biggest development with iccMAX is its support for colour references made using raw spectral data, data that is not converted to CIELab. iccMAX also provides more flexibility in the illuminant selected, instead of only allowing D50. The objective is improved support for communicating spectral values through an optional spectral PCS. Spectral values allow for colour calculations using difference light sources, different ink sets and for different observers. They are based on physical models which make it possible to predict how materials interact, so spot colours can be more accurately simulated. These developments will be welcomed in the packaging industry and other sectors where ink mixing is common or where different ink sequences are used. Sign and display printers will be able to use iccMAX to produce work optimised for different light sources, say indoors or outside or backlit. Other changes in iccMAX are extensions to the type of information that can be stored in an ICC profile, such as the spectral data, and support for CxF. This is a relatively new format specifically designed for colour data exchange.

COLOUR EXCHANGE FORMAT (CXF)

ISO 17972 explains how to use the CxF data format to share measurement data plus additional information about a datafile, in an electronic environment. It has various parts customised for different workflows, however the objective with all parts is to facilitate process automation in colour managed workflows. The data can also be shared beyond graphic arts workflows, so CxF is a useful format for communicating colour data for different applications such as digital signage or textile printing.

WORKING WITH DEVICE PROFILES

Colour managed workflows use ICC profiles and the PCS to do colour transformations and to communicate colour data accurately in the workflow. A device's ICC profile is a bridge between its colour characterisation data and the PCS, ensuring that the outbound colour transformations and subsequent input data are accurate as the datafile moves through the workflow, from monitor to monitor across a local area network or via remote locations. Profiles must be accurately computed, particularly in distributed production environments, because they are the instructions for calculating colour descriptions. The accuracy of these transforms is what will determine the appearance of colours when viewed on screen, printed as proofs or for final output.

Profiles contain one or more tables that provide the mathematics for converting colour values, so there is an input transformation of data rendering colours to the PCS, and an output transformation which applies gamut mapping, re-rendering and separation. Devices are characterised by measuring how they behave relative to a set of reference colours. Measurement charts such as the IT8 and ECI charts have multiple colour patches specifying cyan, magenta, yellow and black in different percentages. These are measured with a spectrophotometer and the values stored in the device profiles. Profiles provide the native values for the device that will reproduce the desired CIELab colour, so obviously the more patches the better for more accurate profiles. A Colour Management Module, either in a computer's operating system or as part of a dedicated colour management system, performs the colour calculations using information the device profile provides. It sounds simple but in most colour production numerous people and devices are involved, and this inevitably complicates matters. Managing all processes from design through to proofing and final output and installation, requires control of the whole system as well as individual workflows within it.

CONTROLLING THE WORKFLOW

Colour management is all about control. Colour print professionals take ownership of every aspect of their workflows, so that they can deliver high quality colour to their customers without a second thought. If you have a high error rate on colour work, or if you are disappointed with the output on your shiny new wide format digital press, it is time to take a long hard look at how colour is managed in your workflow.

Start with an audit of the production department and make an inventory of the equipment, software and processes. Include a step by step description of what happens to a file when it arrives in your factory and ends up as a piece of print. Identify where calibration and validation take place. Evaluate the items on your list to establish what equipment and software is out of date and in need of upgrading, including monitors, or what is not fully utilised such as Raster Image Processor (RIP) functionality. Understand what happens to files when they arrive and what processes customers are applying and why. Make sure you understand the level of training required to implement a colour managed workflow and invest in kit that will support your efforts. Don't forget the viewing booth, because without the correct light environment the colours will appear to be different.

THE FOUR CS

When you know exactly what happens to colour data in your workflow, you will be ready to apply the four Cs of colour management. These are Calibration, Characterisation, Conversion and Consistency, for all devices in the workflow starting with monitors used to view colour files. If possible, include your customers and agencies in the evaluation. ISO 12646 covers how to set up and manage monitors, but output devices are a little more difficult.

Output device characterisation requires calibration and linearisation of the device to ensure that it outputs what it is supposed to output. In other words if you specify a 40% cyan tint, that is what you should get. If when you measure the output, you don't get what you want you need to linearise the device. Only then can you be sure your characterisation data is accurate. You characterise the device by measuring output for different paper types, optimising the screen settings, ink amount and black generation for each paper type.

The next step is to make ICC profiles for all output device and substrate combinations in the workflow, as well as for digital cameras and scanners if you still use them. Do this using standard test forms and ICC profile creation software. Remember that the substrate is the single most powerful influence on colour appearance in the workflow.

The third step is conversion, using the device profiles in different scenarios. This is the part of the colour management process where most colour howlers happen, particularly if you are moving data defined in an RGB space, for instance a softproofing system, into a CMYK space. Errors can also get introduced moving from one CMYK space to another, for instance between different wide format digital presses. The fourth C requires that you follow defined procedures so that everything that is done to maintain your colour managed workflow is done consistently.

One of the great benefits of digital technology in the graphic arts, is that it allows us to quantify information that is otherwise very difficult to define. Colour is an analogue phenomenon, subjective and changeable, a function of light. Binary systems have made it possible to put numbers to colours and to make it possible to process them accurately for printed output. This has brought down the cost of colour print expanding the market and encouraging new ideas for print media. New ways of using colour in print are constantly emerging and it's all because we know how to digitise colour and how to manage it. It isn't easy, but it's entirely possible and it can be very profitable.

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