Computational colour, the visual artist and the printed artefact

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This paper outlines the limitations of digital printing in respect of its ability to replicate the nuances of colour that might be achieved by the artist. It is proposed that there is now available an opportunity for artists and colour scientists to work together to innovate new multi-head printers that could render the 'tactile surface qualities and opaque ink set' of the painter.

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Introduction

In recent years colour science and computational colour have developed exponentially from the time of Munsell [1]. Colour science has for many years been a discipline that is discrete in its own right. In almost all commercial printing, measurement by Spectrophotometer is standard and is undertaken using a colour profile and a proprietary Raster Image Processor (RIP) to transcribe the digital colour file to the printing press. Computational colour is perceived additively through RGB (Red, Green and Blue) or more commonly through L*a*b*, which provides a means of representing colour mathematically in a three dimensional space. This is undertaken in order to transcribe colour information from one device to another, known as 'device independent' colour. The effect of this could be seen as taking the knowledge and development of colour away from the creative artist and place it into the hands of a trained colour scientist who usually has an extensive knowledge of programming, but little training in the visual arts. We now have a very good means of transferring colour from one device to another. For example, an image downloaded from your phone or camera to your computer has one set of colour co-ordinates. A very good transcription then occurs from the computer in additive colour to the printer, with another set of colour co-ordinates. The printer then uses a further set of subtractive CMYK (Cyan, Magenta, Yellow and Keyline, better known as black) colour co-ordinates in order to print the initial image. As little as ten years ago this technology was in its infancy for the general user, and artists and designers still perceive colour in a different paradigm, which leads to some unease at the absence of the artist in these reproductive processes.

The pre-digital paradigm

There are differences in the attitudes and understandings of those artists and designers who live in an all digital environment, who therefore are entirely comfortable with the above, and those with traditional art and design backgrounds, such as painters, printmakers, textile designers etc., who still use colour in a subtractive manner. (For the purpose of this article, I am using the term traditional artist to refer to those of us who received their colour training in a pre-digital environment. This was a training that was not predicated in the half-tone process or Cyan, Magenta, Yellow and Black). Our colour history is still bound up with traditional methods of colour and paint mixing. This history and training may include Ostwald [2] and Munsell, but is more likely to be influenced by the Bauhaus ideas of Itten [3] and the colour experiments of Josef Albers [4] in the 1960s and 1970s. Perceptually, this group of users of more opaque pigmented paint or ink, tend to think that there are three primary colours: red, yellow and blue and three secondary colours: green (yellow & blue), orange (red & yellow) and violet (blue & red), and that the admixture of these three is dark brown or black. To create opaque pastel shades the primary or secondary colours are mixed with white pigment and to create transparent colour, the primary and secondary colours are diluted, or mixed with a transparent base.

This different paradigm exists for a good reason. Current colour science is based upon placing one dot of colour (RGB, or CMYK) next to another on a white surface. A patch of dark green using CMYK, for instance, may be made up of numerous cyan and yellow dots and a few magenta and black dots all placed next to each other. The painter, on the other hand, will physically mix his colours together to get the same dark green, but the painter may not have a white surface to put his colour onto.

Why then, does this matter, when both parts function perfectly well without the need to reference the other?. I believe it is a matter of opportunity and a point where changes could be made. Colour science has reached a stage in its development where colour transfer is so good in terms of half-toning and stochastic algorithms that it no longer relies entirely upon the need to place one spot of colour alongside the next, without causing an interference pattern. This fact is exemplified in the range of twelve colour inkjet printers now available. Traditionally a commercial four-colour separation litho is limited to four colours: cyan, magenta, yellow and black, as any colour printings beyond this number and the half toning would overlap and create an interference or Moiré pattern. A twelve colour inkjet printer will use cyan, magenta, yellow, red, green, blue, light cyan, light magenta, three greys and black, (though it may be argued this is in fact seven). Current inkjet printing, through the use of computation colour, can produce a previously unsurpassed image quality, with a constantly increasing range of achievable colour gamut and the size of printed dot down to one pico litre, (that is 0.000 000 000 0001 of a litre or a billionth of a litre, a drop size that approximates to a 16th of the diameter of a human hair).

From the standpoint of a visual arts researcher and practitioner, even that level of quality is not sufficient to meet the demands and aesthetic values of the artist. Inkjet inherently has a luminous quality through the transparency and the very thin film printed which uses the surface reflectance of the paper (average coverage of a large format printer is approximately 5ml ink to one sq metre of substrate[1]). However, it also by its very nature, has a uniform thickness of deposit. This can vary slightly due to paper surface and coating but fundamentally the layer is even across a flat or textured paper.

[1] *Based on monitored average usage at the Centre for Fine Print Research. UWE, Bristol.*

This is very different from the traditional artist who uses subtractive colour, where the component parts are physically mixed together before application to the paper. The primary difference is in the choices the artist makes even before applying paint or ink. Historically, artists' colour came as a powdered pigment, which was then mixed with a transparent or opaque vehicle to form paint or a printing ink. In general, artists' colour (paint or printing ink) is now available in tubes or cans, but the fundamental difference remains: the artist has the choice of using either the method of mixing colour before applying it to the surface or of enabling that mixing to occur on the surface, or of using both methods in the same image.

The combination of transparency and opacity results in two different properties: Firstly, colour tends to be built up in physical layers, partly due to the larger pigment particle size used in paints and traditional printing inks (artists printing inks and paints tend to have a pigment particle size between 10 and 30 microns, by contrast the average ink jet particle is 0.1 of a micron) and the fact that the opaque pigment can obliterate or adjust the tone of the previous layer upon which it sits.

Secondly, this physical nature and the introduction of white paint or ink, creates a very different surface reflectance to the image, or to be more accurate, a large number of different surface reflectances. I have in the past referred to this differing textural quality as surface tactility [5]. The problem with this computationally, is the sheer volume of extra information that has to be factored in. Surface reflectance of colour and the layer thickness can be dealt with through a calculation called Kubelka-Munk and its subsequent improvements and variations [6], but this appears to be an inexact science.

Recent work has been undertaken by Carinna Parraman at the Centre for Fine Print research, UWE, Bristol to create an alternative personalised colour palette that emulates the type of subtractive colour a traditional painter or visual artist feels more familiar with using. Carrina has developed a model that allows the artist to choose the colours he wants to use and then creates a colour set from CMYK that emulates the artist's personal preferences [7]. Whilst the model allows the artist a degree of familiarity and comfort in its use, combined with the ability to create imagery more akin to artists printmaking processes, It still does not fundamentally create both an opaque and transparent ink set, or deal with the problem of creating a visual tactile surface obtained with traditional paint or ink mixing.

What this debate is ultimately about is the difference between additive and subtractive colour, or more accurately, the difference between additive and manually mixed subtractive colour and how a transcription is made of those differences. Traditionally, additive colour has been the domain of film, television and photography and subtractive colour the domain of the artist, designer and the physical aspects of our world. Potentially in between now lies the very high quality printed artefact obtainable through ink jet printing. This process in itself is slowly growing beyond its heritage within the commercial and industrial printing processes and is becoming an increasing part of the arsenal of the artist and designer.

The artist and the everyday user

Why might the differences between the colour types and the transcription of the one to the other be more important to an artist rather than the everyday user? It is in once sense a matter of the interface between conception and perception. Both conceptually and physically, the current inbuilt constraints of a digital image are based on the fact that the image is created by laying a single square of colour next to another single square of colour. All of the emphasis in image construction is placed upon accurate rendition of each individual square. In other words, each square has a mathematical set of co-ordinates relating only to its colour in a notional three-dimensional space to define its presence and place within the grid. Additionally, in terms of image capture, the software that controls this process is written in order to enhance the software author's conception of accurate rendition. The user has little or no concept of how large or small is the mediation occurring digitally from the image he is trying to capture.

In analogue photographic terms colour is defined not by the activation of individual squares but by the influence of light falling across the whole surface of a chemically sensitive coating. To record each colour the light has to physically sink into the coated layers of emulsion in order to register. The photographer has manual control as to the amount of light that can pass through the lens either by reducing the aperture or by changing the shutter speed. The physical action of the light on the film at the capture stage is unmediated by the photographer. During developing and printing of the film the photographer again regains a degree of control over the chemical reaction that takes place in order to process the film. He can speed up or slow down the process but is still only mediating the action of light, which controls colour density and granularity of the film through the chemical process.

The traditional 'modernist' or earlier painter or printmaker compiled his image in a different manner - primarily by selection and invariably layered the image up from a sequence of parts. It is the process of selection and hence conception that is important - the artist mediates before manifesting the image. This process is different from digital colour capture and analogue photographic capture. In the artist's case, he is either leaving out information or deciding how to present the information he has in the most pertinent manner to convey his conception.

In colour terms, whilst current digital capture and print technologies can accurately recreate a representation of colour which can be measured, there is a relation between the surface characteristic of a printed or painted patch of colour and its reflectance which cannot be accounted for. Therefore, it would be accurate to suggest that the visual appearance of the colour itself cannot yet be represented.

Taking the challenge of representing visual appearance together with the different modes of mediation leads me to suggest we can consider making significant changes to the process of capture, transfer and production, but this change can not happen to all parts of the process in one go. Even though this is a problem that requires an overall solution, we first need a printer that can produce the desired result. In my view there is no theoretical reason stopping the creation of an inkjet printer comprising of a twelve or twenty four colour ink set that combines the accuracy of current image rendition with the tactile surface qualities and opaque ink set of the painter. If the printer is created first, then the process of capture can be examined in relation to the output. Practically there are the problems with the amount of computational power necessary to process this information and the problem of how to factor in when to use opaque white and when to use the paper surface reflectance. This however is a theoretical supposition that will go nowhere without further dialogue between, the colour scientist, the hardware manufacturer, the artist and the analogue photographer.

Conclusion

In conclusion, due to the development path of computational colour and its application to digital printing technologies, there has been a separation between the way in which the technology has developed, its perceived use of subtractive colour and the approach taken by traditional artists and designers to the use of physically mixed subtractive colour. If colour science and the artist are to work together there is an opportunity for a convergence in thinking to aid future development. I would argue there is a potential for a radical rethink of the way in which we map colour science against subtractive colour, which is informed by the practitioner.

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