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Colour Deceives Continually

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Abstract

This paper explores the relationship between additive and subtractive mixing for printing colour. Using mica pigments that are based on additive colour mixing principles, that when combined, create white. Although currently used for decorative effects for printing, can present a challenge to traditional print markets. We describe different plate making and printing methods for photographic and photomechanical processes, and discuss their applications and limitations.

Introduction

In 1852 Hermann von Helmholtz proposed different rules to the mixing of pigments and of lights, which are now known as subtractive and additive colour-mixing. [1, 2] Isaac Newton's theories have long been understood about mixing spectral colour, demonstrating that all the colours of the rainbow could be obtained from white light. He also hypothesised that light was composed of particles of different sizes, red being the largest and violet the smallest. [3]

The term RGB is commonly understood as an additive process, that by combining a red, blue, and green light in a dark room, white light is obtained. Traditional printing with pigments, no light is reproduced and as more pigments are applied, thus results in a reduction in luminance in proportion to how much white is removed. White or the lightest regions, in this instance, are reliant on the whiteness of the substrate, and these regions are a result of an *absence* of ink.

Over the last century, we have relied on the combination of halftones and subtractive CMYK ink primaries to translate a monitor-based image or photograph into a print on paper. Process colours are certainly commercially expedient for many industrial applications.

Printing additively with pigments

Some new pigments and processes work by combining reflection, refraction and interference, and which when all over-layered result in white. Subtractive colours work with reflected rather than transmitted light. Emulating the additive process, television screens and monitors through a side-by-side fixed arrangement of primary colours of red green and blue dots to interdigitate the appearance of a smooth continuous transition of between light to dark colours.

Merck has developed a set of selectively reflecting inks: SpectravalTM pearlescent pigments. SpectravalTM pigments are so-called red, green and blue mica pigments. They can be used to create alternative ways of making images that can mimic the appearance of different materials and colours such as beetles, butterflies, rainbows, and artificial colours. Although currently used for decorative effects for printing on packaging, these may be a challenge to traditional subtractive printing methods.

Printing with RGB absorbing pigments requires a precise halftone registration on white paper so that the dots do not overlap, or we need RGB inks which have less exclusive spectra then the filters in figure 1. For RGB printing, the ink is printed from a negative plate as the ink is held in the dark parts of the plate. CMYK prints are pulled from positive plates. RGB inks made with Spectraval pigments are printed from negative plates as well, but the dots can overlap, or the image can be even continuous tone since the white does not come from the substrate but from the combination of the reflection of the red, green and blue pigments. The black in the image is generated by the substrate, that is by the ink free areas on the black substrate.

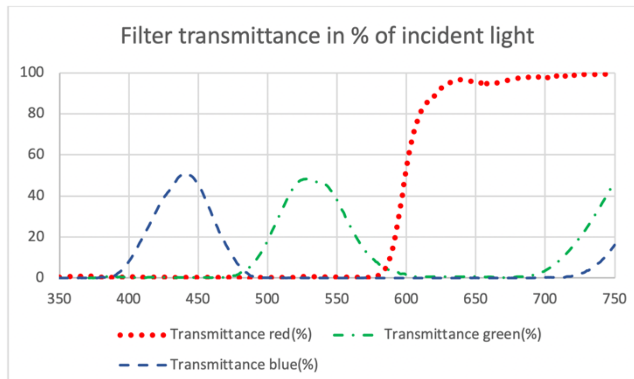

Figure 1: Transmittance spectra of Lee Tricolour filters

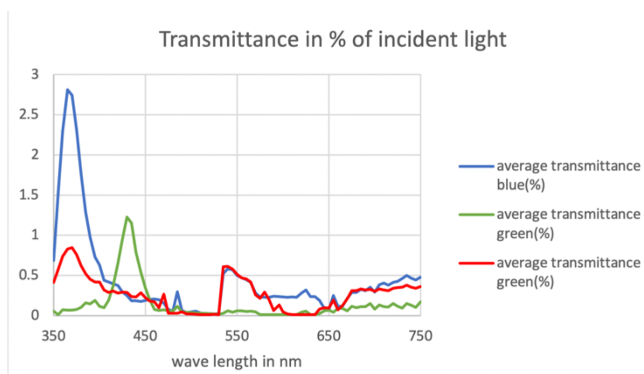

Figure 2: Transmittance spectra of red, green and blue SpectravalTM pigments

The thin mica plates are polydispersed and have diameters ranging from 5 to 25 µm (figure 3), which are too big for any inkjet printer. To record the selective reflection of the pigments, we measured the transmittance spectra of the linseed oil inks as a function of wavelength with an HP UV-vis spectrometer. The data were averaged over 5 nm intervals. The red ink is red in reflection and green in transmission, the blue and green are somewhat yellow in transmission. Assuming that scattering can be neglected, the pigments reflect the light which is not transmitted. The difference between the spectra in figure 1 and figure 2 is striking. The colour perception of green is not generated by transmittance between 470 to 600 nm, but by reflection of almost the whole spectrum, except between 400 and 470 nm, i.e. blue is transmitted.

Blue is achieved by reflecting between 470 and 630 nm, and red by reflecting between 470 and 630 nm and 600 to 680 nm. From Figure 2, it is clear that almost all light is reflected and that any colour can be seen as surprising. On white paper, the pigments are almost invisible since the back scatter from the white substrate fills the dips in reflection. To observe any colour, the pigments have to be printed onto a black substrate (figure 4).

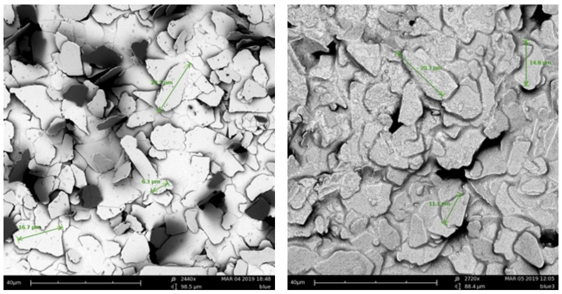

Figure 3: Scanning micrograph of a SpectravalTM pigments (left) as received; (right) dispersed in linseed oil.

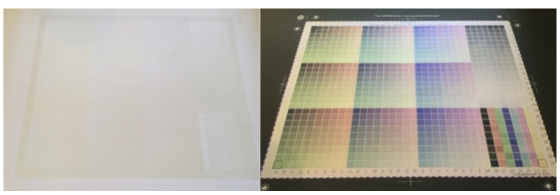

Figure 4: RGB colour separation colour-chart printed onto white paper (left), and same chart on black paper (right)

Not all images are suitable for printing with RGB pigments and include images that contain a wide colour gamut and natural colours and objects that are easily recognisable eg. fruit, plants, people. As demonstrated in Figure 5, the same photograph of a beetle has been photographed directly above, resulting in a desaturated appearance and at an angle revealing a more comprehensive range of colours. The chromatic variability of these micro-structure pigments is primarily due to the stacking and irregular dispersion of pigments, thus creating a three-dimensional effect.

We aim to exploit these materials for the reproduction of light, which may well go some way to address more challenging images that contain highly reflective surfaces, unusual geometry, artificial lighting, interreflections, images that contain glare or specular activity.

Figure 5: (left) photograph of beetle directly above the print; (right) photograph taken at an angle.

Footnote

The paper title is taken from Joseph Albers' Interaction of Colour. *"In visual perception a colour is almost never seen as it really is—as it physically is. This fact makes colour the most relative medium in art. In order to use colour effectively it is necessary to recognise that colour deceives continually." [4]*

References

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[4] J. Albers, Interaction of Colour, Yale University Press, 1963.

Author Biography

Dr Carinna Parraman is Professor of Colour, Design and Print, and Director of the CFPR. She leads a cross-disciplinary research team comprising scientists and technologists, designers, artists, and researchers. She is leader of Expanding Excellence in England (E3), exploring the future of printing and fabrication, alongside traditional methods of making. She is a member of the technical committee for Color Imaging

Dr Susanne Klein is EPSRC Manufacturing Fellow and Associate Professor at the CFPR. She is a physicist by training and has worked in the UK for the last 25 years. During her last two years with Hewlett Packard she worked in optical cryptography. She joined CFPR in 2018, and with her team, she is exploring how photographic and photomechanical processes invented in the 19th century can be transformed into 21st century technologies, for both artists and industry.

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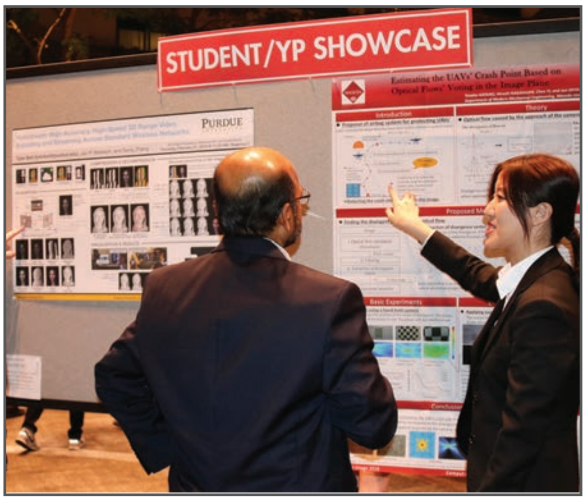

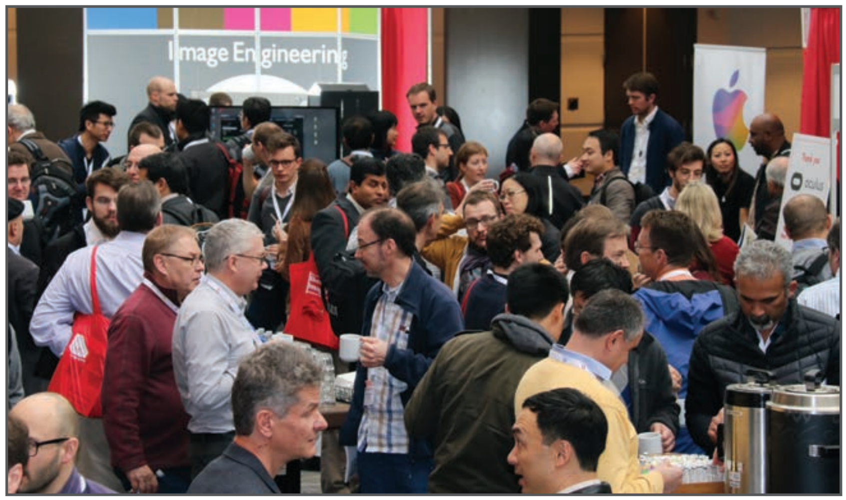

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