# Estimating illuminant U.V. without a U.V. capable instrument.

*Graeme W. Gill, Computer Graphics Technology P.L., Melbourne Australia.*

## Abstract

*In the paper "A Practical Approach to Measuring and Modelling Paper Fluorescence for Improved Colorimetric Characterisation of Printing Processes" [1] it was noted that a limitation in applying this approach to modeling the effects of paper Fluorescent Whitener Additive (FWA) is the lack of affordable instruments capable of measuring the Ultra Violet (U.V.) content of the illuminant being used. Presented here is a novel indirect approach to estimating the illuminant U.V. using readily available instruments, that takes advantage of the same FWA model used in [1], thereby providing a source of illuminant U.V. characterization that is ideal for use with its FWA model.*

## Introduction

One of the limitations of conventional print media color measurements is that the illuminant used by the instrument may not match that actually used in viewing the print. In the absence of fluorescent effects this difference is not significant, since the measured values are translated from one illuminant to the other by the use of a "Source Independence model”. When fluorescence needs to be taken into account however, this different in illuminants becomes quite significant if the illuminants have different relative energies at U.V. and visible wavelengths [2]. The approach described in [1] provides a means of modeling fluorescent effects due to paper FWA, but depends for its operation on a knowledge of the viewing illuminants U.V. content. If the viewing illuminant is well known and characterized (for instance incandescent illumination or daylight) then this U.V. information can be obtained from tables. If the illuminant is not so well known and characterized, then the usefulness of paper fluorescence modeling may be limited. Similar FWA modeling approaches [3], and alternate modeling approaches [4] also depend for their operation on knowledge of the U.V. content of the illuminant. The approach used in [5] avoids the need for direct knowledge of the illuminant U.V. by allowing a human observer to make a visual match between a reference medium and various test patches that assume differing levels of U.V. illumination. In [6] a method of estimating illuminant U.V. is presented that is broadly similar to that presented here, but relies on the use of a fluorescent standard tile that has a known quantum efficiency (Q), or has been calibrated using a known U.V. illuminant.

The approach described here uses several sets of conventional visible wavelength instrument readings of the paper and the illuminant, and exploits the model from [1] of how the illuminant interacts with the paper, to estimate the illuminants U.V. content. The use of the same model and paper in estimating the illuminant U.V. and computing the effect of FWA on the print appearance, has the convenient property that it tends to minimize errors due to approximations and assumptions made in the model.

## Outline

The basic approach is to use a visible wavelength spectrometer to make three measurements: i) The spectral reflectance of the paper that has FWA content, just as is used in [1]. ii) The direct spectral emission spectrum of the illuminant to be characterized. iii) The indirect spectral emission of the illuminant after reflecting it from the same paper as i). By then synthesizing a plausible level of U.V., that when added to the illuminant spectrum measured in ii) results in a modeled paper reflected spectrum that best matches the shape of measurement iii), a useful U.V. included illuminant spectrum is obtained. Because the FWA modeling assumes a certain spectral sensitivity curve, and the measurement approach uses exactly the same assumed spectral sensitivity, the precise shape of the estimated U.V. inclusive illuminant spectrum should not be critical to its usability, and in fact may be better for this particular purpose than a measurement of the actual U.V. included illuminant spectrum.

The three measurements are illustrated as follows:

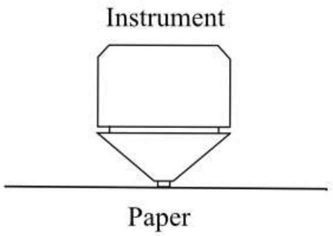

*Figure 1*

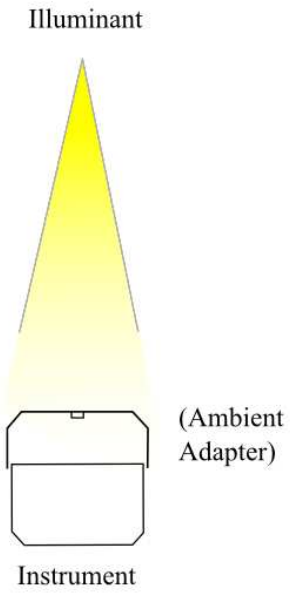

*Figure 2*

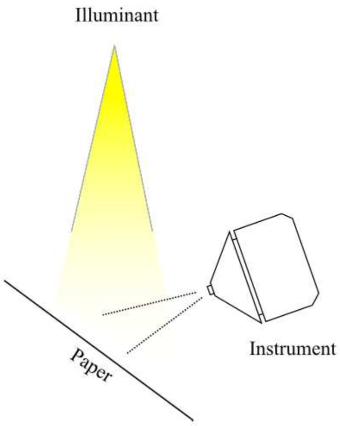

*Figure 3*

## Nature of estimated U.V. spectral model

To have some hope of being useful in a wider context, the synthesized U.V. content of the illuminant should ideally be a plausible extension to the measured illuminant spectrum in the non-U.V. region. The model adopted here is to use the same FWA excitation spectrum used in [1] as the curve to add or subtract from the measured spectrum., as shown in Figure 4. The measured spectrum is tapered to zero from the longer to shorter wavelength of the U.V. spectrum, and the curve is then scaled by the signed "U.V. level" setting, and added to the measured spectrum.

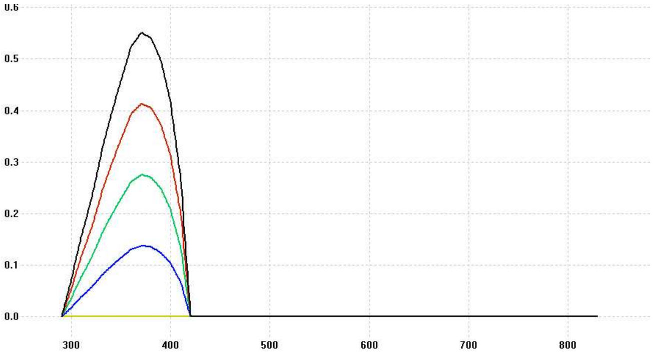

*Figure 4*

Figure 5 illustrates a measured sunlight spectrum with range of different estimated U.V. levels.

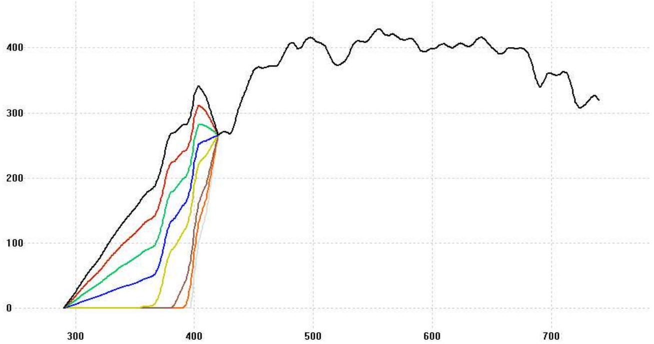

*Figure 5*

## Processing of Measurements

Figure 6 illustrates the processing of the measurements. On the right hand side is the measurement of the illuminant and the measurement of the illuminant reflected from the paper. By simply dividing the latter by the former, an apparent reflectance spectrum of the paper can easily be computed. The apparent reflectance will in fact include the affects of FWA in the paper, under the stimulation of the U.V. in the illuminant.

On the left hand side the reflectance of the paper is measured in the usual manner, the instrument itself dividing out the spectrum of the instrument illuminant to result in the apparent reflectance of the paper under the instrument illuminant. The measured illuminant spectrum then has an amount of synthesized U.V. added to it to create the estimated full illuminant spectrum, and this is then used as the target illuminant in the method described in [1] to compute the paper reflectance as it would appear under the estimated full illuminant spectrum.

These two paper reflectances are then multiplied by a spectrally flat 'E' type illuminant, and integrated using the standard observer curves to produce tri-stimulus values that are then transformed into L*a*b* values with respect to the standard D50 white point. A delta E is computed in an almost standard fashion, the exception being that the a* difference squared component is weighted by a factor of 0.1 to maximize the effect of yellow-blue differences. This is because the FWA response to U.V. illumination is entirely in the blue wavelengths, while any differences in the red and green wavelengths are likely to be due to noise and measurement uncertainty. The level of synthesized U.V. added to the measured illuminant is adjusted using a standard optimization algorithm to give the minimum delta E. This sets the level of synthesized U.V. to be that that best explains the apparent paper reflectance due to FWA effects under the actual illuminant.

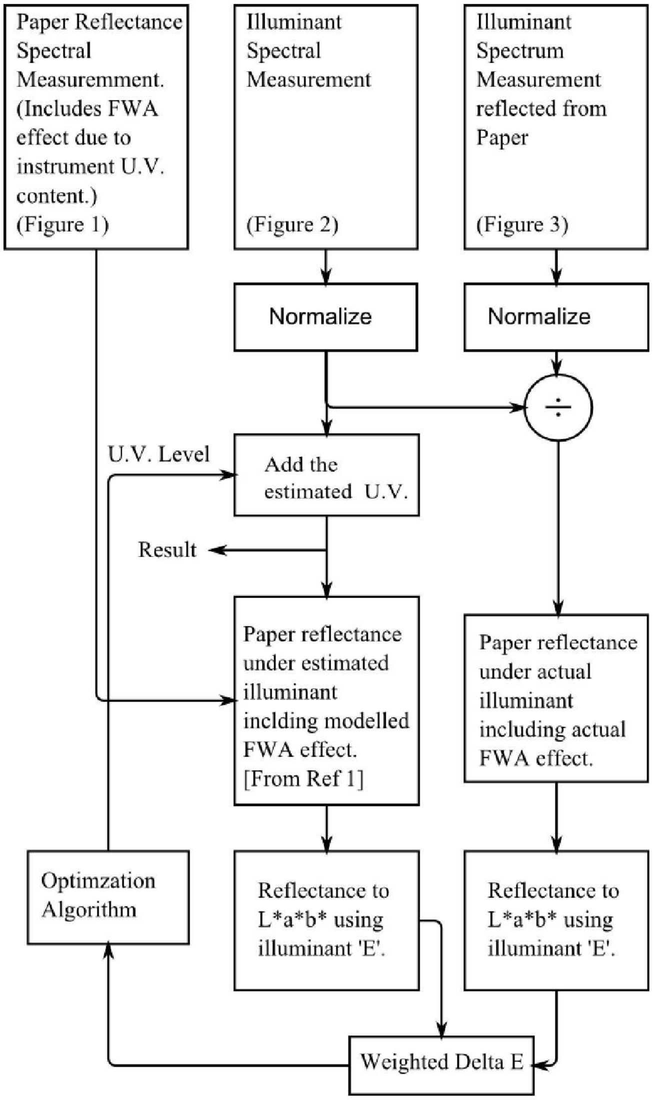

**Figure 6**

Two subtleties used in the optimization are that in fact one of the reflectances is scaled to also minimize the delta E, and that the optimization is regularized by adding a small weighting of the absolute added or subtracted U.V. Level, so that a minimal change to the measured illuminant spectrum is made in the case that the paper and/or measurements exhibit little effect from FWA and U.V. The resulting equation for the value to be minimized is as follows:

$$0.1\,|\text{UV Level}| + (L^*_e - L^*_a)^2 + 0.1\,(a^*_e - a^*_a)^2 + (b^*_e - b^*_a)^2$$

Note that the magnitude of the UV Level value is of the order of 1, while the L*a*b* values are of the order of 100.

## Example results

Figures 7 shows the results of applying this technique to sunlight, using a typical office paper that has a relatively high FWA content. It shows the measured reflectance of the paper under sunlight in **Black**, with the initial zero level U.V. level modeled paper reflectance in **Red**, and the final optimized level of U.V. used in the model shown in **Green**.

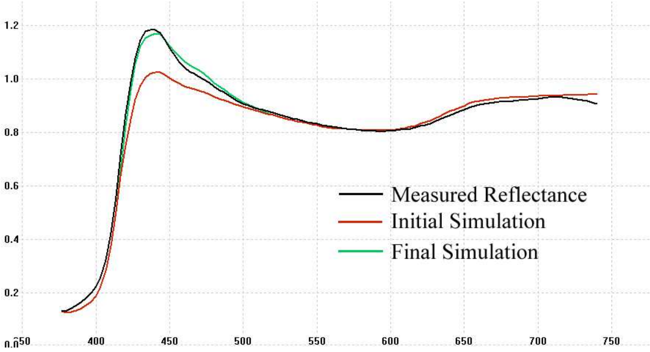

*Figure 7*

## Choice of Paper

Figure 8 shows the estimated U.V. included illuminant spectrum of sunlight using four different papers that have different levels and possibly types of FWA. (Paper 1 being the same as that used in Figure 7). The variation in the level of estimated UV indicates that it is likely that the best results will be obtained if the paper that is going to be compensated during printing for the effect of the illuminant on its FWA content, is also used for estimating the level of UV illuminant.

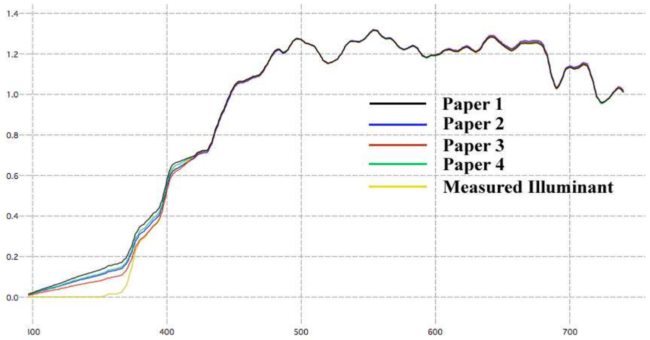

*Figure 8*

## Future Research

An avenue for refining the FWA model further might be to extend this measurement approach to measuring not only the unprinted paper, but also the paper tinted with various sample colors using the anticipated printing process. This may then allow refining not only the illuminant U.V. estimate, but also aspects of the underlying FWA model, such as the different colorants effects on the level of U.V. and corresponding fluorescent emissions from the paper.

## Source Code

Source code for a measurement tool implementing this described technique has been available in the ArgyllCMS package since July 2010, from http://www.argyllcms.com, in the file spectro/illumread.c

## References

[1] Graeme W. Gill, "A Practical Approach to Measuring and Modelling Paper Fluorescense for Improved Colorimetric Characterisation of Printing Processes", Proc. IS&T/SID 11th Color Imaging Conference, Scottsdale, Arizona; November 2003; p. 248-254.

[2] CIE(2004), "The Effects of Fluorescence in the Characterization of Imaging Media", CIE Publication 163:2004

[3] Roger David Hersch, "Spectral prediction model for color prints on paper with fluorescent additives", APPLIED OPTICS, Vol. 47, No. 36 / 20 December 2008

[4] Nikhil Parab, Phil Green, "Soft Proofing of printed colours on substrates with optical brightening agents", Color Imaging XVI: Displaying, Processing, Hardcopy, and Applications, Proc. of SPIE-IS&T Electronic Imaging, SPIE Vol. 7866, 2011

[5] James Vogh "Color Measurement Systems And Methods Addressing Effects of Ultra-Violet Light", Patent No. US7830514, Issue date 9 Nov 2010

[6] Phil Green,Yerin Chang, "A method to estimate the UV content of illumination sources", Color Imaging XVI: Displaying, Processing, Hardcopy, and Applications, Proc. of SPIE-IS&T Electronic Imaging, SPIE Vol. 7866, 2011

## Author Biography

***Graeme W. Gill** is a independent consultant and software & hardware developer. He received a B.E. degree in Electronic Engineering in 1984 from the Royal Melbourne Institute of Technology, before working for Labtam P.L and Colorbus P.L over successive decades. Mr Gill is a member of the IEEE, ACM and IS&T.*