THE APPLICATION OF PRINTING SPECIFICATIONS TO GREY COMPONENT REPLACEMENT

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Abstract: The development of universal printing specifications (or standards) is gradually improving consistency in print production. Nevertheless, many of the specifications in current use are not complete and further development is necessary to ensure that they achieve the objective of complete printing consistency which must be their goal. Where GCR is being applied, further considerations prove necessary and the purpose of this paper is to discuss the importance of these in achieving a high quality of reproduction and suggest how existing specifications would need enhancing to take account of this. From this it is concluded that standardisation of GCR printing parameters is not desirable. In addition to the obvious areas of standardisation such as ink colour, film thickness, gradation (or "dot gain") control and substrate, those factors of particular relevance to GCR are grey balance, additivity failure, and black printer control. The development of a test forme for the analysis of these parameters is described which aims to combine simplicity with completeness and can be used for setting up all parameters of a reproduction system. The measurement methods and procedures will also be described.

Introduction

Following the lead of FOGRA (West Germany's Printing Research Association) in 1977 various attempts have been made to set "standards" for the printing process. These consist of the specification of a number of parameters of the process which will ensure that any printer which meets these will be able to reproduce a proof made in a separate site with the minimum of difficulty. It means that colour separations can be produced in a central location for printing in any number of sites providing that the proof of those separations was made to the standard. The printed

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results in each site can then be expected to match the proof approved by the customer.

There is often a misconception about standardisation; that it reduces quality to an "average" level. This needs to be dispelled. Obviously the overall quality level of the print is a direct function of the colour gamut which can be achieved with the ink and paper being used. To this end the standard will define the limits of quality. However, there is little point in proofing with a system which has significantly different limits and so this can hardly be seen as a quality reduction. Beyond this, the quality of separation is virtually independent of the press characteristic except for the reproduction of fine detail. Certainly all other parameters can be compensated for during scanning and the proof should reflect them. The quality level is thus still determined by the colour separator. Obviously the gamut limitation written into a standard should not be seen as totally permanent. As technology changes it may be possible to improve this. Furthermore, the argument concerning detail is real and for these reasons standardisation should not be static. As our understanding of ink/press/substrate interactions is enlarged and the transfer function of the printing process can be improved the standards should be adapted to accommodate this. Nevertheless to bury our heads in the sand and say that because of this problem standardisation should be resisted is quite ridiculous. If proofs do not reflect the press capability the disappointment and uncertainty when they are printed is far more serious.

Having established that I am very supportive of the role of standardisation in colour reproduction we should now turn to GCR and determine whether it is as important that this be standardised; or indeed whether there are any benefits at all. My opinion here is equally dogmatic; it should not. Certainly recommending a level of GCR may be desirable in certain instances but as will be made clear in the paper the disadvantages of precise standardisation outweigh any advantages and certainly do not offer any logical justification for extension of the standards which already exist. Optional appendices may be justified, which serve as a guideline in those instances where GCR is required, but detailed standardisation is not.

Standardisation - objectives and parameters

The objective of standardisation is very clear. By specifying the important parameters of image transfer and controlling them within clearly defined tolerances the average quality level and cost effectiveness of colour reproduction can be significantly improved. The value of the parametric constants for all the reputable standards have been established by extensive evaluation of practical production constraints combined with significant research studies into the behaviour of such factors as ink transfer. It is not my intention in this paper to review this work; a summary was included as part of an earlier TAGA paper, Johnson (1985a), to which the interested reader should refer.

The important variables which affect image transfer may be summarised as follows and any comprehensive standard needs to refer to these and define how they may be quantified: a) Platemaking/Contacting, b) Ink Colour and Opacity, c) Ink Film Thickness, d) Ink Sequence and Trapping, e) Tonal Rendition and f) Substrate.

All of the major standards (particularly those from FOGRA, PIRA and SWOP) include these parameters either directly or indirectly and it is my contention that such a specification is necessary and sufficient. No more and no less is required. However, the important word is less. If a standard is to be workable all of the above must be considered and proper measurement procedures established.

The measurement methods for the above currently fall into three categories. Microline/fine halftone dots are used to quantify contacting and platemaking. Spectrophotometry/colorimetry is essential for determining ink colour and is also satisfactory for the remaining ink parameters. Alternatively densitometry will suffice for the remaining ink parameters providing the ink colour has been properly specified. Unfortunately, because it is impractical at present to exclude colour tolerances and metamerism from the colour standards densitometry is not a precise tool. Various techniques are being offered to overcome the problem such as densitometer calibration from Pira and printed samples from SWOP. Standardisation of densitometers has also been proposed.

Obviously if everybody has access to colorimetry then the problems can be resolved but this is currently not the

case. Let us hope that the development of a portable spectrophotometer by Gretag is the precursor to cheaper models since with these generally available nearly all the remaining problems associated with specifying standardisation parameters can be resolved very readily.

The only outstanding parameter then to be specified is the substrate and this is by far the most difficult. It has a direct impact on each of the ink parameters listed earlier and strictly these effects should be specified for each substrate. In practice it is acceptable to specify conditions for categories of paper (e.g. coated, uncoated, etc) and all of the existing standards do this. However, for optimum standardisation each product sector (such as newspapers) should produce it's own standard but based on the procedures and measurement methods used elsewhere. Gradually these specific standards will then be incorporated into the generalised ones.

The main point to be summarised from the above discussion is what is standardised. For each substrate the printing characteristics of each ink are defined and the way in which they interact. Not the combination of inks needed to reproduce the original. It is in this context that the standardisation of GCR needs to be considered. This will be done in section 4. However, prior to that a brief review of GCR techniques will be useful to properly understand some of the standardisation problems.

Implementation of GCR

The implementation of GCR was discussed in an earlier TAGA paper, Johnson (1985b). It was stated that various algorithms could be used and Neugebauer equations and modified masking equations were given as examples. However, the Crosfield algorithm did not use either of these but had been based on one proposed by Otschik (1981) whereby the grey component of a colour is computed directly and replaced by the appropriate amount of black ink. In summary there are 4 steps which need to be followed for each pixel. These are: 1) calculate and remove the grey component from the three colours, 2) replace with the appropriate amount of black, 3) add the initial black (determined for gamut extension to the CMY ink set) to the replacement black, and 4) compensate for additivity failure.

It is clear that there is no unique solution to this

algorithm. The amount of grey to be replaced can be varied from 0-100% of its total and this is the definition of fractional GCR employed. 70% GCR simply means that after calculation of the grey component in each pixel only 70% is removed and replaced with black. To confuse matters further, however, it is possible to set GCR such that it is only applied over part of the tonal range. It is therefore possible to have a set of "GCR separations" with "normal" highlights or shadows. I do not propose, in this paper, to go into the pros and cons of this; suffice it to say that such facilities have been added at the request of printers around the world. What it means in practice is that to define a proportion of GCR, just for one manufacturer's system, could mean specifying a number of parameters. When other systems are considered, with different computational procedures, the problem becomes even more complex. It is in this context that standardisation should be considered.

Standardisation of GCR

If GCR is to be standardised we need to review what additional parameters must be defined and also consider the measurement techniques to be employed. Initially I will consider the Crosfield GCR algorithm and what is required for that.

Clearly the most important parameter is grey balance since that defines the grey component to be removed. But grey balance is a direct function of all the parameters defined earlier; platemaking, ink colour/film thickness/opacity/sequence, tonal rendition and substrate. Thus the definition of all these parameters automatically specifies grey balance. It must be measured with a colorimeter or assessed visually.

The next parameter to consider is tonal rendition of the black ink. The effect of this determines the amount needed to replace the grey component removed and can be assessed densitometrically. However, that is already standardised according to my earlier summary.

Finally we need to consider additivity failure since this is a key part of the Crosfield algorithm. This follows directly from the decision to treat GCR as a "post" process. This was done to permit the operator to set up the scanner in his normal manner and then compute the required amount of GCR automatically. However, like grey balance, this is also a function of all the parameters

defined earlier and is thus, indirectly, already specified.

It is clear from this that all the parameters necessary to define GCR are already standardised in any reputable standard. Why then was I so dogmatic earlier that GCR was not a suitable topic for standardisation. The reason is simple, the tolerances in any standard are far too wide to achieve a high quality of reproduction and it is impractical to make them any tighter. Thus the grey balance and additivity corrections will vary even for different printers producing work to within the standard.

Given this variability it may seem that GCR would not be viable in a standardisation environment. However, that would not be a reasonable conclusion. Standardisation is an attempt to improve correlation between proofs and prints and whatever is achieved for normal separations is equally valid for GCR sets. However, what it must not do is make the tail wag the dog! If we try to be too specific in a standard it becomes quite unworkable and falls into disrepute. This is what we must avoid. It's already taken far too long to get where we are now without retarding that acceptance by unreasonable additions.

What is clear is that the standard specifies a proofing condition together with a tolerance and the colour separations must be proofed within this. However, to maximise the quality of the separations the colour separator will work to tighter tolerances; those of the proofing system itself. It is these same tolerances that should be used to set up the GCR characteristics. In the next section the means of obtaining that data will be defined in greater detail.

For different algorithms rather different information would be required. Neugebauer equations, for example, require data on all the single, two, three and four colour solid overprints and to take account of the Yule-Nielsen effect various halftone values are also required. Masking equations on the other hand, particularly the empirically derived higher order equations, may require a different range of colours for the derivation. The calculation may be based on colorimetric or densitometric data obtained from these colours.

Thus it follows from this discussion that, in my opinion, it is folly to attempt to standardise the GCR printing conditions any more precisely. The existing

standards are more than adequate and require no further extension. Providing that the colour separator proofs his GCR sets to within the specified standards then the printer can freely mix those produced with one level of GCR on a Crosfield system with another set made to a quite different level on, say, a Hell system. Any set of colour separations from any system, with or without GCR, will print together perfectly satisfactorily if they have been proofed to the standard specified. It is this that constrains the colour separator to set up his scanner properly as described in the next section.

Of course it is quite acceptable to add, as an appendix, data to a standard which specifies grey balance, additivity effects, colour of Neugebauer primaries, etc. This can then be used for general guidelines by anybody who wishes to. However, if we are not to run the risk of producing "average" quality separations it should not form a part of the standard itself.

A different aspect of standardisation, which is of concern to some people, refers to the proportion of GCR applied. As explained earlier various definitions can be used each of which is perfectly consistent within itself. It is similar to the fact that we can measure length in a variety of units each of which is perfectly well defined. However, when buying a bag of sand we do not specify the size of each grain, we simply expect that the average size will be correct for making mortar. The same applies to GCR; we do not need to specify the precise configuration of each pixel but simply know that it will achieve the required effect. How then do we specify this?

I believe we can be quite simplistic about this; a high degree of precision is not required. I would suggest that the ratio of Cyan to Black be specified, for 3 or 4 black levels from 25% to 100%, for a grey scale. To within a tolerance of $\pm$ 50% from the specified value would probably suffice. After all there was never any rigid specification for UCR and that varied from one system to another quite significantly. The appropriate specification of the maximum dot area was quite adequate.

Setting up for Grey Component Replacement

Having stated that GCR is not directly suited to standardisation what is clear is that to apply it properly it is vital to have a precise specification of the

particular printing condition. To obtain that data a test image is essential.

Bearing in mind the steps outlined in section 3 it is clear that the information which must be obtained is as follows: 1) grey balance, 2) Lightness (or visual density) of a trichromatic grey scale, 3) lightness or (visual density) of a black grey scale and 4) additivity failure data.

(Note: it is also worthy of mention that if the black ink is not close to neutral then ideally the grey balance data should be compensated for that. In practice, however, we have not found that necessary).

The simplest way of doing this is with a test forme which contains grey balance fields of the type proposed by Elyjiw & Archer (1972), a black scale of varying dot size and a field in which varying levels of black ink overprint a grey scale. The grey balance fields allow us to select the grey balance either visually, colorimetrically or, if we are sure of a limited metameric effect, densitometrically. Obviously the visual density of these points can then be determined and expressed as a function of the density of the black scale. The replacement of three colour grey with black is then simply achieved by using this function. Additivity failure data is established from the black on three colour grey overprint. Since we use 10 levels of black each on 10 levels of grey the form of the function can be established quite precisely. However, in practice we find the approximation in which additivity failure is expressed as:

$$y = a + b - (kab)$$

where y is the resultant density, a is the density of the three colour grey, b the density of the black and k the reciprocal of the convergence factor as suggested by Yule (1967) works well. Generally the error is greatest for high levels of both a and b but this does not create practical problems providing good shadow separation is present in the scanning set-up.

Summary

The inclusion of specific printing data for GCR in a standard is not recommended. The existing standardisation data, providing it is properly measured and evaluated

provides all that is required. Additional information could be provided as an appendix for guidance to those who are interested in simulating algorithms or who are happy with less than optimum quality but it should be recognised as such. Specifications determined for the actual printing or proofing characteristic, which will generally have lower tolerances than those in a standard, are necessary for high quality GCR.

Specifying proportional GCR cannot be precisely achieved as a "single number" without complex measurement However, approximate descriptions can be established by simple average ratios of say, cyan to black for a limited number of steps on a grey scale. Given the way in which UCR has been specified in the past, with few problems, this should be more than adequate.

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