Colour Reproduction - Past, Present And Future.

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Abstract. The development of colour reproduction in Printing, from being a craft skill to something approaching an automated production process, is described. Some of the main milestones in this transition are described; and consideration given to some of the likely near term developments.

Introduction

This paper provides a personal view, based on more than 30 years experience, of the history of colour reproduction in graphic arts. In particular I focus on the changes which have occurred during the 50 years of TAGA's existence. I then go on to discuss developments that I believe will have a major impact in the future and some of the issues currently outstanding. The technological details presented are rather limited; references are provided that will enable the interested to reader to follow up on these. What I try to focus on is the overall perspective and the philosophical and workflow issues that these developments will require.

The Past

Colour Separation: Colour reproduction by Printing has a complex history. It was probably about 300 years ago that colour images were first produced using 3 primary inks. According to Field (1988) it is believed that the use of black ink as a key was introduced soon after this. Printing images in more than 4 colours is also far from new. Hand produced printing surfaces, such as hand engraved copper plates employing mezzotint screens, were often produced utilising many colours as well as the 4 colours so often used today.

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However, the images made at this time were really not reproductions (even if they were images of natural scenes or paintings) but original images produced manually. It was only following the introduction of the halftone screen and colour sensitive photographic materials that the first commercial halftone 4 colour reproductions were produced just over a century ago. Development after that time was rapid and as the process was introduced more widely it was adapted to suit the printing surface preparation procedures required by the various printing processes. These were often quite different to each other and required a variety of craft skills. However, the fundamental procedure was similar for all of them, particularly for four-colour printing which has dominated the industry for the best part of the past century. The colour image was sequentially exposed to some photographic media through a red, green and blue filter in order to produce the cyan, magenta and yellow printing surfaces respectively. The black was obtained through a filter which approximated the visual photopic luminosity function, although it may have been approximated by sequential exposure of red, green and blue light. This procedure, whereby the red, green and blue content of the original is recorded and converted into the cyan, magenta, yellow and black records required for printing, is what I will refer to as colour separation in this paper. The images that result from this procedure are called the separations.

The first major attempt to turn 4 colour reproduction into more of a production process and less of a craft skill came from the development of photographic masking. Prior to this time colour reproductions were produced by taking the printing surfaces produced from the red, green and blue light exposures and manually etching the printing surface (which was dominated by Letterpress printing) to obtain the correct colours. Plates were etched in local halftone regions in order to reduce amount of the ink of that colour printing. By combining one of the continuous tone colour separations which was used as the original image when producing the halftone, with another of the separations (but of opposite polarity and lower contrast) it was possible to reduce one ink wherever another was printing. This correction was precisely what the colour etcher was doing and it greatly simplified the procedure.

However, it was only following the classic theoretical work of Hardy and Wurzburg (1937) and Yule (1938a and b) that the whole procedure was sufficiently formalised to enable it to gain wide-spread acceptance. Hardy and Wurzburg specified the requirements for an 'ideal' set of primaries against which colour correction requirements could be defined. Yule developed the mathematical formulation of this procedure and showed how this could be used to define the characteristics of the masks. Although subsequent work showed limitations to the theory for turbid media such as printing inks, it still proved effective in enabling masking procedures to be developed. Yule also discussed

how the black printer could be defined to both expand the colour gamut and enable UCR or GCR to be achieved.

Masking procedures evolved rapidly during the 1940s and 1950s and a whole variety of techniques were introduced. Amongst these was masking based on colour film, introduced by the photographic film manufacturers, which led to a further simplification of the production process by the introduction of direct screening, as a practical production technique, in the 1960s. This was a process which enabled screened positives or negatives to be produced at the time of colour separation - not as a separate, subsequent, step. But, in parallel to this another evolution was occurring - that of the colour scanner - which has really taken place over the past 50 years, the timeframe of these TAGA conferences.

Although reproduction of colour images was dominated by the use of cameras to achieve colour separation until the early 1970s colour scanners slowly gained an increasing role. The first scanners were built in the early 1940s but really only as prototypes. Murray and Morse (1941) produced a scanner based on solving Yule's masking equations while Hardy and Wurzburg (1948) employed the famous Neugebauer equations (1937) for their solution. Both scanners eventually evolved into commercial products, albeit expensive and of limited stability, although the latter was very short lived. The former evolved into the P.D.I range of scanners which were used commercially for many years. The first TAGA conference in 1949 included a paper on scanning and few conferences since have failed to include some highly relevant material on this subject.

Initially scanners had been introduced to undertake the separation process by mathematical means, in order to replace the complex photographic procedures previously used. However, in all early scanners the calculation was achieved on analogue computers and the production of the image on film was concurrent with the scanning; generally with both scanning and exposing cylinders rotating on a common drive shaft. Eventually, electronic halftone screening, Gast (1974), and enlargement, Wilby and Pugsley (1970), came together with digital colour separation, following the development of the first (almost) fully digital scanner by Crosfield Electronics, Pugsley and Woods (1975). By the early 1980s, driven by the development of a variety of page composition and image retouching systems for colour images, the scanning and exposing sections of scanners became separated. During the subsequent period the scanner and image assembly and editing systems have undergone massive change and, increasingly, separation is moving away from the scanner towards the workstation or RIP.

Colour Pagination: For many years the digital pagination of monochrome images, derived from the typesetting sector, and that of colour images, derived from the scanning sector, remained as separate operations. The systems for page composition of colour images, first developed in the late 1970s, produced page

separations in which the only text in them was obtained by raster scanning; otherwise they were combined with text by manually stripping together separate pieces of film. It was only in monochrome production that some of the established typesetting vendors ventured into the merging of vector encoded text and raster encoded graphics into complete digital pages, in the very early 1980s, as the media capacity became large enough to accommodate it. Experiments with colour using such systems were generally limited in quality and did not really gain wide acceptance.

This changed in the early to mid 1980s. On the one hand the vendors of colour pagination systems started to incorporate text importation from typesetting vendors' systems within their own systems, but generally these consisted of raster files which had been produced by a proprietary raster image processor (RIP) which could not be edited. The initial attempts to handle colour in the monochrome systems which had evolved from the typesetting sector were potentially more versatile, since the mixing of raster and vector data had already been established, and it was here that the changes were dramatic. However, the traditional typesetting vendors found themselves overtaken by a technological development which was to eventually have a profound effect on the whole industry; the evolution of the personal computer (particularly the Macintosh) and the early laser printers. This led to the development of semi-professional page composition software, particularly Aldus Pagemaker, designed to run on the personal computers and be output on laser printers. When this was combined with the gradual acceptance of Adobe Postscript as the basis of an industry standard RIP, that led to multiple software packages evolving which enabled production of colour pages as a 'consumer' process which became known as Desktop Publishing.

At the same time, the evolution of CCD technology permitted development of scanners with a range of performance (in terms of quality and productivity). This meant that cheap scanners for digitising images started to appear and although the initial quality of desktop systems was poor, both for text and graphics, it was inevitable that this would improve. By the early to mid-1990s the 'consumer' software was able to achieve much of what had been previously been produced by the proprietary colour systems and desktop publishing had become the mainstream.

However, the path to this situation was not straightforward. There were a lot of expectations of the early desktop publishing systems that they were not able to fulfil. They had evolved in a market that was different from the requirements of many Graphic Arts printers and publishers and it became apparent that they were incapable of meeting the needs of this market. The terms 'high-end' and 'low-end' evolved as descriptors of the type of products being produced and many in Graphic Arts spoke rather disdainfully of the capabilities of desktop publishing.

They seemed to overlook that the advances that had been made in the Graphic Arts market in a relatively short time were largely the result of technology changes and believed there was some skill level they possessed that would always differentiate them from the mass market regardless of any convergence of technology. While events have shown that there was some truth to this it never seemed likely that the markets would remain clearly differentiated. Much of the skill they relied on could be learnt by others, or replaced by the brute force of high power computing. They also overlooked the fact that consumers are more than willing to forego quality if price, and other advantages, arise. This has also proved to be the case.

As already stated, the typesetting vendors were the first to suffer. Word processing for the office had quickly developed from running on proprietary systems to run on the early personal computers. As these became faster it was natural for pagination systems to be developed and Pagemaker was the fore-runner. Within a few years the specialist typesetting industry had virtually ceased to exist. Text input and pagination was increasingly achieved on the ubiquitous Macintosh, or occasionally PC, and the typesetters themselves were replaced with imagesetters (generally from the same vendors) running a Postscript RIP which could output the Postscript files containing both text and graphics produced by the various software packages. The evolution into professional colour was somewhat slower; but only because of a few fundamental limitations which Adobe, and to a lesser extent the application software vendors, were surprisingly slow to resolve (halftone screening, trapping, image compression to resolve the issue of large file sizes and colour separation flexibility come to mind as the main ones).

The main areas of concern with the early desktop systems were productivity and quality. The productivity issues were particularly significant for colour (because of the large file sizes) and were only resolved by inclusion of large amounts of memory and massive discs in the computers and workstations, compared to what was typical at that time. However, this made them expensive and either produced workstations that were little different in cost to the existing high end systems based on mini-computers, or required multiple workstations (and hence more labour) to produce the same throughput. But this situation did not last long. The dramatic specification increases in personal computers and workstations over recent years has led to machines that are now far more powerful than those mini-computers, even with their massive amounts of special purpose acceleration, so widely used only a decade ago. The main issues which now affect productivity have little to do with computation times, file access times, etc. that bedevilled the earlier generations, but are a direct result of ill-defined workflows. I will return to this later.

The main quality issues were associated with the quality of type fonts, halftone screening issues and colour reproduction quality. These issues are currently being resolved and expectations are changing. High quality type fonts can be licensed relatively cheaply, because of the large number of users, and are becoming more widely available. There are still copyright issues when exchanging pages and, although procedures are being implemented to resolve this, the legal situation is not completely clear for all fonts in all countries. However, the inevitable consequence of the whole technological evolution has been a decline in typographic quality but, apart from a handful of professionals, who cares? When typesetting was expensive typographic quality was deemed to be of paramount importance to the publisher, as the price tumbled it suddenly became less so. It seems that quality has its price!!

Halftone screening algorithms (which avoided screen clash) proved to be a major limitation in the early RIPs. It was only in the early to mid 1990s that these became satisfactory. Given the very acceptable solutions that evolved 10 to 15 years earlier (albeit with some special purpose hardware), on the various colour scanners of the day, this is surprising; since it showed that the problem was relatively straightforward to resolve. One can only assume that the RIP vendors did not perceive traditional pre-press as a key market. It was thus one of the factors that enabled the proprietary system vendors to remain in the market as long as they did. However, algorithms have now been developed by RIP vendors which largely prove acceptable to most users.

Colour reproduction quality is still an on-going problem. Procedures are being put in place which will improve the quality obtained by many users; specifically the development of the ICC profile specification and the recommendations for standard colour spaces such as sRGB. These will allow for a less ambiguous definition of colour than had previously been achieved by such systems, but the subjective nature of the process means that the quality obtained may still be problematic for the professional market. However, I remain confident that workflow procedures will develop which obviate this. Again, I will return to this later.

One of the major issues confronting the pre-press industry in the 1980s was that of the transfer of files. It had seemed so obvious to many of us that the ideal way to transfer images between pre-press and printer was in electronic form. I remember sitting at a forum in London, England, in 1983 in which there was a discussion about proofing issues arising when film separations were transferred between pre-press and printer. I gave my views on that and then went on to say that it was only a short term problem by forecasting that within 5 to 10 years all file transfer would be electronic. Needless to say I was hopelessly wrong; even 15 years later there are still substantial numbers of images and pages transferred as film. Certain scanner companies make a very good living out of producing

scanners that do an excellent job in providing de-screened or 'dot-for-dot' electronic files of pages and images for inclusion in all electronic workflows. Even though some of these are made from archived films most are not; they were almost certainly produced from electronic files a few days or weeks earlier.

There were various reasons why my forecast for electronic transfer was so inaccurate. One was to do with the nature of the files produced on the old high-end systems. Each vendor had its own native format for both the continuous tone and text and line art components of the raster file format they were encoded in. The inevitable complexity meant that there was no way the average user could convert one to another. I had totally under-estimated the difficulty in convincing vendors (including the one I worked for) of the need to be able to freely exchange files. To a large extent the development activities of these vendors were driven by the demands of their existing customers; but these were the same users who had developed workflow procedures around the use of film and could not appreciate the benefits of electronic transfer of images. Even amongst those who speculated on it idly there probably seemed to be too many unresolved issues quite apart from file format; proofing, media for the file exchange and time for conversion into the native format being amongst them. Thus, there was little real demand, and without it the vendors used their development resource to meet the more immediate customer demands.

However, some markets did slowly start to develop a need and pressure came to a head in the USA, in the mid-1980s, when Tom Dunn convinced all the main high-end pre-press vendors at that time to come together and develop a file format for data exchange. The development of this was tortuous but eventually agreement was reached. Unfortunately, there were a number of problems; the only media capable of handling such file sizes at that time was magnetic tape and the media format was somewhat intimately bound up with the resultant file format agreed by these vendors. This limitation, together with some appallingly slow vendor implementations of the conversion from the exchange file format to the native one, gave this procedure a very bad name. Eventually, the necessary procedures were put in place to make the format media independent and base it on what had by then become the most popular format for the exchange of raster data - TIFF.

But, by that time raster data was not universally popular for the production of colour pages. The efforts of Adobe to develop a programming language that enabled object-oriented (vector) files to be converted to the raster format required for output, independently of the device itself, had accelerated the professional acceptance of pagination systems derived from the word processing software that had supplanted the proprietary typesetting systems. As these systems evolved into colour the Postscript language, as well as the application software generating the code, quickly grew to develop many of the features

required for high quality colour imaging and pagination. With the introduction of Postscript level 2 in the early 1990s the transformation was more or less complete. In principle, colour pages could be adequately defined by Postscript and it became the most common format for the exchange of page information despite a number of issues which I will consider in the next section.

Looking back over the past decade, with the benefit of hindsight, it is easy to see the key developments which brought about the changes we now accept. However, at the time things were not so clear. It was by no means a foregone conclusion that Postscript would dominate the RIP market the way it has. Reading the literature of the time confirms my recollection that there were a number of such products; many of which were as good, if not better, than Postscript. In some cases the fact that the high end system vendors suffered so badly in the market was not that they failed to understand what was required by the industry but backed the wrong products. Certainly they were slow to react once the winners started to emerge and it is my view that this was their biggest mistake.

The Present

Colour separation and control: In many ways colour reproduction today is technically very similar to that which has existed for many years. However, what has changed is the workflow, as new technology has permitted so much more flexibility to the user. The development of low cost, distributed systems of colour reproduction has meant that colour management, first investigated in the 1960s (although one might argue that the work of Hardy and Wurzburg used a colour management approach), has had to evolve to enable the flexibility required by many users.

Colour management can be differentiated from the traditional approach, which is still used by many requiring the highest levels of quality, by the reference colour space used. For the traditional approach the colour space, often defined by density values, was specified differently by each equipment vendor. Based on this a series of empirical equations were defined to enable separation and the operator was provided with controls to change the parameters for the specific printing conditions encountered. Colour management, on the other hand, attempts to use the CIE system of colorimetry as the basis of its colour transformations. The relationship between this and each of the scanner RGB values and the printed CMYK values are defined, typically by profiles based on colour measurement. These profiles can then be combined to produce the overall transformation that enables separation. However, the development of empirical profile editing software suggests that the two approaches seem to be converging to a multi-level approach, depending on the quality levels required, much as the traditional systems had previously done.

The reasons for this complexity have been discussed in so many TAGA papers that it is impossible to list them all. For a short list, based only on my own contributions, see Johnson (1989, 1990, 1992a and b and 1995) as well as papers published elsewhere (1982 and 1991). Among the main reasons for the complexity are that it is not possible, in general, to reproduce an exact copy of an image by printing, simply because the gamut of colours found in the original image cannot be matched. Furthermore, there are various issues in a cross media comparison which mean that any measurement of the original image should not be replicated on the print, if the two are required to look alike. The result of these issues is to produce a fairly complex colour transformation if the best approximation to the original image is to be achieved, which becomes slightly more complicated if artefacts of the original image such as colour casts need to be removed.

It is not easy to visualise these effects and so some sort of proof is required. So long as the proof replicates the printing process the visualisation is valid. Even with traditional workflows, where separations were often proofed directly using systems such as 3M Matchprint and DuPont Cromalin, the match to printing was not always, if ever, exact. However, it was usually close enough to be acceptable, and users often learnt to predict the differences to be expected on print. However, in any environment where proofs are not made from the final processed image, as may well be the case with a colour managed workflow, the likelihood of the match becomes even more tenuous. Although with careful control of calibration and good colour management it should be possible to ensure that digital proofing devices match printing devices, at least as well as the systems of old, there will always be an element of uncertainty unless sensible cross media control procedures are implemented such as an industry wide agreement on a set of colour patches which should be output on any device where matching is anticipated. These colours would be the equivalent of the colour control bars of the traditional methods but would need a slightly larger range of colours than used in those systems to better define colours achieved by overprinting different colorants. This proposal is discussed in more detail in Johnson (1997). In this context one of the main objectives for digital printing systems must be to provide a system where one copy is little more expensive than multiple copies. The traditional ideal of proofing on the press that a job will be printed on can then be realised!

One architecture which is widely expected to provide the solution to these problems is that proposed within the ICC profile specification (1997). This is a specification which is designed to carry colour encoding information along with an image. By using this information at the time the image is rendered, together with knowledge of the colour characteristics of the rendering device, the correct colour should be achieved for the reproduction of the encoded image. However,

since the output rendering includes the gamut mapping implied earlier, and since this is not standardised, it is to be anticipated that even devices with the same gamut could well produce different results according to the particular vendor's output profile selected. Thus it is my expectation that any workflow pattern that requires an exact colour match for an image produced at different times, and probably on different printing devices, as is the case where a proof has been produced and approved for subsequent printing elsewhere, will require that both input and output profile accompany that image. So long as the proofing process does not exceed the printing gamut, and reasonable process control is maintained, comparable reproduction on both proof and print is assured. This is also discussed in more detail, together with suggestions as to how the proofing gamut may be constrained, in Johnson (1997). A very similar approach has been proposed by McDowell and Warter (1997).

File Exchange: It was stated earlier that Postscript has become the most common format for the exchange of colour pages. Unfortunately using this approach issues frequently arise from the way in which the RIP processes the page; it is still common for pages not to get interpreted by the RIP as the user intended. The various applications tend to handle the creation of the code in different ways and various interpreters may render a set of commands differently to each other. Although Adobe try to prevent this by authorising Postscript interpreters it is not possible to remove this variability completely, particularly for complex pages. Furthermore, it is common for various resources, such as fonts and images, to be missing at the time of interpretation. Thus, a page may not render as intended by the producer. It is for this reason that files need to be pre-flighted, or checked, prior to output to any digital press where the risk of error is at its greatest.

In order to overcome this the Portable Document Format (PDF) has been developed, Adobe (1996), which attempts to resolve many of the problems. Essentially a Postscript file is interpreted by the distiller software and converted to PDF. This can be considered similar to pre-flighting. If the file distills satisfactorily it is far more likely that it will be interpreted satisfactorily by the RIP. It is to be hoped that it will provide the panacea claimed for it, particularly following the publication of the qualified PDF format (PDF-X) being developed by CGATS to ensure full graphic arts functionality while minimising interpretation issues to the greatest possible degree. I believe that the exchange of raster files, using the TIFF/IT format specified in ISO 12639 (1997), is actually a better solution to this problem but is one that many users are reluctant to implement because of the need to provide RIPs at the workstation rather than the output device. Despite this its use is increasing in certain market sectors. However, PDF also provides significant opportunities for additional information to be specified, which may prove useful in certain applications, and helps to make it even more versatile and attractive. I can foresee TIFF/IT files being sent

within a PDF 'wrapper' to ensure the best of both worlds, despite the CGATS committee protestations that it is not intended for that!

However, quality and unambiguous interpretation of files are probably not the major issues which face the pre-press industry at present. In many ways the more significant ones are to do with workflow, although these do also have implications for quality. The development of computer-to-plate systems and digital printing processes, at both consumer and professional levels, as well as the distribution of pre-press as described below, caused by the rapid change in technology, is in turn causing a dramatic restructuring of the industry.

Workflow: In its early days desktop publishing was just that. It was basically undertaken at individual workstations (usually Macintoshes), isolated from each other just as the high-end systems had been. However, what really brought this whole process to commercial viability, particularly in complex areas of publishing such as Newspapers where many individuals need to work in parallel, each dealing with individual pages or parts of pages, was the use of standard platforms combined with networking. This enabled the development of server based architectures; running standard databases which could be accessed by all the individual workstations. This means that as desktop publishing has evolved into the pre-press mainstream the server and networking architecture has become key to many publishers. Although the high end system suppliers had developed fairly sophisticated local area networks (LANs), running on proprietary high bandwidth fibre-optic links, this only served to keep them competitive for a fairly short time. The relatively closed nature of their systems was a major disadvantage and although they built various bridges into the world of standard platforms it was inevitable that such systems could not survive. Eventually, as the performance of the standard platforms and networks increased, and the 'shrink-wrap' software improved, the cost and relatively closed nature of these systems made them unacceptable; even though they could often be more productive for specific applications and provide higher quality.

I do not intend to spend much time discussing the hardware details of current systems; it will probably be out of date by the time you read this anyway! Suffice it to say that whereas a Sun workstation, running UNIX, was the most common file server just a year or two ago it now seems to be being replaced by dual Pentium Pros, increasingly running Windows NT. Although NT is not as mature as its main rivals, the Microsoft brand name and its efficient multiple server architecture seem to me to make it a likely winner in the long term. Although it is to be expected that the number of processors offered in individual servers will increase from 2 to 4 or 8 during the near future, with improved workload 'division', a multiple server architecture is probably more efficient for Graphic Arts since it offers the redundancy so important to many publishing environments.

However, despite the tone of the above discussion it would be wrong to think that specialised systems, such as those produced by the former high end pagination system manufacturers, are 'dead'. Certainly the proprietary hardware produced by such vendors in the 1980s is highly unlikely to ever re-emerge, but niche applications running on high power workstations still have a role. Companies such as Barco, Dalim and Wright Technologies all have proprietary pre-press software running under UNIX on Silicon Graphics or Sun workstations. In fact it is ironic that Dainippon Screen, who were the least successful of the four high end pagination system vendors, is probably the one who has most successfully made this transfer.

What each of these companies (and others) has done is to identify some pre-press area where the standard packages are weak and provide solutions focused on these. Some of the solutions are plug-ins to the more popular applications, other are quite separate but still permit integration by relying on a 'standard' file format (invariably Postscript) as either input or output (or both). Thus they focus on niche areas that have special requirements such as packaging, or improving productivity and workflow in various sectors. How long they can last is another matter.

There are many significant workflow implications from the developments of the last decade. Some of these follow directly from the relatively open nature of file formats which permits easier exchange of all categories of pre-press output as digital files. Management of this becomes a significant issue. Other implications follow from the unwillingness of some suppliers, for perfectly good reasons, to move away from film as an exchange medium. This film has to be integrated into an electronic environment. And yet others follow directly from the distribution of the different parts of the process to a number of users, including multiple printing sites for the same document. We have to ensure that the information required for rendering the data at multiple sites is complete and unambiguous, so that it is capable of being correctly interpreted by all users.

The most typical workflows in the past varied for different market sectors. However, they could all largely be summarised by saying that at a page level the most common workflow was for a single company to take responsibility for all the colour imaging, and often include the stripping of the text and monochrome films also. It was when the various pages were brought together to form an advertising flyer, newspaper, book or magazine that the differences came. Newspaper and large magazine publishers often had their own printing and pre-press facility which undertook all of this in one plant. However, advertisers usually wanted control of their own pre-press. In many cases they would subcontract it to a specialised, independent, pre-press vendor, although some of the publishers had their own pre-press that did also offer the necessary quality

and service. Many book publishers and low circulation magazine publishers, who also used the services of these pre-press vendors for their colour and monochrome images, would often rely on the printer to strip the pages as he made up the printing forme. Many printers, who required small amounts of typesetting and imaging for simple booklets and leaflets, and advertisers who wanted flyers produced for advertising purposes used the specialist pre-press industry also.

In such a situation the typical procedure was for the pre-press specialist to digitise images, convert them into the CMYK required for printing, generate the halftone screen, produce a set of colour separations on film and provide a colour proof. Often after more than one iteration, the proof was approved and it was then sent to the printer with the separations. Sometimes the first proofs were simply of the colour images and subsequently, after these had been approved, a page proof, with text stripped in, was submitted for approval. Standardisation of printing and platemaking meant that proofing processes could be developed independently of the printer, which provided a reasonably satisfactory simulation of the print, and the control process was such that the approver of the proof could be reasonably confident that the printed result would match it.

A lot of the work that had previously been undertaken by these specialist pre-press suppliers has started to be distributed in two directions; to the originator or the printer. The imaging and pagination can be transferred to the originator of the page who supplies electronic files to be output to film, direct to plate or direct to press by the printer. But, there are areas where the current pre-press suppliers are hanging in. Some users require too little imaging to justify their own high quality scanners since there is still a quality limitation with many of the newer, lower cost, offerings. Such users may still purchase scanning, at low cost, from the pre-press specialists. However, these suppliers may not always be the traditional vendors; the evolution of PhotoCD, despite its almost total lack of success, to date, in the consumer market it was aimed at, shows one example of how the pre-press originator can gain benefit from imaging produced for a quite different market. The development of digital imaging for other markets will bring other such opportunities and the evolution of the digital camera may, eventually, render scanning unnecessary; although it still has a long way to go in terms of quality and ease-of-use. However, there are certain imaging requirements for Graphic Arts which require some expertise in image editing; there is currently a significant drop in quality of many colour images where the images are produced on systems that cannot accommodate this - we will return to this later. Of course, it may simply be a re-run of the typographic quality issue. Do many users really require the quality judged necessary by the 'professionals'?

Other pre-press suppliers are managing to provide a proofing and film imaging service but it is difficult to see even the smallest printers resisting the urge to add

this service to their offerings; particularly as they are driven by the need to offer proofing in a direct to plate or direct to press workflow. Yet other pre-press suppliers are concentrating on the design and studio facilities they may well have offered in the past. This is an area where high quality digital photography has had some success, in the capture of still images for advertising, where resolution can be traded against speed of imaging.

However, while such specialist activities will ensure that some of the pre-press specialists will survive I cannot see it being many. The hardware, shrink-wrapped pagination and image editing systems are now sufficiently cheap, functional and user friendly that they can be justified by almost every 'occasional' user; particularly where quality is not paramount. And, of course, the printer will offer the service for those requiring higher quality imaging, or the specialist niche software mentioned earlier, as well as the output functionality (proofing and imagesetting, direct to plate or direct to press). It may be that many of the printers will make this transition by acquiring pre-press specialists. Examples of this trend started at least 10 years ago and have been growing since. Thus the pre-press specialists still exist, even though some of their roles have changed; in many cases they have simply been absorbed into the printer or originator.

Many of the workflow issues are associated with the smaller market sectors. The larger newspaper and magazine publishers have already developed pretty effective workflows within their own environment although they will undoubtedly be improved further. However, where they interface with the advertising sector, and other originators, is where I see certain problems arising. Ensuring the complete unambiguity of files that are obtained from elsewhere, both in terms of colour and interpretation, still remains an issue.

The sort of workflows that are put together by all large users rely on server based, locally networked systems running various sorts of databases optimised for the specific task in hand. Some do still use proprietary application systems but increasingly they are moving to networked shrink-wrap applications though for some time these will continue to be supplemented with the specialist plug-ins and other applications referred to earlier, particularly for file management and control. Thus, the total workflow is fairly easy to define in such a closed environment, even for the largest of users. File format issues do not arise, such issues as colour, screening and fonts can easily be managed and the main problem is one of file and database management. It is when any system has to relate to the outside that many of the issues arise.

Changing to the sort of workflow required by such an industry structure, in which many of the stages that were all the responsibility of one supplier are now completely separated, together with the evolution of computer-to-plate and direct

printing, greatly increases the potential sources of error. Whereas in a traditional workflow a print buyer could expect to see a contract proof made from the film separations long before the image was committed to the printing plate, the first time he or she may see the final interpretation of their page in a modern workflow, that incorporates the halftone screen, shows the final colour and includes the correct fonts, could well be at the time the final colour print is being produced. If consistency is to be maintained, and the workflow is to be highly efficient, it is necessary to ensure that the traditional workflow checks are either rendered unnecessary by rigorous standardisation and control, or are replaced by a new control process, such as that described earlier.

However achieving a colour and font match between electronic files is not the only workflow problem by far. It is still a fact that a very high proportion of images are presented as hard-copy images (ready screened monochrome and colour separations). In many cases this is done to avoid proofing ambiguities, in others it is a re-use of old material, while for others it represents a way of avoiding file format and interpretation errors. So, any workflow still has to accommodate these either by scanning them in as high resolution raster files (thereby encoding the halftones and linework as binary files) or descreening them (to convert the image information to continuous tone). Both techniques, but particularly the former, are prone to modify the image without careful calibration. Even assuming that such images are effectively included into a digital page, and it has been ensured that all size and positional information is correct, there are other ambiguities with electronic file exchange that are less easy to define.

A major problem, to many printers and pre-press bureaux, has been RIP interpretation of a page. As already stated significant ambiguities can arise, leading to errors of interpretation that make a proof almost essential. At the very least pages have to be 'pre-flighted' to ensure that all is well with them and even so this may not pick up some errors. Another problem is the matching of halftone screens across devices. This may seem like a trivial problem; after all who cares if a screen is 145lpi rather than 150? Of course nobody does unless there is object moiré - a phenomenon whereby the screen, or more likely the output resolution of the device, beats with some constant frequency of an image, or screen moiré. The resultant patterns can be very intrusive and users would like to be pre-warned of it.

It should be clear from this discussion why many of these issues need to be fully resolved if the pre-press and printing industries are to at least retain, and preferably enhance, the efficiency previously achieved as well as ensuring a satisfactory predictability of production. Without such resolution productivity will fall or quality diminish. As already indicated the latter may be seen as acceptable; it is already happening. However, with a small amount of will it is

not inevitable; most of the problems can be overcome by inter-industry agreement that would largely resolve them. For example, the way in which colour consistency can be ensured has already been discussed and a finalisation of the CGATS PDF-X file format currently under discussion would go a long way to resolving other issues. Recommendations on procedures for selection of halftone screens when objectionable moiré is observed could also be produced.

The Future

So, having reviewed what has happened in the past, where does colour reproduction go from here? Can we expect an evolutionary change or is there another revolution around the corner? In the next few paragraphs I will risk the inevitably high chance of being wrong and try to forecast what I see happening over the next few years. The future promises that the process will become more distributed, with many more media being widely used. In fact, printing, as we know it, faces a major threat as we move into the new millennium. This will again impact workflow and require that colour becomes even more of a commodity item.

Hardware and software: The dominant networked computer for running the pagination and image editing applications is still the Macintosh. However, it is on the decline and my guess is that will cease to be the dominant product by the year 2000. It has had a very high share in the Graphic Arts market, perhaps as high as 90% at its peak. Because of this it still has a loyal following. There are many features concerning its user interface and ease of operation that still make it attractive. However, the gap has narrowed considerably as recent Windows packages have improved in this regard and an increasing number of Graphic Arts applications are offering Windows versions. The competitive nature of the PC hardware market makes it an attractive product. I would expect that the PC will rapidly overhaul the Mac as the computer of choice in pre-press. This transition will only be retarded (but not stopped) by the loyalty of current Mac users. Unless the Mac finds new market areas I expect to see Apple going the way of the former high-end pre-press vendors.

However, it is conceivable that we will increasingly see the networked computers become less powerful and rely on increasing power from the servers; exactly like the mainframe and mini systems running terminals from many years ago. Some commentators are forecasting that web-browsers will replace Windows or the Mac OS on such systems because, running Java, they are (potentially) truly platform independent. However, at present I feel the applications are too complex for this to be realistic; we will need to see a lot more bandwidth and better server performance for this to happen. However,

neither of these events are unlikely so it could be a trend for the future and may be the saviour of Apple.

Ironically the Mac is not the only casualty of the rapid changes in technology and product development. As already pointed out one of the main reasons for the success of desktop publishing, which led to the demise of the proprietary systems popular at that time, was the development of Aldus Pagemaker. But that company is no longer in existence. In 1995 it entered a 'merger' with Adobe which has seen the Aldus name disappear. The product still survives but under the Adobe name. Thus, two of the major developers of the desktop revolution have either disappeared, or are struggling, little more than a decade after their impact. Such is the nature of change in this business and it will continue in the future.

I stated earlier that some specialist suppliers have been able to survive against the shrink-wrap software/standard platform offerings in certain niche areas. This is because traditional pre-press is not the main focus of these shrink-wrap vendors. Their main market is software for the production of Newsletters, In-house journals and the like. Inevitably the productivity and workflow requirements of such systems is different to that of pre-press and so any available development resource is primarily directed at particular problems in these areas. But for how long? When does a Newsletter become a Newspaper? Why should we not expect the quality and functionality expectations of such market sectors to continue to converge with those of traditional pre-press? In 5 years time will there be a difference? Furthermore, productivity will be achieved by simply increasing hardware performance without specialist software. It is my expectation that these two factors will combine to push these specialised suppliers into a smaller and smaller area that will eventually make them uncompetitive. It is only those that have competitive input and output device offerings, or act as system integrators for large systems, or have found other market sectors, that will survive. But even here, the development of digital cameras and digital printing will make this market more difficult; by early in the next millennium I expect to see few of these companies in the same business.

Output: The impact of direct to plate and direct to press means that the demise of film must be coming. Whether it takes 5 or 20 years to disappear is debatable but in my view it will happen sooner rather than later. I am aware of many arguments in favour of film as an imaging medium, rather than direct to plate, but many of these tend to assume current workflows and ignore the tenacity of those users who are determined to make new technologies work. Some do it simply to be prestigious, others for economic reasons that they perceive will eventually arise; though they usually overestimate the timescale of this! In this particular instance there is also an environmental aspect to the argument. Similar negative arguments to those concerning the replacement of film were put

forward about why the demise of typesetting and the high end systems would not happen. Just as the large sales of typesetters were totally replaced by imagesetters in just a few short years I anticipate the same happening to imagesetters now. Of course we have to remember that it has already taken 20 years to get to where we are now in terms of direct to plate; it has been a technology waiting for the pagination and imposition systems to mature. Once that happened it was inevitable that the imaging media would rapidly evolve to meet the need. In many ways the most popular technologies in use today (thermal, silver halide and high speed polymer) are those that have been with us since the outset of direct to plate in the 1970s, or soon after.

However, apart from imaging technology there is little else in direct to plate to directly require change from current colour reproduction procedures, apart from the need for productive, reliable and accurate proofing systems. I believe we largely have suitable systems now; as stated earlier the challenge is in ensuring a colour match to the print. The only uncertainty is the prediction of moiré and I believe procedures can be implemented to obviate this problem where traditional screening is pursued. The fact that imaging will be the domain of the printer, and that correction on plate is not so simple as for film has some implications in that it will be necessary to take extra care in ensuring files are correct and are interpreted properly. However, those are largely procedural matters which should be easy to resolve given the will.

The impact of digital printing technology may ease this resolution. It really depends upon which solutions prove most viable. Some so-called digital printing systems do little more than move the plate imaging step onto the press. Whist this offers the advantage of proven press technology, possibly with efficient manpower utilisation, it is not really what I like to think of as digital printing. Ideally it should be possible to produce one copy, or a million copies, at more or less the same cost per copy. If we can achieve this many of the issues raised in the last paragraph disappear. Single copies can be produced as proofs very efficiently. The issue then will be shipping it to the user.

This seems an appropriate point to speculate on what will happen with remote proofing. As originators will be producing their own pages they will also be producing a proof of some sort of quality, be it soft or hard. The only other sort of proof they are likely to require is of the interpreted page as already discussed but it is difficult to see how this can be displayed at a remote site. Video is possible for looking at artefacts such as moiré, and consideration of interpretation issues; but not for colour. However, if high quality, cost effective, single copy digital printing is introduced, with adequate inter-press controls, that will not be necessary. A proof can be made locally even if the final printing will be done elsewhere.

However to achieve all of this the quality and productivity of the current digital printing systems needs to improve. I may be guilty here of failing to acknowledge what I have accused others of earlier; namely that people will accept a quality reduction if other advantages accrue; as already pointed out this has happened for typographic quality and now seems to be happening for colour. But even so, I feel that current quality levels are not yet adequate. The productivity requirements will put more demands on the network bandwidth and memory used, which will also need to increase to accommodate the possibility of multiple single copies rather than long print runs. However, all of these developments seem likely; they are only continuation of an existing evolution. Productivity is also an issue if runs remain high since the digital presses then need to emulate current procedures. Whether printing will really be on-demand I still have some doubts about and so high speed production, such as that achieved on web presses, will be needed. I am sure long runs for some products will be broken up into shorter ones, temporally, but not newspapers and magazines. They may be broken up geographically but reasonably high speed will still be needed.

Thus, I do not expect that direct to plate or digital printing technologies will have a massive effect on colour reproduction procedures. The distribution of printing, both geographically and temporally, will require more stringent process control procedures but again I do not really see this as a major issue. Such control has been necessary for years. If anything the only real impact will accrue from the greater amount of colour that may be required; as cost and convenience improve new markets always appear.

However, the trend for vendors of pre-press to go out of business will accelerate. Even if the total amount of colour pre-press increases it will largely originate from the user, as already discussed, and output imaging responsibility will be with the printer in most cases. As already stated, I also anticipate that the specialist software vendors will lose their role as the shrink-wrap software becomes yet more functional. It is only in the management and control of large systems that there will be a requirement for specialist software and even that is not peculiar to pre-press. Other industries also have a need for this and I foresee general file management systems being capable of being tailored by the user much more than at present.

There is little doubt that different market sectors will be affected differently by these developments. The sheet-fed printing market will be more likely to go direct to press in the short term; the long run and high speed printing requirements of Newspapers and many Magazines makes it less likely for these sectors unless they dramatically change their format. I really cannot see this at present. Thus they are more likely candidates for direct to plate technology until really high speed, large format, digital printing is a reality.

The World Wide Web: One of the major question marks overshadowing the pre-press and printing industries today is the whole future of hard copy reproduction. For over two decades we have heard the prophets of doom forecasting the end of print but if anything it has grown in volume by almost any reasonable measure you can think of. However, it would be wrong to see this as proof that the suggestion of its demise is fundamentally wrong. Although I personally much prefer to get my information by reading traditional hard copy I am not sure that I am at all typical. There will undoubtedly be an increasing use of multi-media for sharing information and, of course, there is the Web. Here I know I am not typical because I find the frustration and cost of the Web (remember that local telephone calls are charged in Europe) makes me reluctant to browse on it. I only use it when I have a clear strategy for gathering data for a project; even then the idiosyncrasies of the system still frustrate me. I cannot think of one example where I have used the Web to replace hard copy although sales of such material to me have probably been lost because in the time it sometimes takes to log onto a site I could have read a short book!

Nevertheless, I do recognise that the Web has the potential for a major impact on the sale of print, particularly as the telecommunication systems increase their bandwidth and the servers become less clogged up. Whether it realises that potential is quite unclear at the present but I would not like to bet against it. Of course there will be ways in which it has a positive impact on print; it has the potential for advertising to a major new market for printed material. However, if the concept realises its full potential the net impact must be negative. Everybody only has so many hours a day for leisure so, unless there is a significant net increase in leisure time, together with the income to enjoy it, other activities will suffer. Of course the same was said of television when it came to fruition, and that certainly did not have a net negative impact on print, though it changed the nature of the more immediate information dissemination media such as newspapers. However, I think the major difference was that the people who watch a lot of television are not likely to have been those who read as an alternative; here it was the cinema and other leisure activities which suffered. With the Web I doubt if that is the case. The most likely users of the Web are those who seek information and these are the consumers of print.

Of course much Web activity is not related to print at all. I use it for downloading software and finding information I am otherwise unlikely to bother with. But many publishers see the potential, or risks of the Web. Many probably will not do much until their advertising starts to shift to it, or book sales start to fall, but some are at least experimenting with it in order to hedge their bets and to advertise the hard copy itself. Only time will tell if the impact on print is negative; my instinct tells me it will be, though every time I use it I find that hard

to believe! However, I cannot believe that those access issues will not be resolved and thereby make it far more user friendly.

So, what are the implications for colour reproduction? If the Web does start to play a significant role in disseminating information that is currently the domain of printing, colour reproduction, as we know it, will largely disappear to be replaced by a Web relying on video and audio technology. It is almost certain that much of the quality we now take for granted (which is, as discussed earlier, already lower than it was) will reduce significantly. The process of imparting information and selling goods via the Web will require a different approach. Moving images and other dynamic effects will replace the quality so necessary when only the still image, with no audio, can be used to 'sell' the product. Thus, my worst case scenario is that pre-press as we know it today, will lose its specialist role. Still images for the Web will be the domain of any Web builder. Any specialist role, if one remains, will be in the area of video. 'Pre-Web', rather than pre-press, will have begun to mature. The only areas that will remain significant for print will be for such things as packaging, wallpaper and textile printing, etc. Maybe this is where the Graphic Arts colour reproduction specialists should be honing their skills.

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