High Fidelity Color Rendering and Reproduction

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Abstract:

Four color process limits the color gamut achievable in the rendering of computer graphic imagery, and in the reproduction of imagery captured on film to a fraction of that which can be processed by the human visual system.

Manual and photomechanical processes for printing with an enlarged color palette have proven too difficult, labor intensive, expensive, and dependent upon highly skilled craftspersons to be widely used in the graphic arts.

The same market and technology driving forces that are propeling market growth and the development of technology for "good enough color" will also create new opportunities for the deveolpment and deployment of high fidelity color reproduction and rendering technologies.

The first wave of applications will be in packaging, promotional graphics, greeting cards, labels, stickers, coupons, magazine and book covers, free standing inserts, art books and posters, exhibits, and textiles. Among the technologies of significance will be colorimetric and spectroradiometric scanning, multi-spectral color separation, stochastic screening, hi-fi visualization and modeling software, as well as advanced process control systems.

This paper identifies potential research, development, and product opportunities for manufacturers of presses, inks, scanners, proofing systems, prepress systems, and image computing software.

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Hypothesis:

Methodologies which expand the color gamut, tone rendering, dynamic range, spatial frequency modulation, and other appearance domains of the print medium will grow in significance in the coming decade.

This will be true for systems which provide the means to closely approach "unity" reproduction of scenes or objects, as well as for those which provide the means to produce "high fidelity" renderings of mathematical functions and other abstract image data models in printed media.

Introduction:

The predominant thrust of technical research in the graphic arts has been to optimize the faithfulness or "fidelity" of an original to its reproduction by a "best fit" mapping of the sampled and quantized input values of an original, to the color gamut, tone reproduction, and spatial frequency domains of the output reproduction system . The default values for such rendering or reproduction systems have predominately been those of "conventional" four color process.

Trinary subtractive systems limit the fidelity of a rendering to a fraction of what can be be modeled with today's computer graphic software or of what can be rendered in additive trinary systems such as color transparencies or display monitors.

The color gamut, spatial frequency modulation, and tone rendering achievable in a four color reproduction using deterministic halftone screening and common ink sets are a fraction of what can be percieved by the human visual system, or of what a camera can capture on film. (Saarelma & Oittinen, 1983; Field,1984.)

Fidelity has generally been balanced with other factors such as the length of the production cycle, and cost.

Although there have been exceptions in specialty applications such as greeting cards and mapping, a research and development orientation geared toward "best fit" solutions has been consistent with the needs of the graphic arts industry and society at large. This has generally been the case whether the objective has been to "reproduce" an object or a scene, or whether the objective has been to "render" a mathematical image model developed with visualization software. However, powerful cultural, technological, and business factors are changing and expanding the demand for color reproduction and rendering beyond the scope of current graphic arts markets and media.

Research, product development, and service infrastructures for color rendering and reproduction in the consumer electronics, office equipment, computer, and graphic arts indutries are on a collision course in the 1990's. The relative merit of "best fit" color reproduction methods dominant in the graphic arts are being challenged by "good enough" color rendering and reproduction systems being developed elsewhere.

Commodity Color:

Four color process will become commodity color. As printers, separators, typesetters, color laboratories, and postscript service bureaus retool to handle 4 color process digitally, previously separate industry segments will compete to provide similar front-end services. Increasingly, customers will take aspects of color production in house, and driving forces will become exogenous to the graphic arts industry. Four-color prepress costs may decline by as much as 50-75% by 1995 as much a result of over capacity as due to gains in technological efficiency.

New color technologies will not evolve only as cheaper, faster versions of their predecessors. New product categories will emerge that embody new design principles and new levels of functionality, connectivity, intelligence, media agility, and ease of use.

Appliance principles and design philosophies will be applied to four color reproduction and rendering systems. Such as:

1. **Mindshare**: Attention is in short supply. Distill functions. Simplify steps.

2. **Packaged functionality**: Functionality at a level of abstraction approriate for a complete process or task. Not a platform, not a tool.

3. **Responsive symbolic environment**: Context sensi tive. Adaptive. Staff, mentor, and valet.

4. **No Muss / No Fuss**: Auto everything.

A major challenge for graphic arts companies in the materials and equipment segments will be to harness their expertise in colorants, substrates, process measurement and control, digitally controlled printing systems and related imaging devices to the powerful driving forces generated by the consumer electronics, office products, computer, communications, and entertainment industries.

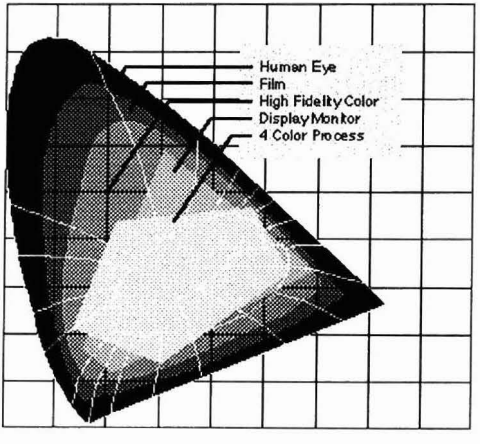
The Opportunity:

The same market and technology forces that are creating new opportunities for "good enough color" will also propel a market for more colorful and complex forms of printing. Offset printing and four-color process are facing challenges from electronic media and from other color imaging technologies which offer greater immediacy,

greater convenience, lower cost per unit, lower minimum order quantities, and other advantages as compared to four color offset as generally offered today.

What is High Fidelity?

In it's simplest forms high fidelity color processes increase and / or change primary colorants to expand the color gamut of the printing system. Image data preparation may include colorimetric or spectro-radiometric scanning, 3D scene synthesis techniques, multi-spectral color separation, and stochastic screening techniques. More ambitious methods may also employ advanced coating, finishing, micro-lenticular lamination, illumination and display techniques in order to achieve 3D and other visual effects.



The pursuit of high fidelity in color reproduction and rendering is at least several centuries old. It represents a basic desire to give full expression to visual concepts which has parallels in the cinema, the fine arts and other visual media.

For over a century, fine art reproductions, greeting cards, maps, and other specialty products have been produced by manually or photo-mechanically separating an original into 5 or more colors. British woodblock prints of the 1830's utilized up to 29 color plates (Friedman,1978). And, as recently as this year, a facsimile reproduction of the Celtic illuminated manuscript, the Book of Kells, was produced by Facsimile Verlag Luzerne with as many as ten colors per page. 1480 copies were produced at a pre-publication price of $14,800 per copy (Bulzone, 1991).

The process of printing with a large palette of colorants has proven too dificult, labor intensive, expensive, and dependent on highly skilled craftspersons to be widely used throughout the industry. Yet major components of the infrastructure required to make high fidelity rendering and reproduction controllable, cost effective, and widely available are already in place. Most printing companies today employ presses with six or more printing units in order to enhance the visual appeal of printed products through the use of spot colors, varnishes, and laminates. Such presses can be readily adapted to high fidelity process reproduction methods. Such an adaptation can provide graphic arts companies with a strategic differentiation vector enabling them to avoid the coming commodity color shakeout

Automation of high fidelity processes will require affordable industrial-strength computing such as can be found in today's generation of RISC -based general computing platforms.

The physics and mathematical foundations for high fidelity color have existed for over 50 years. As noted by Masia, a system based on tristimulus matching is theoretically capable of producing a colorimetrically exact reproduction of an original for all colors that fall within the gamut of the reproduction system (Masia 1984).

Recent work by Fischer (1989) on stochastic screening , by Gur (1989) on error diffusion and contrast modulation, by Viggiano (1990), Johnson & Luo (1990), Huntsman (1989), Granger (1990) and others on colorimetrry, color modeling, and perception have laid important groundwork required to pursue the practical application of techniques such as multi-spectral separation and non-deterministic screening techniques to "extra-trinary" color palettes (Dankert, 1990).

In addition, the important work being conducted by CIE, ISCC, ISO, ANSI, and other standards organizations has accelerated the progress being made toward the availability of objective color and appearance models, and toward related appearance measurement and control methodologies.(Carli, 1991) (McDowell,1990) (Blum, Hofmann,Kromker, 1991)

Why High Fidelity?

Although four color process and spot color embellishments have served the graphic arts industry and society at large well, and though they will be an important option for adding value to printed products through visual differentiation, high fidelity rendering and reproduction will have strong appeal to many markets. The rising tide of "good enough color" will flood our visual ecosystem with comodity color. This will simultaneously raise the boat of high fidelity color rendering and reproduction.

Top advertising agencies, design offices, exhibit and promotion firms, museums, and many businesses have demonstrated a shift in their priorities with regard to printed communications in recent years. They have placed increasing importance on collateral materials and promotions rather than on run-of-press advertising. They are continuously seeking ways to break through the clutter. They want greater choice, flexibility, predictability, and control over the modulation of color and of other appearance characteristics in the materials they produce.

The first wave of applications which will derive benefit from a high fidelity alternative to commodity color will most likely come from entertainment, packaging, promotional graphics, book and magazine covers, greeting cards, trading cards, labels, stickers, art books and reproductions, exhibit materials, maps, and textiles. The second wave will include other forms of color and image intensive products such as advertising inserts, some magazines, scientific and medical books.

In a fully developed scenario, color buyers would employ desktop software to create high fidelity content in an increasingly filmless process, where PostScript provides an end-to-end conduit for objective color information. They would specify the budget, appearance, and other in-service characteristics they desire such as gloss, dimensionality, surface texture, fade resistance, metamerism, level of color fidelity, etc. Intelligently designed software would adjust scanning, rendering, image processing, color separation, screening, platemaking, and other variables to deliver a given level of fidelity to the original object or conceptual model. Response tracking systems in the in-service environment would provide feedback to the specifier with regard to the effectiveness of their visual communication strategy.

High Fidelity methodologies :

A: Represent a revenue opportunity potentially accounting for as much as 15-20% of the $150 billion dollar world-wide color printing market by the end of the decade.

B: Represent a differentiation strategy for graphic arts firms in the specifier, service, equiptment, software,and imaging materials segments which is incremental. They will enable such firms to build on existing research and product develop ment efforts, and to provide value added through visual differentiation.

C: Provide printers with 6+ color presses a basis for sustainable competitive advantage requiring mini mal incremental capital investent.

It is hoped that the hypothesis advanced in this paper will stimulate interest in the development of advanced technologies and techniques which will facilitate effective and efficient high fidelity rendering and reproduction in print media.

Significant technologies will include:

Colorimetric and spectro-radiometric scanning systems

Hi-Fi visualization and image data modeling software

6+ color printing and proofing systems

Extensible page modeling software

Multi-spectral separation & stochastic screening software

Water Based Inks

Waterless or "Driographic" printing systems

Advanced appearance measurement & control systems

Expert systems for process optimization, simulation,

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