Paris, March 4 2009

ICC DIGITAL PRINT DAY
Welcome in Paris!
There should be a smart color management!
Towards a smarter color management!

- Océ’s markets
- Color & Printing technologies in Océ
- Innovation in Digital Colors
- Océ & ICC
Océ … Printing for Professionals

- 3 bln€ in revenues

Océ Business Services

15%

Digital Document Systems
- Document Printing
- Production

29%

Wide Format Systems
- Technical Document
- Display Graphics

56%
**Five things you need to know about this toner pearl printer**

- World-class speed: up to 31 seconds per A0 (600 dpi / CMYK/piezo)
- Unmatched media capacity: up to six 42 inch wide rolls
- Direct-dry plain paper prints for immediate use
- Handles applications from CAD & GIS to full color posters
- "Green machine": no ozone, no odor, no system contamination
Océ JetStream 2200

- **High speed printers of exceptional quality**
  - The Océ JetStream 2200 is a digital, full-color printing system capable of producing exceptional quality full-color data at high speed.
  - Océ JetStream technology uses a high speed paper path to produce CMYK full-process color output at a speed of 500 feet (150 meters) per minute
  - 675 – 2700 ppm / A4 / 
  - 600x600 / CMYK / water
Arizona 350 XT

- New UV-curable, flatbed printer for huge, high quality prints
  - Extra large 2.5 x 3.05 meter flatbed table
  - Unique Océ VariaDotTM imaging technology (6-42pl / piezo)
  - Near-photographic image quality
  - Roll Media Option and White Ink Option in one printer
  - True production capability at the highest possible print quality
A steady stream of digital colour improvements

Productive & Ease of Use

- Océ Print Assistant (2008)
- CMM full MFM (2004)
- CMM in Copy (2002)
- Colour MFM controller (2001)
- Colour Print controller (1995)
- Colour as Pen Set (<1995)

4th March 2009

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Research areas:
- Halftoning
- Color management, gamut mapping
- Graphical file formats interpretation
- Rasterization
- Image processing: segmentation, documents type detection, denoising, compression…
- GPU for color image processing
- Modulation Transfer Function
- …
Enhance Prints by Modulation Transfer Function

\[ MTF(f) = \frac{A_{out}(f)}{A_{in}(f)} \]

4th March 2009

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Our goal is to maintain the high-frequency content in the output print and produce a printed image with a constant $MTF=1$

We compensate for the degradation due to the printer by boosting the amplitude of the input signal.
Impact of the compensation on the MTF of the printout

Good compensation for all frequencies and bias values
Tests show that users prefer compensated printouts

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ICC Digital Print Day
Classify documents to automate printer systems

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Documents classified as mixed content
Documents classified as photos
Documents classified as Text/CAD

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Memory Colors
Memory Colors

4th March 2009

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Min ΔE (preserving Hue)
Preserving details & saturation with Océ SGMA
Our latest research calls for the use of a smart CMM

- Spatial gamut mapping algorithms
- MTF compensation
- Image segmentation:
  - Specific mapping of memory colors
  - Region specific strategies
Therefore we need more expertise on ICC specs

- Joining ICC was the best way to learn about the ICC architecture.

- This is why Océ joined the ICC in 2007

- We are looking forward being more and more active in the ICC
Using the sRGB v4 profile in digital print workflows

prepared by Jack Holm
for the ICC Digital Print Day
4 March 2009
Paris, France
Use cases

- Previewing content prepared for printing on sRGB displays
- Evaluating suitability of sRGB content for printing
- Consistently color re-rendering sRGB content for printing
- Color re-rendering print-referred content for the Web
- Exchanging print-referred data using sRGB
Previewing

- The ability to preview or “soft proof” content prior to printing is extremely valuable
  - even with digital presses it is easier to design on-screen

- To produce an accurate preview, the viewing conditions and content colorimetry should match
  - ambient illumination, adopted white, apparent viewing mode
v2 profile inconsistencies

- v2 Display and Output profiles often do not transform to PCS colorimetry in the same way
  - v2 Display profiles typically include scaling of the display black point to zero on the PCS
    - a v2 perceptual transform
  - v2 Output profiles typically map the content colorimetry to the PCS without scaling the medium black point
    - a colorimetric transform

- The ICC provides a v2 sRGB profile with a colorimetric transform
  - http://www.color.org/srgbprofiles.xalter

- The legacy sRGB profile that many people use contains a black-scaled (perceptual) transform
Previewing setup

- Adjust display white point to match either:
  - a perfect reflecting diffuser placed on the print viewing surface
  - the print medium base

- Adjust the display ambient so the adaptation to the display is similar to that when viewing the print

- Make sure the viewer-observed display black point is at least as dark as the viewer-observed print black

- Profile the display accurately, without obstructing the veiling glare or applying black point scaling
Problems with previewing

- If the display profile is black-scaled, or created from measurements that do not include the veiling glare, it will not accurately map the viewer-observed display colorimetry to the PCS
  - Consequently, the preview colorimetry on the display will be incorrect
- If there are print colors that are outside the display gamut they will not reproduce correctly
Previewing behavior differences

- Previewing with black-scaled v2 display profile
  - BPC off – the print black point is added to display black point (in linear light)
    - e.g. if the print black point L* is 20 and the display black point L* is 11, the preview will place the print black point at L* 25
  - BPC on – the print black point is mapped to the display black point
    - e.g. if the print black point L* is 20 and the display black point L* is 11, the preview will place the print black point at L* 11
Previewing behavior differences

- Previewing with an un-black-scaled v2 or v4 display profile
  - BPC off – the print black point is accurately reproduced on the display (assuming the display black point is sufficiently low)
    - if the print black point is lower than the display black point colors will be clipped just like any other out-of-gamut colors
  - BPC on – the print black point is mapped to the display black point as before
The v4 sRGB profile

- The colorimetric intent transforms in the v4 sRGB profile do not include black scaling
  - If a display is calibrated to sRGB, and the print viewing conditions are such that the desired white point matches the display white point, the colorimetric rendering intent of the v4 sRGB profile can be used to produce accurate previews

- The perceptual transform in the v4 sRGB profile contains color re-rendering between an sRGB display and the ICC v4 perceptual reference medium
  - A complete color re-rendering as opposed to just a black point scaling
What is color re-rendering?

- Taking content/image data that has been prepared for reproduction on one medium and re-optimizing it for a different medium
  - a blend of art and science
  - there is no single “correct” color re-rendering

- The v4 sRGB perceptual transforms morph between the sRGB color gamut and the ICC v4 perceptual reference medium gamut
Illustration of gamuts

![Diagram showing gamuts of sRGB and PRMG with re-rendered sRGB highlighted]
Printing behavior differences

- When using ICC v2 profiles (with black scaling) to print sRGB images using the perceptual rendering intent
  - The sRGB display black point is mapped to zero in the PCS, but no other color re-rendering is performed by the source profile
  - The destination profile color re-renders from some assumed PCS reference medium
Printing behavior differences

- When using ICC v4 profiles to print sRGB content using the perceptual rendering intent
  - The sRGB content is color re-rendered to the v4 perceptual reference medium by the source profile
  - The destination profile color re-renders from the v4 perceptual reference medium
v2 perceptual printing strategy

- Construct v2 output profile perceptual transforms to color re-render from black scaled sRGB in the PCS
- Use the perceptual rendering intent for sRGB content only
  - or display-referred content that is close to sRGB
- Use MRC+BPC to perform color re-rendering when the source profile is not sRGB-like
v4 perceptual printing strategy

- Construct v4 output profile perceptual transforms to color re-render from the v4 perceptual reference medium
- Use the perceptual rendering intent when full color re-rendering is desired, regardless of the nature of the source and destination
- MRC+BPC can also be used if desired
Advantages of v2 strategy

- Already widely used
  - Requires less user re-education

- Produces excellent results when source and destination media are similar (MRC+BPC), or when source is sRGB (perceptual)
  - For these cases, v4 will not necessarily produce better results
Disadvantages of v2 strategy

- The rendering intent is dependent on the nature of the source content
  - This can be confusing as the rendering intents are supposed to depend on the reproduction goal and not the source
- Full color re-rendering is only supported for sRGB-like source content
- To communicate the intended color re-rendering, it is necessary to communicate the intended output profile
  - Different output profiles may produce significantly different color re-renderings
Advantages of v4 strategy

- Rendering intent choice depends only on reproduction goal
  - Easier for new users to understand
- Supports full color re-rendering from any source to any destination
- Variability in output should be reduced when printing sRGB because most of the re-rendering is in the sRGB profile
- Provides a reference print-like interpretation for any source content
Disadvantages of v4 strategy

- R&D may be necessary to develop profile making tools that utilize the v4 perceptual reference medium
- Some user re-education necessary due to different behavior
- The print-like v4 perceptual reference medium may increase variability when the source and destination are both displays, but have significantly different characteristics
  - Display colorimetric intent accuracy will typically be improved
Evaluating suitability of sRGB content for printing

- When sRGB content is printed colorimetrically, some valid sRGB colors may be clipped, and the print medium gamut may not be optimally utilized.
- When sRGB content is printed using the perceptual transform in a v2 output profile, the results will depend on the output profile.
  - Content that prints well with one output profile may exhibit problems if a different output profile is used.
    - This issue can be even more extreme if printer/driver color transforms are used.
- It can be difficult to determine whether sRGB content is exactly as desired.
Consistently color re-rendering sRGB content for printing

- If the v4 sRGB profile is used when printing sRGB images, consistent print-referred reproduction colorimetry is produced in the PCS
  - A print medium similar to the v4 perceptual reference medium can be used to verify the quality of sRGB content
  - If other print media are used, the variability should be low since the secondary color re-rendering starts with the perceptual reference medium
Color re-rendering print-referred content for the Web

- In some cases, content produced for printing will have colors outside the sRGB gamut, and at the same time will not fully utilize the sRGB gamut
  - When used as a destination profile, the v2 sRGB profile does not perform any color re-rendering (except for BPC, when applied)
- If the v4 sRGB profile is used as the destination profile, the print source colors will not be clipped and the full sRGB gamut can be utilized
Exchanging print-referred data using sRGB

- Since the v4 sRGB profile perceptual transforms round-trip with reasonable accuracy, it is possible to use the sRGB color encoding to exchange print-referred images with minimal loss.
What happens if my output profile is not a v4 profile?

- When using the v4 sRGB profile with v2 output profiles, the results should be checked
  - Checking is also a good idea when introducing any new v2 profile into a workflow

- If the v4-v2 perceptual transform does not produce good results, two workarounds are possible
  - Use the v4 sRGB profile to convert perceptually to ROMM RGB, and the v2 output profile to convert MRC+BPC from ROMM RGB to the destination (a two-step conversion)
  - Assign the appropriate v2 sRGB profile to the source content
Why is the posted v4 sRGB profile still a “beta”?  

- Some concerns about gamut mapping of extreme out-of-gamut colors  
  - not often encountered in practical use  
- Lack of experience when using with other v4 profiles  
- Some interest in continued investigations, but limited resources available  
  - Appearance matching reproduction goal  
  - sRGB primary mapping
Summary

- The v4 sRGB profile supports several new use cases for digital printing
  - But some behaviors are different from existing use cases
- The v4 sRGB profile is designed to be used with other v4 profiles, but can be used with v2 profiles with similar care as is required when using v2 profiles in general
  - When different profiles are used results may be different
- The v4 behaviors are not limited to the sRGB profile
  - They will result when using other v4 profiles
ICC Digital Print Day

Graphic arts workflow requirements for digital presses

W Craig Revie, Fujifilm Limited
Current workflow for conventional and digital print

**Document designer**
A person or program that creates a document intended for print

**Proof printer**
Used to create an accurate simulation of the result of printing under the intended printing conditions

**Standard printing conditions**
Printing conditions defined by a standard such as ISO 12647

**Intended printing condition**
The printing press, substrate and inks on which the document was designed to be printed (may be actual or averaged)

**Actual printing condition**
The printing press, substrate and inks on which the document is actually printed

**Creation**

**Proofing**

**Printing**

**Retargeting**
Standard printing conditions based on offset printing

- Calibration processes based on ISO standards are becoming widely adopted
  — becoming a requirement for print buyers
  — ability to ‘print to the standard’ used to advertise print shops
- Many digital presses can match offset printing standards
  — result not optimal for digital presses – only part of the colour gamut used
  — digital press manufacturers would like an option to use extended colour gamut
Possible future workflow for conventional and digital print

Document designer
A person or program that creates a document intended for print

Proof printer
Used to create an accurate simulation of the result of printing under the intended printing conditions

Intended printing condition
The printing press, substrate and inks on which the document was designed to be printed

Standard printing condition
New standard optimal for both digital and conventional print

Actual printing condition
The printing press, substrate and inks on which the document is actually printed

Creation

Proofing

Retargeting

ICC DIGITAL PRINT DAY
Standard printing conditions for digital press

- Digital presses have a wide range of inks and substrates
  — significantly differently colour gamuts
- **Standard reference conditions based on a single digital press**
  — has been discussed but probably not a viable alternative
- **Possible direction would be to define a series of synthetic gamuts**
  — to cover the range of digital printing
  — retarget documents at the time of proofing and printing

- Requires effective retargeting strategy…
PDF document elements

• PDF supports a rich set of document element types, most of which are in common use
  — CMYK, Grey and black elements
  — RGB images
  — Spot colours
  — Duotones, tritones…
  — Transparency
  — Varnish and special inks

• With care documents can be constructed that can be printed reliably using PDF/X (conventional workflow)

• In some cases proofing (monitor and hard copy) and retargeting requires additional data about the content or intended printing condition
CMYK, grey and black elements

Objective
Define elements in printing space for print production reasons

- Print
- Proof
- Retarget

Print and Proof
- Total area coverage limit must be communicated separately or guessed from ICC Profile

Retarget
- No way to indicate whether pure colour or accurate colour is the objective
- Not always obvious when black-only elements should be preserved
- Object-based retargeting of elements using overprinting may be compromised

Avoid fuzzy edges by using black only
Avoid 'scum dots' by using device yellow only
Overprinting effects (trapping, small text...)

Alto

ICC Digital Print Day
‘RGB’ Images and other content

Objective
Keep image as ‘RGB’ to avoid loss of colour gamut when retargeting

Print and Proof
• No way to indicate whether BlackPoint compensation should be applied

Retarget
• Retargeting may be compromised when ICC v4 profiles are not used
Spot colours

Objective
Use special ink for corporate brand or for special design effect

Print
• Designer must use ‘well known’ names for spot colours
• No easy way to communicate actual printing of tints of spot colours

Proof and Retarget
• Cannot communicate both L*a*b* and process-equivalent colour values
• Retargeting system may need to perform spot-to-process conversion
Duotones, tritones...

Objective
Small number of inks (often spot inks) used to print a grey image to achieve a special effect such as sepia-tone

Proof and Retarget
• No standard way to communicate the colour of ink combinations – it is usually impractical to create ICC Profiles for each combination
Transparency

Objective
Allow elements on the page to be blended together to achieve special design effect

Print and Proof
- Some RIPs (not PDF/X-4 compliant) do not handle transparency correctly

Retarget
- In some cases the result of transparency blending may be slightly different due to change in blending space
Varnish and special inks

**Objective**
Varnish increases apparent colour gamut so that varnished area has high visual impact

**Proof**
- Apparent colour of areas with and without varnish hard to predict on proof
- Some monitor proofing application can simulate effect of special inks but no standard means exists to communicate the additional metadata

**Retarget**
- Redesign is usually necessary

Colour matching of special inks on hard copy proof not usually practical
What is driving this?

- The Packaging industry (mostly) uses a variety of “special” inks
  - Varnish
  - Metallic
- These inks have properties which are not stored/transmitted in a PDF
- That means that these PDFs can not be properly “soft-proofed”
  - or even hard-proofed on simple devices
- It is also difficult/impossible to preflight documents for proper ink usage
Specific Technical Problems

• PDF has no provision for “ink laydown order”

• PDF has no provision for “ink opacity”
  • something that is quite different than PDF’s transparency model

• PDF has no provision for other “ink properties”
  • metallic
  • other??
Incorporating information about specialized ink properties, such as those that might be present in standards such as CxF can be easily accomplish.

Outstanding questions to be answered
- Is information per-colorant, per-page or per-colorant?
- Use a complete CxF or just partial one?
  - somewhat related to question 1 about what is being specified and where
- What/when is this information to be used?
  - is it more about “metadata” or does it have to be used during rendering?
  - final print, proofing, both?

Final solution should then be standardized either as part of some future PDF/X or as part of 32000-2.
• Use DeviceN & NChannel color model
  • PDF (>=1.3) provides for a source color specification called DeviceN
  • PDF (>=1.6) extended DeviceN with NChannel for extended properties
    • per-colorant properties such as tint transform and alternate values
    • mixing hints

• Advantages
  • Already part of the PDF & PDF/X standards
  • Supports up to 32 colors

• Problems/Issues
  • All color specifications would need to be in DeviceN - no RGB, CMYK or ICCBased
  • Can not be used as an OutputIntent only as a source color
  • Does not currently stipulate Ink Laydown order (but could be easily changed)
  • Does not provide for an Opacity specification (but could be easily added)
  • No standard methods for conversion to RGB/CMYK for both soft & hard proofing
• Support for N-Color ICC profiles
  • PDF provides for ICC profiles as both source profiles and destination profiles (OutputIntent), but restricts both to 1, 3 or 4 colorants
  • PDF/X-5n allows for an n-color profile as OutputIntent, but only via external reference

• Advantages
  • Industry standard
  • Stipulates Ink Laydown order
  • Provides for Opacity specification
  • Standard methods for conversion to RGB/CYM for both soft & hard proofing
  • Can be used in conjunction with standard RGB, CMYK and ICCBased assets

• Problems/Issues
  • ICC profiles limited to 15 colors
  • Incompatible with existing PDF standards (ISO 32000-1, PDF/X, etc.) - would need to be first incorporated into ISO 32000-2 and then other standards updated to match.
Where to go from here?

- PDF/X committee (ISO TC 130/SC2) is reconvening in at the May meeting of TC 130
  - Updates to PDF/X to align with ISO 32000-1
  - Needs of the packaging community (aka this problem)
    - looking at both of the options previously listed and considering our options

- ICC (you folks!) needs to consider the 15 colorant limitation

- Someone needs to evaluate the CxF issues
That's All Folks
Matching GRACoL / TR 006 and FOGRA39 in Digital Printing

Jan-Peter Homann
ICC Digital Print Day 2009
About the presenter

• Color Management Consultant specialized on the standardized print production
• Member of FOGRA, IDEAlliance and ICC GASIG
• Author of the Book
Relevant ISO-Standards, specifications and certifications

- ISO 12647-2 (Offset printing)
- ISO 12647-7 (proofing and validation printing)
- ISO TS 10128 calibration workflows incl. near neutrals calibration
- ISO 15930 PDF/X
- ICC registry characterization-data / reference printing conditions
- GWG recommendation of standard profiles
- FOGRAcert and Process Standard Offset
- IDEAlliance certifications
ISO 12647-2

- Basis for the standardized offset print production
- FOGRA39 and GRACoLcoated / TR006 are reference printing conditions compliant to ISO 12647-2 coated paper
- Users expect colors in digital printing matching offset printing
- Standard color settings for in applications for print-data creation are reflecting offset printing on coated paper
ISO 12647-7  proofing / validation printing

- ISO standard for hardcopy proofing during the standardized print production
- Control of matching reference printing conditions like FOGRA39 or GRACoLcoated / TR006
- ISO 12647-7 / validation printing addresses output on toner based digital printing systems.
- FOGRA and IDEAllinace are working on certifications for digital printing systems using parts from ISO 12647-7
- Several solutions for controlling color in proofing according ISO 12647-7 could be used also for controlling color in digital printing
ISO TS 10128 calibration workflows incl. near neutral calibration

- This ISO technical specification describes different workflow for calibration of printing systems based on TVI, near neutrals calibration or DeviceLink-profiles.
- Near neutrals calibration combined with colorimetric control of solids secondaries is a good strategy for bringing digital printing systems in an optimal state for matching e.g. FOGRA39 or GRACoLcoated / TR 006
- Kodak and Heidelberg and others already offering solutions for near neutrals calibration.
ISO 15930 PDF/X

ISO 15930 PDF/X is the standard for data delivery in the standardized print production. For communication about color between the creator of the print-data and the print provider, PDF/X recommends to agree on reference printing conditions like e.g. FOGRA39 or GRACoL coated / TR 006 hosted at the ICC. The Ghent Workgroup [www.gwg.org](http://www.gwg.org) backed by all relevant vendors works on workflow specifications for PDF/X in practice including recommendations for ICC profiles.
ICC characterization-data registry
GWG list of profiles

**Mission**

The color management subcommittee investigates color management issues and best practices for PDF/X-3 and PDF/X-4 workflows and defines how to implement and promote them in the GWG specifications for PDF file creation and preflighting.

**Current Activities**

- Color management in PDF/X-4: The committee is reviewing best practices and white paper creation on how to create such PDF files, what requires an Output Workflow has to fulfill, when to perform the final color conversion and which color spaces to use.
- Transparency flattening of device dependent and device independent PDF: Since transparency flattening can not be done without active color management, we are looking into current issues to evaluate the use of specs that allow for transparency on one hand but default color managed color spaces on the other hand.
- Output test suites: The subcommittee is working together with the Process Control subcommittee to create patches for the following issues: color managed objects and white overprint issues related to various color spaces.

**List of recommended ICC Profiles**

We recommend that PDF producers creating PDFs for print contact their printer or regional association in order to communicate about the best suitable profile to use for color conversion and proofing for a specific print run on a specific paper type. This GWG recommendation concerning standard profiles for printing can be used as a personal guideline in case there is no contact between the PDF creator and the printer.

Download the table as PDF

Download the table as XLS spreadsheet

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Jan-Peter Homann ICC Digital Print Day 2009
FOGRAcert machines

Whether new or used - the purchase of a press, a computer-to-plate system or a proofing system always represents a considerable investment. On the basis of a widely recognized examination, Fogra can determine if the system fulfills the required parameters, providing the buyer or the seller with the necessary degree of security.

- You can send or recommend this article
- Print version of this article
FOGRAcert processes

The capabilities of the entire printing process (by achieving the target of Process Standard Offset Printing) or of individual stages (for example, the correct preparation of print data) can be proved with a Fogra certificate.

- You can send or recommend this article
- Print version of this article
IDEAlliance Certifications

IDEAlliance.org/industry_resources/branding

About PPC

PrintProperties

A Working Group of IDEAlliance

The Print Properties and Colorimetrics Working Group conducts industry research and develops technical solutions for IDEAlliance Working Groups that focus on the graphic arts and for ANRS/ICC/ICAM. Work advanced by this group in 2007-2008 includes:

- Development of the GRACOL #1 Characterization Data Set
- Development of the SWOP P3 Characterization Data Set
- Development of the SWOP P6 Characterization Data Set
- Development of the IDEAlliance ISO 12647.7 2007 Color Control Strip
- Development of procedures for the IDEAlliance Hand Copy Proofing Certification Program
- Development of procedures for the IDEAlliance Monitor Proofing Certification Program

Projects currently underway include:
- Development of procedures for the IDEAlliance Digital Press Color Certification Program
Concept of Color Management by Calibration

Method could also be used for FOGRA39 target with ISO TS 10128
Adding ICC-(DeviceLink) profiles to the printing chain

- Check, if color management is applied Pre-RIP or post RIP
- If color management is applied Pre-Rip on an object by object basis, mind the PDF overprinting troubles
- Use in this case (dynamic) devicelinks which deliver:
  - preserve separations
  - preserve purities of solid-scales, secondaries scales and achromatics
Validate the result according ISO 12647-7

- Use a software for validating color output according ISO 12647-7
- The validation should be done on basis of an ECI 2002 or IT8/7.4 Testchart
- Several proofing vendors offering such solutions
- Certifications of FOGRA and IDEAAlliance will probably make similar evaluations both for systems and print providers
Dealing with papers containing a lot OBA

- The majority of papers for digital printing containing a lot of OBA
- FOGRA39 and GRACoLcoated / TR 006 represent papers with low to medium usage of OBA
- Current certifications for ISO 12647-7 validation printing ignore the problem of papers with a lot of OBA
- If a certification is needed, use a paper with low to medium OBA and a paperwhite matching FOGRA39 or GRACoLcoated / TR 006
- Take care, that visual appearance on papers with a lot OBA matches a reference proof or print on papers with low to medium OBA
Thank You

www.colormanagement.de
Ecma International Open XML Paper Specification
Named Colour, N-Channel Colour Syntax in OpenXPS

Ann McCarthy

ICC Digital Print Day, 4 March 2009
Based on the Microsoft XML Paper Specification

230 technical improvements negotiated among print vendors, RIP vendors, and software vendors from Japan, USA and Europe

Interim drafts have been posted on the Ecma site for public comment throughout the development process

Publication is planned this year

In the area of colour – OpenXPS represents a strong advance to enable ICC colour management
• Each colour object (text, graphics, raster images) can have an associated ICC profile

• Each raster image can also have an embedded ICC profile

• Any non-sRGB or non-scRGB colour object MUST have either an embedded (raster) or associated ICC profile

• Includes a provision to recognize device-ready encoding and avoid unnecessary re-rendering, in conjunction with a print ticket / job ticket mechanism

• For rendering consistency, specifies a required fallback interpretation for each colour encoding, applied if the ICC profile is not usable
OpenXPS Standardization

Colour Rules

- OpenXPS Documents support sRGB and other source colour spaces, including scRGB, CMYK, N-Channel, and Named colours (see Clause 15 for details)

- Consumers (software components consuming OpenXPS) MUST support the following source colour features:
  - Greyscale colours (single channel) in vector data, with/without alpha
  - Greyscale colours in image data, using the JPEG, PNG, TIFF, or JPEG XR image formats, 1-bit, 8-bit, 16-bit, Fixed, Half, Float, with/without alpha
  - sRGB colours in vector data, with/without alpha
  - sRGB colours in image data, using the JPEG, PNG, TIFF, or JPEG XR image formats, 8-bit or 16-bit, with/without alpha
• Consumers MUST support the following source colour features (continued):
  • scRGB colours in vector data, with/without alpha
  • scRGB colours in image data, using the JPEG XR image format, Fixed, Half, Float, with/without alpha
  • CMYK colours in vector data, with/without alpha
  • CMYK colours in image data, using the TIFF or JPEG XR image formats, 8-bit or 16-bit, with/without alpha
  • N-Channel and Named colours in vector data, with/without alpha
  • N-Channel and Named colours in image data, using the JPEG XR image format, 8-bit or 16-bit, with/without alpha

• Producers and consumers MAY support the following source colour features:
  • N-Channel colours in image data, using the TIFF image format
The following ICC profile classes can be used in OpenXPS Documents:

- Input
- Output
- Monitor (RGB)
- ColorSpace Conversion
- Named Color

The set of usable N-component LUT-based profiles is limited to 2-, 3-, 4-, 5-, 6-, 7-, or 8-colour channels

The set of usable Named colour profiles is limited to 1-, 2-, 3-, 4-, 5-, 6-, 7-, or 8-colours

**XPS ICC source profile colour spaces**

- grayData ‘GRAY’
- rgbData ‘RGB’
- cmykData ‘CMYK’
- 2colourData ‘2CLR’
- 3colourData ‘3CLR’
- 4colourData ‘4CLR’
- 5colourData ‘5CLR’
- 6colourData ‘6CLR’
- 7colourData ‘7CLR’
- 8colourData ‘8CLR’
OpenXPS Standardization
N-Channel and Named Colour
### N-Channel and Named colour vector syntax

<table>
<thead>
<tr>
<th>N-Channel colour with alpha*</th>
<th>Color=&quot;ContextColor ProfileURI AlphaFloat, Chan0Float, ..., ChanN-1Float&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.g., ‘5CLR’</td>
<td>Color=&quot;ContextColor 5nchannelprofile.icc 1.0, 1.0, 0.0, 0.0, 1.0, 0.0&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Named colour with alpha*</th>
<th>Color=&quot;ContextColor ProfileURI AlphaFloat, TintFloat&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.g., ‘GRAY’</td>
<td>Color=&quot;ContextColor /namedtintprofile.icc 1.0, 1.0&quot;</td>
</tr>
</tbody>
</table>

*AlphaFloat = 1.0 is opaque
N-Channel and Named colour raster syntax

Images can depend on colour profiles using either of two methods:

- Associated: Colour profile contained in a separate part associated with the image (first precedence)
- Embedded: Colour profile embedded in an image using the image format specific mechanism

When associating a profile with an image the syntax is:

```xml
<ImageBrush ImageSource="{ColorConvertedBitmap ../Resources/Images/image.tif ../Metadata/profile.icc}" ... /></ImageBrush>
```

- ../Resources/Images/image.tif is the ImageSourceURI
- ../Metadata/profile.icc is the ProfileURI
• **ICC Profile use with source N-Channel colour data**
  - For 1-channel colour use a monochrome profile
    - Profile header colour space signature is ‘GRAY’
    - The profile includes an AToB1Tag (relative colorimetric) if the single colour is chromatic
    - If the AToB1Tag is present the grayTRCTag is not used
  - **Alpha values and N-Channel float values smaller than 0.0 and larger than 1.0 are clamped to the valid range from 0.0 to 1.0 before any further processing**
  - Before an N-Channel value is used as input for an ICC profile colour transformation, it is linearly scaled (with specified rounding/clipping) to the 8-bit or 16-bit input range of the ICC profile
ICC Profile use with source Named colour data

- A named colour is expressed as a combination of
  - An ink name and transform information in an ICC profile
  - A tint level (percentage ink dilution) given in the XPS vector colour syntax or in a JPEG XR raster image file

- Two ICC profile methods are available for named colours
  - For a single named colour – use an ICC monochrome profile that includes a tint LUT for the named colour
  - For one...eight named colours – use an ICC Named Color profile containing the 100% PCS values for each named colour — via the ICC namedcolor2Tag
    - If device colour values are included, these correspond to the ICC profile colour space of data
    - E.g., the working space RGB values used in the design
More on using an ICC monochrome profile with a tint LUT to define a single named colour

- Use profile header colour space signature = 'GRAY'
- Include an AtoB1Tag (relative colorimetric rendering intent) mapping named colour tint levels to PCS values
- Encode the ASCII prefix-root-suffix name of the named colour into the profileDescriptionTag of the ICC profile
- Use the tint LUT to map the PCS colour value for the specified tint level to the corresponding output device colour value

Alternatively – recognize the encoded name and use an output device-specific tint LUT

- Lookup an output device-specific colour value for the named colour tint
• Benefit of the tint LUT in the ICC monochrome profile for a single named colour – when the output device does not recognize the named colour

A cyan colour that traces the max chroma boundary of the sRGB gamut at 202 degrees

<table>
<thead>
<tr>
<th>r</th>
<th>g</th>
<th>b</th>
<th>L</th>
<th>a</th>
<th>b</th>
<th>hue</th>
<th>chroma</th>
<th>ratio a:b</th>
</tr>
</thead>
<tbody>
<tr>
<td>192</td>
<td>253</td>
<td>255</td>
<td>95.00</td>
<td>-19.00</td>
<td>-8.00</td>
<td>202.8</td>
<td>21</td>
<td>2.38</td>
</tr>
<tr>
<td>0</td>
<td>238</td>
<td>248</td>
<td>85.00</td>
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<td>50</td>
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<tr>
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<td>221</td>
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<td>80.00</td>
<td>-43.00</td>
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<td>0</td>
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<td>196</td>
<td>69.00</td>
<td>-38.00</td>
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<td>41</td>
<td>2.38</td>
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<td>0</td>
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<td>181</td>
<td>64.00</td>
<td>-36.00</td>
<td>-15.00</td>
<td>202.6</td>
<td>39</td>
<td>2.40</td>
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<tr>
<td>0</td>
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<td>146</td>
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<td>-31.00</td>
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<td>34</td>
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<td>131</td>
<td>47.00</td>
<td>-29.00</td>
<td>-12.00</td>
<td>202.5</td>
<td>31</td>
<td>2.42</td>
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<td>26</td>
<td>2.40</td>
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<tr>
<td>0</td>
<td>32</td>
<td>34</td>
<td>10.00</td>
<td>-12.00</td>
<td>-5.00</td>
<td>202.6</td>
<td>13</td>
<td>2.40</td>
</tr>
</tbody>
</table>
Thank You

Questions?
Color Management on Digital Presses using DeviceLink Technology

Heijo Reinl
Color Proofing and Color management
CGS Publishing Technologies International
Future is Digital
Offset vs. Digital Printing

- **DRUPA 2008:**
  digital printing has arrived where offset was in 1968.
- Digital printers of all price segments are now capable of producing quality comparable to offset.
- Any digital device can be controlled much easier and more accurate. Offset has 200 individual parameters.
- Digital printing gains market share, offset and screen printing lose volume.
- **2000:** 80% offset printing – **2020:** 30% replaced by digital printing.
The Daily Color Dilemma
The Daily Color Dilemma
Results in Reality

- Common ICC-based solutions produce color matches that are only about 80 – 85 % accurate
  - Perfect results require time and expert knowledge
- Different results from device to device (analog or digital)
- One print run is different from the other
- Differences from day to day
- Prints do not match a standard
Workflow using print standards:
Color manage ONCE, render to MANY

Color Manage ONCE to a Print Standard, Render to many Press Devices
Digital Presses Matched to FOGRA ISOcoated V2 / ISO 12647

- Canon Image Press C1
- HP Indigo 3050
- HP Indigo press 5000 / 5500
- Konica Minolta C451
- Konica Minolta C6500
- Xerox iGen 3 / 4™
- Xerox DocuColor™ 242 / 252 / 260
- Xerox 700 Digital Color Press
- Xerox DocuColor™ 5000 / 5065
- Xerox DocuColor™ 7000 / 8000 Digital Press

And so on ...
Match Results

- The result are prints within Fogra ISOcoated v2
  - $\Delta E < 1...2$ average
  - $\Delta E < 5...8$ max
**Aim: ISO 12647-7**

- ISO 12647-7: worldwide accepted tolerances for proofing processes working directly from digital data

<table>
<thead>
<tr>
<th>Tolerance</th>
<th>$\Delta E_{ab}^*$ paper white</th>
<th>Average $\Delta E_{ab}^*$ of all color patches</th>
<th>Max. $\Delta E_{ab}^*$ of all color patches</th>
<th>Max. $\Delta E_{ab}^*$ of primary colors</th>
<th>Max. $\Delta H$ of primary colors</th>
<th>Average $\Delta H$ gray patches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>5</td>
<td>2.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Usage of device link technology
ORIS PRESS MATCHER

color management for analog and digital presses
Why using device link technology

What is the difference between:

- Color match using ICC profiles
- Color match using device link

Additional advantages

Any drawbacks?
ICC based color management

- **RGB** input profile
- **CMYK** input profile
- **CMYK** press profile

Profile connection space = LAB

Black separation is lost and generated, according to the output profile.
Device link based color management

RGB input profile

CMYK input profile

Profile connection space

4 dimensions

CMYK press profile

black separation is unchanged, a gradation change according to the output profile may be applied, if necessary
Advantages of device link technology

- Easy to create
- Easy to optimise / tweak
- ICC DeviceLink file format accepted by many RIPS
Drawbacks

- Fix color match between target color gamut and press device

  If you use more than a few target color gamuts you need lots of device links. May be a logistic challenge.
Creation of device links

Easy to create:

- Use of ICC profile for color matching
- Color matching with iterations
Device link creation using ICC profiles

Settings for the black separation
Device link creation using ICC profiles

Settings for the black separation
A device link profile is easy to edit
Result with ICC method

Gamut / match before

Gamut / match after
Color matching with iteration

Approach to achieve Delta E = 0
Color matching with iteration
A device link profile is easy to edit.
Result with iteration methode

Gamut / match before

Gamut / match after
Color Management on Digital Presses using DeviceLink Technology

Thank you for your Attention!
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Specially-formulated Media

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Publishing
Advertising

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Color management with ORIS
CIE Illuminant D50 Simulators: Ganz & Griesser Coefficients for UV Calibration

Veronika Lovell and Danny Rich

Sun Chemical Corporation
Color Research Lab

March 4, 2009
Abstract

- 1970s - CIE published its recommendations for the assessment of whiteness as viewed under CIE standard illuminant D65.
- Gärtner & Griesser devised a method to adjust the UV portion of an instrument source.
- Ganz and Griesser then introduced methods for whiteness and tint assessments under CIE D65/10° simulations to evaluate larger sample areas.
- The system of whiteness assessment has advantage that the instrumentally determined values coincide with the visual ratings on the white scales.
- These methods have been adapted and adopted by many industries that use FWA additives, such as textiles, plastics and paper.
- In contrast, graphic reproduction uses CIE illuminant D50 rather than D65 and 2° observer rather than 10°.
- In this paper we propose a method to derive a set of Ganz-Griesser coefficients for CIE illuminant D50 and 2° observer and a new D50 simulator design.
ISO 13655 Revision & ICC Recommendations
(spectral measurement and colorimetric computation)

**ISO 13655 Revision**
- Measurement backing - reflectance of white and black backings defined
- Handling fluorescence - can use either M1 or M2 measurement condition
- Instrument sources - 4 instrument sources are defined:
  - M0: spectral power distribution of Illuminant A (i.e. unfiltered tungsten)
  - M1: spectral power of CIE D50 (300-780nm)
  - M2: any spectral power but with UV excluded
  - M3: any spectral power, with UV EX and polarization to suppress gloss

**ICC recommendations**
  - 45:0 (reflectance) or 0:d (transmittance)
  - 10nm or 20nm interval
  - D50 illuminant for calculating XYZ
Whiteness

- Color, including the color “White”, is a perception and such is not measurable.
- However, color systems have been developed and successfully used over decades
  - 3 parameters systems
  - provide quantification, allow comparisons
- White characteristics = high lightness + low color saturation
- Each whiteness formula has a specific “whiteness bias”, i.e. whiteness preferences of different human observers.
  - difficult to assess due to personal taste
  - many formulae were developed based on experiments
- Different media have different amounts of FWA and matching the white point is difficult or impossible (measurement and appearance).
CIE and Ganz Whiteness Formulae

**CIE Whiteness Formula**

Whiteness (CIE) = Y + 800(x₀-x) + 1700(y₀- y)

**Ganz Whiteness Formula**

Whiteness (Ganz) = (DY) + (Px) + (Qy) + C

The formula parameters D, P, Q, C can be calculated as follows:

- \( D = \delta W/\delta Y \)
- \( P = (-\delta W/\delta S) \{\cos (\phi+\eta)/\cos (\phi)\} \)
- \( Q = (-\delta W/\delta S) \{\sin (\phi+\eta)/\cos (\phi)\} \)
- \( C = \{W_0(1-\delta W/\delta Y)\} - (P_{x_n}) - (Q_{y_n}) \)

where:

- \( \delta W/\delta Y = 1 \) (contribution of lightness to whiteness)
- \( \delta W/\delta S = 4000 \) (contribution of saturation to whiteness)
- \( \delta W/\delta H = (-\delta W/\delta S) \tan (\phi) \) (contribution of hue to whiteness; \( \phi = 15^\circ \))

- \( \phi = 15^\circ \) (equi-chroma lines in Munsell system are parallel to the 15° curve, also white bias of most observers)
Ganz-Griesser Method of Assessing Whiteness

Figure 1. Chromaticity Chart for D50/2° with RWL = 470 nm.

\[ W_0 = 100 \] (degree of whiteness of physical ideal white)

\[ \lambda_d = 470 \text{ nm} \] (dominant wavelength; RWL)

\[ x_d \text{ and } y_d \] (point of intersection of the RWL with the spectrum locus of CIE 1931 observer)

\[ \eta = \text{atan} \left\{ \frac{y_n - y_d}{x_n - x_d} \right\} \] (angle between RWL and x-axis of chromatic chart)
Whiteness (Ganz-Griesser) Calculation for D50/2°

Whiteness Calculations for D50/2°

\[
P = (-\delta W/\delta S) \{\cos (\varphi + \eta)/\cos (\varphi)\}
\]
\[
Q = (-\delta W/\delta S) \{\sin (\varphi + \eta)/\cos (\varphi)\}
\]
\[
C = \{W_0(1-\delta W/\delta Y)\} - (Px_n) - (Qy_n)
\]

Whiteness (Ganz) = \[ Y - 1511x - 3855y + 1904 \]

\[
x_d = 0.1241 \quad x_n = 0.3457
\]
\[
y_d = 0.0578 \quad y_n = 0.3585
\]
\[
\eta = \tan {\left( (y_n - y_d)/(x_n - x_d) \right)} = 53.6°
\]

D = \[ \delta W/\delta Y = 1 \]

\[
P = (-4000) \{\cos (15+53.6)/\cos (15)\} = -1511
\]
\[
Q = (-4000) \{\sin (15+53.6)/\cos (15)\} = -3855
\]

C = \[ W_0(1-1) - (-1511 \times 0.3457) - (-3855 \times 0.3585) = 1904 \]
Whiteness (Ganz-Griesser) Calculation for D50/2°

Adaptation of New Parameters

Reference white scale:
9 paper samples + 3 metameric sets for D50 from CIE 51.2-1999 publ.

Daylight with UV

UV only

CIE Whiteness units ~ 100 -160
Ganz Whiteness units ~ 125 - 250
**Whiteness (Ganz-Griesser) Calculation for D50/2°**

**Adaptation of New Parameters**

The formula parameters must be adapted to the given conditions of a measuring instrument, especially the illuminant.

The assessing method requires the absolute tristimulus values for D50/2° of a reference white scale as a basis for the assessment.

Calculations for each \(i\) step of the scale:

\[
S_i^* = x_i V + y_i \\
W_i^* = W_i - DY_i
\]

where:

\(W_i\) is nominal whiteness values of the white scale

\[V = 1 / \{(\tan(\varphi + \eta))\}, \text{ and} \]

\[D = \delta W/\delta Y = 1\]
Whiteness (Ganz-Griesser) Calculation for D50/2°

The tabulated values $S_i^*$ and $W_i^*$ are graphed and the regression line is plotted.

<table>
<thead>
<tr>
<th>Name</th>
<th>$W_i$ GANZ</th>
<th>$S_i^*$</th>
<th>$W_i^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>124.34</td>
<td>0.4838</td>
<td>38.95</td>
</tr>
<tr>
<td>W2</td>
<td>139.39</td>
<td>0.4796</td>
<td>55.13</td>
</tr>
<tr>
<td>W3</td>
<td>153.61</td>
<td>0.4761</td>
<td>68.56</td>
</tr>
<tr>
<td>W4</td>
<td>168.56</td>
<td>0.4730</td>
<td>80.75</td>
</tr>
<tr>
<td>W5</td>
<td>190.26</td>
<td>0.4679</td>
<td>100.44</td>
</tr>
<tr>
<td>W6</td>
<td>198.38</td>
<td>0.4647</td>
<td>112.71</td>
</tr>
<tr>
<td>W7</td>
<td>219.72</td>
<td>0.4590</td>
<td>134.71</td>
</tr>
<tr>
<td>W8</td>
<td>221.95</td>
<td>0.4588</td>
<td>135.51</td>
</tr>
<tr>
<td>W9</td>
<td>245.81</td>
<td>0.4517</td>
<td>162.81</td>
</tr>
<tr>
<td>Set#1</td>
<td>58.25</td>
<td>0.5004</td>
<td>-25.05</td>
</tr>
<tr>
<td>Set#2</td>
<td>64.72</td>
<td>0.4988</td>
<td>-18.68</td>
</tr>
<tr>
<td>Set#3</td>
<td>62.10</td>
<td>0.4995</td>
<td>-21.47</td>
</tr>
</tbody>
</table>

$W_i$ GANZ – nominal values  
$W_i^*$ - graphical adaptation method

Whiteness (Ganz) = $Y - 1511x - 3855y + 1904$

GretagMacbeth Color i7
Whiteness (Ganz-Griesser) Calculation for D50/2°

UV Excitation level - \( \delta W/\delta S \)

A measure for the intensity of the UV excitation in the light emitted by the measuring instrument source is the value \( \delta W/\delta S \approx 4000-4200 \) with the white scale.

The higher the value, the weaker the UV excitation.

\( \delta W/\delta S \) is calculated from the whiteness formula parameter \( P \):

\[
P = (-\delta W/\delta S) \{\cos (\phi + \eta)/\cos (\phi)\}
\]

where:

\[
\{\cos (\phi + \eta)/\cos (\phi)\} = -2.647
\]

\( \phi = 15° \) and \( \eta = 53.6° \)

\[
\delta W/\delta S = P \cdot (-2.647) = (-1513.5) \cdot (-2.647) \approx 4000
\]
D50 Simulator - Validation of Whiteness Coefficients

D50 Simulator

- A new simulator is being constructed
- It consists of
  - 150 watt xenon lamp based solar simulator
  - 80:20 beam splitter
  - UV spectral shaping filter (details to be released after validation)
  - VIS spectral shaping filter (details to be released after validation)
  - Custom integrating sphere to combine UV & VIS radiance

- The designed optical system for a D50 daylight simulator aims to minimize the VIS range metamerism index, $M_{vis}$, and the UV range metamerism index, $M_{uv}$, specified by ISO 23603:2005.

- The aim also is that a simulator obtains high color rendering index (CRI) specified by CIE 13.3.
D50 Simulator - Design

Specifications of the proposed D50 simulator

<table>
<thead>
<tr>
<th></th>
<th>CIE D50 illuminant</th>
<th>Proposed D50 simulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP</td>
<td>$u'_{10}$</td>
<td>$v'_{10}$</td>
</tr>
<tr>
<td></td>
<td>0.2102</td>
<td>0.4889</td>
</tr>
<tr>
<td>CCT</td>
<td>5000 K</td>
<td>5014 K</td>
</tr>
<tr>
<td>$M_{vis}$</td>
<td>0</td>
<td>0.23 (A)</td>
</tr>
<tr>
<td>$M_{uv}$</td>
<td>0</td>
<td>0.12 (A)</td>
</tr>
<tr>
<td>CRI</td>
<td>100</td>
<td>97-98</td>
</tr>
</tbody>
</table>
D50 Simulator - Sources

Unfiltered Xenon Source

Filtered Xenon Source
Conclusions

- Ganz-Griesser coefficient were derived for Whiteness formula under CIE illuminant D50 and CIE 1931 observer.
- The derived instrument-specific formula parameters can improve the correlation between measured and visual assessments.
- Present work is focused on building the close-to-real D50 simulator with minimized UV and VIS metamerism indexes and higher color rendering index for more advanced assessment tests.
- Preliminary visual tests show good correlation results.
- The work continues with different types of substrates, plastics and textiles.
- Examination of the 45:0 geometry, which could provide a method for making whiteness measurements using the same geometry as used for brightness in the pulp and paper industry.
References

- Gärtner F and Griesser R. A Device for Measuring Fluorescent White Samples with Constant UV Excitation. Die Farbe 1975;24:199-207
- Griesser R. The Absolute Ganz/Griesser Whiteness Assessment Method. CIBA-GEIGY Instruction Leaflet FC5.51, 1988
THANK YOU!

QUESTIONS

veronika.lovell@sunchemical.com

danny.rich@sunchemical.com
The optical interaction between ink and paper
Nils Pauler
Print quality of home & office ink jet
Scanner measurements

- Line: sharpness, raggedness, bleeding
- Print density
- Unevenness
- Colour gamut
- A range of phenomenon
  - What is caused by paper?

Spectrophotometer
The optical interaction between ink and paper

Measurements and simulations (Kubelka-Munk & Murray-David)

- Optical properties of the paper
- Light scattering of the ink layer
- Ink penetration
- Non ideal light absorption of the inks
- Dot size
- Fluorescence
- Examples of different colour gamut
The light scattering (s) and light absorption (k) of paper and ink

Print density = $\log_{10}(R_{\text{paper}}/R_{\text{print}})$

**Paper:**
Low k and high s to achieve high reflectance

**Ink:**
High k and low s to achieve low reflectance
Plain paper, Coated paper and Photo paper
with fluorescence radiation of FWA

![Graph showing fluorescence intensity vs. wavelength for plain, coated, and photo paper.

- **Roo (%)**
- **Wavelength, nm**

Legend:
- Plain
- Coated
- Photo

Nils Pauler M-real/DPC
The light scattering of the ink layer from pores, pigment or surface roughness

Calculations using Kubelka Munk theory

<table>
<thead>
<tr>
<th>Ink weight g/m²</th>
<th>Print Density</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
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<td></td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D</th>
<th>s=5</th>
<th>s=10</th>
<th>s=20</th>
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</thead>
<tbody>
<tr>
<td>Paper</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Nils Pauler M-real/DPC
Simulation the effect of ink penetration
linear and with a barrier

Linear penetration with lower rate
Increased plateau value of density

Barrier
Increased density

Calculations using Kubelka Munk equations

Nils Pauler M-real/DPC
Print density vs. ink weight
the influence of ink penetration and light scattering
Measurements with a spectrophotometer

![Graph showing the relationship between print density and ink weight for transparency and plain paper. The graph indicates that s(transparency) = 5-10 and s(paper) = 50-80.](image-url)
Test printing; Print density vs. ink weight

The influence of ink penetration (hydrophobic sizing) and light scattering (filler)

Print Density

Water based ink jet

Ink g/m²

Print Density

sized, no filler
not sized, no filler
sized, filler
not sized, filler

Densitex

0,5

0,7

0,9

1,1

1,3

1,5

0 2 4 6

Nils Pauler M-real/DPC
Ink jet print with ink amount 1 g/m² and 5 g/m²

1 g/m²

5 g/m²

The ink adsorbs to the fibres
Penetration of ink into plain paper
determination with Kubelka Munk theory

Spectrophotometer

\[
\ln \left( \frac{F(R_0, R_\infty) \times F(R_p, R_\infty)}{F(R_q, R_\infty)} \right) = \ln(F(R_0, R_\infty))
\]

\[
Pen\% = 100 \times \ln(F(R_0, R_\infty))
\]
Ink jet print with sex different ink amount

Plain paper

Printed side

Back side
Penetration of ink into plain paper

Determination based on reflectance measurements

Ink penetration

Ink g/m²

%
Plain paper and Photo gloss paper
The influence of ink penetration and light scattering

Plain paper:
Low Colour Gamut

Photo Gloss paper:
High Colour Gamut

Ink jet prints

Nils Pauler M-real/DPC
Test chart for measurement of Colour Gamut

RGB coordinates

Magenta    Cyan         Yellow

Upper

Lower

Nils Pauler M-real/DPC
Colour gamut of Photo gloss paper compared to plain paper

Silica gel

Measurement with spectrophotometer

Nils Pauler M-real/DPC
Calculation of the colour gamut

$k$ of process inks

$s$ and $k$ of paper
Calculated colour gamut

High ink penetration

Low ink penetration

Low light scattering
Process inks
increasing ink weights (Ink jet)

Transmittance   Absorption

Nils Pauler M-real/DPC
Increasing ink weight
Calculation using Kubelka-Munk theory
Colour area
Measurements with spectrophotometer

What is the best ink level for ink jet?

![Graph showing colour area measurements with spectrophotometer. The graph compares different ink levels for sized, not sized, and with and without filler. The x-axis represents InkLevel and the y-axis represents Colour area. The graph shows distinct lines for each category, indicating varying performance at different ink levels.](image)
Comparison ideal inks and process inks
Calculations using Kubelka Munk theory
the upper part of colour gamut

Ideal inks

Process inks

Nils Pauler M-real/DPC
The difference between offset and Ink jet

Measurements with spectrophotometer

Offset is smaller with a concave shape
Light absorption of process inks are similar

Ink jet

Offset

Offset: Prüfbau on Mylar film 0-4 g/m²
Inkjet: Ink jet on transparency 0-5,5 g/m²
Colour half toning

**Ink jet photo gloss**
- Colour control:
  - Changing the dot size
  - Changing the dot frequency
  - Changing the ink amount

**Offset**
- Colour control:
  - Changing the dot size
  - (Changing the dot frequency)
Dot gain or tone value increase

Mechanical and optical dot gain

‘Corona’
Comparison of large and small dots
Test printing with inkjet with 5 ink levels

Large (condensed) dots

Small (disperse) dots
Comparison of large and small dots
at 5 ink levels
Test printing and measurements with spectrophotometer
Halftone and continuous tone

Compared at ink amount per unit area

<table>
<thead>
<tr>
<th>Tone value %</th>
<th>Ink weight g/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>25%</td>
<td>0.50</td>
</tr>
<tr>
<td>50%</td>
<td>1.00</td>
</tr>
<tr>
<td>75%</td>
<td>1.50</td>
</tr>
<tr>
<td>100%</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Half tone

Cont. tone

Nils Pauler M-real/DPC
Simulation

Half tone: Murray David 2, 3 and 4 g/m²
Continuous tone: Kubelka Munk 0-2, 0-3 and 0-4 gm²

Continuous tone is more effective than half tone
(Compared at ink amount per unit area)
**Simulation**

Half tone: Murray David 2, 3 and 4 g/m²  
Continuous tone: Kubelka Munk 0-2, 0-3 and 0-4 g/m²

*Half tone is more linear than continuous tone in a* vs. b* plots*
The tone values 0-100 %
measurements on prints with three ink levels
Simulation for increased ink level
for half tone and continuous tone

0.6 g/m²
0.9

1.2

Half tone has concave shape of gamut
continuous tone has convex shape
The difference between offset and Ink jet

Measurements with spectrophotometer

Offset is smaller with a concave shape
Two different printers
Plain paper

Printer1

Grid with ICC profile

Printer2

Grid with colour correction of the printer

The effect of Key black?
Measurements of Colour gamut
With spectrophotometer

Colour gamut

Un coated

Coated

Photo gloss

KDE

OfsUnc  XerUnc  I-JetUnc  OfsCoat  XerCoat  I-jetPh  I-jet2Ph

Nils Pauler M-real/DPC  36
Photo ink jet
with and without colour correction

Grid: No colour correction

Even ton steps

Grid: Colour corrected with ICC profile

Aggregation due to gamut mapping
Summary

• High reflectance of the paper and low light scattering of the ink layer is needed to get high gamut

• Ink penetration should be low (hydrophobic treatment, barrier, dye fixation)

• Non ideal properties of process inks explain the darkening and colour strength reduction for higher ink weight

• The small dot size of ink jet can explain the convex shape of colour gamut

• The fluorescence influence the shape of gamut and is a problem in colour management work

• The use of Key Black can explain the tornado shape of gamut

• Colour correction influence the evaluation of colours of the gamut
The RGB star

sRGB D50/2

Printer1 no colour correction

Printer1 with ICC profile

Photo quality

Nils Pauler M-real/DPC
Half tone and continuous tone
process inks and ideal inks
Spectral Reflectance Modeling: Methods and Applications

Michael J. Vrhel, Ph.D.
Artifex Software Inc.

Professor H. Joel Trussell
North Carolina State University
Recently released
with Cambridge University Press.
Background and Motivation

• Limited number of spectral reflectance databases available to researchers
  
  - http://www.cs.sfu.ca/~colour/data/

• Spectral reflectance data can be used in a number of areas including
  
  - Design of color and spectral measuring instruments.
  - Design of multiband imaging devices.
  - Assessment of whole system (scan-to-print) performance.

Databases used for guiding designs as well as assessing performance.
Example: Color measurement models

\[ m_i = H^T L r_i + n_i \]  
Example color measuring system model

\[ m_i^T = \begin{bmatrix} m_1, \ldots, m_K \end{bmatrix} \]  
Measurement vector for reflectance $i$

\[ H = \begin{bmatrix} h_1, \ldots, h_K \end{bmatrix} \]  
Transmittances of color filters

\[ L \]  
Illumination spectral distribution (diagonal matrix)

\[ r_i \]  
Spectral reflectance $i$

\[ n_i^T = \begin{bmatrix} n_1, \ldots, n_K \end{bmatrix} \]  
Noise vector
Example: Color measurement models cont.

\[ t_i = A^T L_v r_i \]  
CIEXYZ value for illuminant \( L_v \)

\[ e = E \left\{ M \left[ L(t) - L(F(m)) \right] \right\} \]  
Average perceptual error across reflectance

\( F \)  
Mapping from measurement to CIEXYZ

\( L \)  
Mapping to perceptual space

\( M \)  
Metric

Useful to have additional “spectra” to provide as input to assess performance.

This brings us to the problem of modeling the spectra in our existing data bases to generate spectra with similar properties.
• Previous work has focused heavily upon a principal components decomposition of the spectral data bases.

• Here we look beyond correlations and include additional information about the spectral data.

• We introduce three approaches to modeling spectra using copulas, artificial-neural networks and successive projections onto convex sets.
Spectral Reflectance Statistics

- Previous methods have focused upon the mean and covariance structure of the data.

- If data were multivariate Gaussian, this would be sufficient. However data is not Gaussian distributed and these two quantities do not completely characterize the data.

- Data is bounded between 0 and 1.

- Probability distribution of data varies across wavelengths.
Data collected of 170 natural objects from 390nm to 730nm at 2nm intervals.

Ten bin histogram at wavelength 460nm
Method 1: The Copula

• Goal is to create data with
  1) Correlations similar to real spectral data set.
  2) Marginal distributions of individual wavelengths same as real spectral data.

• Given a RV $x$ uniformly distributed between 0 and 1 we can easily create a RV $y$ with a desired probability distribution function $F$.

\[ y = F^{-1}(x) \]

• How do we force correlations between adjacent wavelengths, while maintaining marginal distributions?
Sklar’s Theorem: Any joint probability distribution can be written in the form

\[ F(x_1, \ldots, x_N) = C\left[F_1(x_1), \ldots, F_N(x_N)\right] \]

\( C \) is called a copula. It couples the marginals into the joint distribution.

Typically (for tractability) the multivariate Gaussian distribution is used.
Method 1: The Copula cont.

Step 1: Generate set of zero-mean unity variance correlated Gaussian random variables.

Step 2: Map random variables to reflectance using Gaussian CDF and appropriate inverse of wavelength CDF to obtain desired marginal distribution.

\[
[r]_i = F_i^{-1}\left\{\frac{1}{2}\text{erf}\left(\frac{[v]_i}{\sqrt{2}}\right)\right\}
\]

Note that we obtain the desired distribution for each wavelength and we have correlations between wavelengths.

While Pearson’s correlation is not maintained due to the nonlinear mapping, rank-type correlation measures (e.g. Kendell’s tau and Spearman’s ) are maintained due to the monotonic nature of the mapping.
Method 2: Artificial Neural Network

- ANNs provide a method to introduce correlations and bounding constraints.

- Input to ANN will be uncorrelated white noise, output will be simulated reflectance spectra.

- Use a 2-layer feed forward network with a sigmoidal nonlinearity:
  \[ \phi(x) = \frac{2}{1 + \exp(-2x)} - 1 \]

- Output function enforces [0 – 1] bound constraint:
  \[ \psi(x) = \frac{1}{1 + \exp(-x)} \]

- Spectra mostly contained in eight dimensional space, use eight hidden neurons.
Method 2: Artificial Neural Network

What distributions should be used for input vectors $\mathbf{e}$?

Use distributions of whitened spectral data.

$$
\mathbf{w} = \Lambda^{-1/2} \mathbf{D}^T [\mathbf{r} - \bar{\mathbf{r}}] \\
\mathbf{K}_r = \mathbf{D} \Lambda \mathbf{D}^T
$$

**Step 1:** Train Network

a) Whiten real spectral data (i.e. remove cross wavelength correlations).
b) Compute cumulative distribution (via histogram) for each wavelength.
c) Use Levenberg-Marquardt algorithm to train network.

**Step 2:** Use Network

a) Generate uncorrelated uniform distributed unity variance random variables.
b) Use cumulative distributions to generate marginal distributed white input.
c) Feed through the network.
Method 3: Set Theoretic Approach

Desire to generate NxM matrix $\mathbf{R}$, which has M columns of simulated spectra.

Force constraints upon $\mathbf{R}$ using alternating projections onto convex sets.

The set theoretic approach is based upon defining various properties of the solution as sets.

A feasible solution is any member of the intersection of all of the sets we have defined.

Dependent upon initial value and order of projections.
Method 3 : Set Theoretic Approach cont.

\[ C_{\text{bound}} = \left\{ R \mid r_{\text{min}_i} \leq r_{i,j} \leq r_{\text{max}_i} \right\} \quad i = 0, \ldots, (N - 1) \quad j = 0, \ldots, (M - 1) \]

\[ C_{\text{mean}} = \left\{ R \mid \| R1 - M \mathbf{r}_{\text{mean}} \|_2 \leq \delta_{\text{mean}} \right\} \quad \mathbf{1} \text{ vector of all ones} \]

\[ C_{\text{cov}} = \left\{ R \mid \| RR^T - M (K_r + \mathbf{r}_{\text{mean}} \mathbf{r}_{\text{mean}}^T) \|_F \leq \delta_{\text{cov}} \right\} \]

**Step 1:** Generate random NxM matrix.

**Step 2:** Perform alternating POCS on above constraint sets, stop upon convergence.
Results Chromaticity

Generated 1000 spectra using each of the three methods

Real chromaticity

ANN chromaticity
Generated 1000 spectra using each of the three methods

Copula chromaticity

POCS chromaticity
Results Spectra

Difficult to show all the spectra.

Pick one closest to flat 50% gray followed by spectrum that is most orthogonal to previously selected ones.

Real spectra

ANN spectra
Difficult to show all the spectra.

Pick one closest to flat 50% gray followed by spectrum that is most orthogonal to previously selected ones.

Copula spectra

POCS spectra
Relative Quantitative Comparisons

<table>
<thead>
<tr>
<th>Method</th>
<th>$\varepsilon_{cov}$</th>
<th>$\varepsilon_{mean}$</th>
<th>$\varepsilon_{rank}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copula</td>
<td>0.68</td>
<td>0.18</td>
<td>0.42</td>
</tr>
<tr>
<td>ANN</td>
<td>0.45</td>
<td>0.17</td>
<td>1.00</td>
</tr>
<tr>
<td>POCS</td>
<td>0.10</td>
<td>&lt;0.0001</td>
<td>1.74</td>
</tr>
</tbody>
</table>

\[
\hat{\epsilon}_{mean} = \left\| S1 - Mr_{mean} \right\|
\]

\[
\hat{\epsilon}_{cov} = \left\| (SS^T - s_{mean}s_{mean}^T) - K_r \right\|_F
\]

\[
\hat{\epsilon}_{rank} = \left\| T(S) - T(R) \right\|_F
\]

$T$ computes Kendall rank correlation matrix.
Consider simulation of color measuring instrument with red green blue Gaussian shaped transmittances and MLSE estimator for CIEXYZ tristimulus values.

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Average ΔE 2000</th>
<th>Max ΔE 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Data 170 samples</td>
<td>0.46</td>
<td>4.80</td>
</tr>
<tr>
<td>Copula 10000 samples</td>
<td>0.50</td>
<td>10.68</td>
</tr>
<tr>
<td>ANN 10000 samples</td>
<td>0.52</td>
<td>12.85</td>
</tr>
<tr>
<td>POCS 10000 samples</td>
<td>0.51</td>
<td>20.38</td>
</tr>
</tbody>
</table>
Application – Finding worst performance

compare histograms of DE00 errors for objects, sim1, sim2, sim3

Chromaticities of largest errors

Largest POCS error
Application – Finding worst performance

POCS 10 Largest error spectra

Worst case spectrum

Reflectance

nm

400 450 500 550 600 650 700
Final Remarks

- Quantitatively best method depends upon measure.
- ANN approach has advantage of speed once network is trained.
- Copula method enables enforcement of marginal distributions.
- POCS approach is iterative (slower) but has flexibility to include additional constraints.
Elements for a Spectral CMS Framework

Kristyn Falkenstern
(London College of Communication),
Phil Green (London College of Communication) &
Marc Mahy (Agfa Graphics)
Overview

• Colorimetric CMS Framework
• Spectral CMS Framework
• Spectral estimation
• Spectral CMS Workflow
• Conclusions
Colorimetric CMS Framework

- Generic Workflow
- Proofing Workflow (D50, viewed under D50 Simulator)
- Proofing Workflow (D65 Simulator & D50 Simulator)
- Duotone Rendering
- Static CMM
- Limitations
Generic Workflow

• **Current CMS approach**
  
  – CMS is based on
    • “Profile” per device
    • Creation of device links based on profiles
    • Apply links to color data

![Generic Workflow Diagram]
Proofing Workflow

- *D50 as match, viewed under D50 simulator*

  **Viewing conditions**
  - D50
  - CIE 1931 Observer

  **PCS viewing cond.**
  - D50
  - CIE 1931 Observer

  **Viewing conditions**
  - D50
  - CIE 1931 Observer

  *but viewing conditions are often D50 simulator*
  => visual mismatch possible
  => how large?

![Graph showing wavelength (nm) vs. lighting conditions](image)
Proofing Workflow

- **D50 to D65 simulator**

**FOGRA39** → **PCS** → **Proofer Profile**

**Viewing conditions**
- D50
- CIE 1931 Observer

**PCS viewing cond.**
- D50
- CIE 1931 Observer

**Viewing conditions**
- D65 simulator
- CIE 1931 Observer

- **No match!!**
- **For most characterization data : no spectral data is available (e.g. FOGRA39)**

**This is where spectral estimations are needed**
Duotone Rendering

- *Color mixing model for 2 Spot Colors*

\[ R(\lambda) = T_M(\lambda)T_Y^2(\lambda)R_p(\lambda) \]
Static CMM

- **Static CMM**
  - Functionality related to
    - combining profiles
    - color conversions to or from the PCS
    - Rather static concatenation of color transforms
Limitations

- **Limitations colorimetric CMS approach**
  - Fixed viewing illuminant
    - Usage of source / destination profiles with different illuminants
  - Restriction on the CMF
    - Usage of different CIE Standard Colorimetric Observers
    - Color Deficiencies
  - Spectral Matching
    - Accurately reproduce colors under multiple viewing conditions
    - Preservation of the K-channel
Spectral CMS Framework

- Definition
- Required Elements
What is a spectral CMS?

- **Extension of colorimetric CMS**
  - Including spectral CMS framework
  - Preserve all current colorimetric functionality

- **Make the colorimetric CMS more flexible**
  - Make extensive use of spectral information
    - Viewing conditions, reflectance data, …
  - Extend the definition of PCS
    - Other illuminant, different dynamic range, different medium, …
What does a spectral CMS need?

• A “Spectral CMS Framework” needs
  – Spectral Data
    • Viewing conditions
      – Spectral power distribution (illuminant)
      – Color matching functions
    • Reflectance data (for digital print)
  – Dynamic CMM
    • Rebuilding transforms for different illuminants / CMF
    • Ink mixing models for spot color reproduction
    • Spectral estimation of reflectance curves for XYZ
Spectral Estimation

- Calculating the CIE XYZ tristimulus values
- Finding the convex set
- Reflectance Set Plots & Projection Plots
- Convex Set Results
- Determining the Optimal reflectance curve through Quadratic Programming
Calculating the CIE XYZ Values

• *Tristimulus values*

\[
X = k \sum_{i=1}^{N} R_i I_i \bar{x}_i \\
Y = k \sum_{i=1}^{N} R_i I_i \bar{y}_i \\
Z = k \sum_{i=1}^{N} R_i I_i \bar{z}_i
\]

– with \( R_i \) the reflectance spectrum of the object, \( I_i \) the spectral power distribution of the illuminant, \( \bar{x}_i, \bar{y}_i, \bar{z}_i \) the Color Matching Function (CMF), & \( N \) the dimension of the spectral space
Finding the Convex Set

- **Spectral reflectance estimation**
  - Definition
    - Invert the tristimulus values & solve for $\overline{R}$ with $0 \leq R_i \leq 1$ for all $i : 1 \rightarrow N$
    
    $A' = \begin{pmatrix} \overline{x}_1 I_1 & \overline{x}_2 I_2 & \cdots & \overline{x}_N I_N - X \\ \overline{y}_1 I_1 & \overline{y}_2 I_2 & \cdots & \overline{y}_N I_N - Y \\ \overline{z}_1 I_1 & \overline{z}_2 I_2 & \cdots & \overline{z}_N I_N - Z \end{pmatrix}$

    $A' \begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_N \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$

  - Solution space
    - Convex set in spectral space
Reflectance Estimations

Spectral Estimation of FOGRA 39- White [0 0 0 0]
Reflectance Estimations

Spectral Estimation of FOGRA 39- Cyan [100 0 0 0]
Conclusions

Spec examples

Estimation

Spectral

Colorimetric

Convex Set in CIELAB

*Convex set: calculated for D50 and D50 simulator*

- Mapping into CIELAB space
  - Original viewing conditions (D50 & 1931): 1 point in XYZ & CIELAB
  - For D50 simulator: many points that form a convex set in XYZ

$D50$ simulator

$=>$ visual mismatch possible

$=>$ how large? Compare $D50$ and $D50$ simulator
Projection Results

– FOGRA39 Estimates for Solid Cyan under D50 Simulator
Results Reviewed

- \textit{Results}
  - FOGRA39: Within the convex set for D50 simulator

<table>
<thead>
<tr>
<th>Color</th>
<th>Max. Spectra</th>
<th>Max $\Delta E^*_{ab}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>8.15</td>
<td>3.85</td>
</tr>
<tr>
<td>Solid Black</td>
<td>4.24</td>
<td>13.65</td>
</tr>
<tr>
<td>Solid Cyan</td>
<td>12.41</td>
<td>19.04</td>
</tr>
<tr>
<td>Solid Magenta</td>
<td>10.80</td>
<td>13.71</td>
</tr>
<tr>
<td>Solid Yellow</td>
<td>9.32</td>
<td>7.33</td>
</tr>
</tbody>
</table>
Convex Set Results

• Compare D50 and D50 simulator (con’d)
  – For a real CMYK printer: D50 and given CIELAB value
    • Mapping into CIELAB space
      – For D50:
        » one point
      – For D50 simulator:
        » path
        » Maximum $\Delta E^*_{ab}$: ~ 2
Optimal Reflectance Curve

- **Selecting a spectrum out of the convex set**
  - Quadratic programming
    - Equation:
      \[
      \begin{pmatrix}
        \bar{x}_1 I_1 & \bar{x}_2 I_2 & \cdots & \bar{x}_N I_N \\
        \bar{y}_1 I_1 & \bar{y}_2 I_2 & \cdots & \bar{y}_N I_N \\
        \bar{z}_1 I_1 & \bar{z}_2 I_2 & \cdots & \bar{z}_N I_N
      \end{pmatrix}
      \begin{pmatrix}
        R_1 \\
        R_2 \\
        \vdots \\
        R_N
      \end{pmatrix}
      =
      \begin{pmatrix}
        X \\
        Y \\
        Z
      \end{pmatrix}
      \]
    
    with \( 0 \leq R_i \leq 1 \) for all \( i \)

    - Constraint:
      - Smoothness
      - Aim curve
      - Aim curve scaling
Optimal Reflectance Curve

- **Creation of spectral measurement files**
  - Quadratic programming
  - Aim curve of similar process as starting point
  - Used several scaled versions of aim curve
    - Aim curve with smallest spectral difference selected

![Diagram](image)

- **Convex set**
- **Scaled versions of aim curve**
- **Best fit**
- **Spectral difference**
- **Scaling factor**
- **Best scaling value**
Finding the optimal curve

- Quadratic Programming Results -
  - CGATS TR 006 (XYZ D50): Within the convex set for D50 simulator
  - FOGRA39 as the aim curve

<table>
<thead>
<tr>
<th>Illuminant D50 Simulated</th>
<th>Original CI ELAB</th>
<th>Orig. Est CI ELAB</th>
<th>Norm Est. CI ELAB</th>
<th>Not ΔEab*</th>
<th>Norm ΔEab*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid White</td>
<td>L* 88.66, a* 4.37, b* -0.86</td>
<td>L* 88.60, a* 4.20, b* -1.32</td>
<td>L* 88.65, a* 4.37, b* -0.88</td>
<td>0.50</td>
<td>0.03</td>
</tr>
<tr>
<td>Solid Black</td>
<td>L* 18.64, a* 1.83, b* -0.49</td>
<td>L* 18.63, a* 2.02, b* -0.45</td>
<td>L* 18.65, a* 2.08, b* -0.35</td>
<td>0.19</td>
<td>0.28</td>
</tr>
<tr>
<td>Solid Cyan</td>
<td>L* 55.30, a* -35.43, b* -45.47</td>
<td>L* 55.35, a* -35.20, b* -45.53</td>
<td>L* 55.32, a* -35.41, b* -45.29</td>
<td>0.24</td>
<td>0.17</td>
</tr>
<tr>
<td>Solid Magenta</td>
<td>L* 47.84, a* 68.03, b* -5.22</td>
<td>L* 47.52, a* 68.16, b* -5.87</td>
<td>L* 47.78, a* 68.00, b* -5.21</td>
<td>0.74</td>
<td>0.07</td>
</tr>
<tr>
<td>Solid Yellow</td>
<td>L* 84.12, a* 0.33, b* 81.37</td>
<td>L* 84.00, a* 0.12, b* 81.61</td>
<td>L* 84.09, a* 0.29, b* 81.77</td>
<td>0.34</td>
<td>0.41</td>
</tr>
</tbody>
</table>
Spectral CMS Workflow Examples

- Proofing Example
- Multi-Tone Example
- Metameric Patch Example
Proofing Example

- Matching for the proper viewing conditions

- Dynamic CMM
  - Check viewing conditions of press and proofer profile
  - If needed recalculate the AToBx table of the FOGRA39 profile with
    - the viewing conditions of the proofer profile
    - Estimated spectral data for the Fogra39 characterization data set
  - Make a link with the proofer profile
Multi-tone Example

• Quality issue in spot color reproduction
  – Often combination of spots and process colors
  – Most spot color models require spectra of
    • Media
    • Solids
  – To guarantee continuity in image gradations
    • Spectra have to map exactly to the given XYZ / CIELAB
Metameric Match Example

- **Metameric patches for CMYK devices**
  - Multiple CMYK values map to a given CIELAB

- **Example**
  - Look for a set of CMYK values that
    - are the same for a first illuminant
    - have a maximum $\Delta E^*_{ab}$ for a second illuminant
  - Set of CMYK values can be used to check the viewing illuminant
  - Can be calculated based on the proofer profile
Conclusions

• **Spectral CMS framework offers flexibility**
  – Profiles are also container for spectral data
  – Dynamic CMM is necessary

• **Spectral estimation**
  – Convex set in spectral space
    • Comparison D50-D50 simulator:
      – $\Delta E^*_{ab}$ up to 20 theoretically
      – $\Delta E^*_{ab}$ up to 2 for CMYK ink jet printer
  – Selection of a spectral curve
    • Quadratic programming with normalized aim curve

• **Applications**
  – Proofing, spot color rendering, metameric matches, …
Thank you for your time

???
Reflectance Estimations

Spectral Estimation of FOGRA 39- Black [0 0 0 100]
Reflectance Estimations

Spectral Estimation of FOGRA 39- Magenta [0 100 0 0]
Reflectance Estimations

Spectral Estimation of FOGRA 39- Yellow [0 0 100 0]
Spectral Color Reproduction: Model Based and Vector Error Diffusion Approaches

Jérémie Gerhardt

ICC Digital Print Day
Paris 4 March 2009

Fraunhofer Institut Rechnerarchitektur und Softwaretechnik
Outline

1. Introduction to spectral color imaging
2. Spectral color reproduction pipeline
   - Model based approach
   - Vector error diffusion approach
3. Comparison of the two approaches
4. Conclusions and perspectives
Conventional color reproduction workflow
Metameric match
Metamerism mismatch

original scene

reproduction
Color acquisition system I

- CIE illuminant D65

- Normalized camera sensitivity

- Sunlight spectrum

- Color filters: red, green, blue
Color acquisition system II

- SPD illuminant
- Spectral reflectances
- Sensors sensitivities
- CIE 1931 CMFs
Spectral color imaging I
Spectral color imaging II

- Spectral reflectance
  e.g. 31D vectors (400 – 700nm, $\Delta \lambda = 10$nm)

- Various possible operations on the spectral data
  $\Rightarrow$ color rendering for different illuminants/observers
  $\Rightarrow$ archiving/compression
  $\Rightarrow$ display
  $\Rightarrow$ reproduction in the form of a hardcopy
Spectral color reproduction pipeline

1. Spectral image
   - n contone grayscale images
2. Gamut mapping
   - n contone grayscale images
3. Spectral colorant separation
   - m contone colorant channel images
   - HT by colorant channel
4. HT by spectral vector error diffusion (sVED)
   - m bi-level channel images
5. Print
Model based approach

- Forward spectral printer model
  - Colorant combination
  - Print
  - Spectral reflectance

- Inverse spectral printer model
**Spectral Neugebauer model:**

⇒ color reproduction seen as an additive color process

The spectral color estimation of a colorant combination is the summation of the NPs weighted by their coverage:

\[
\hat{R}(\lambda) = \sum_{i=0}^{2^m-1} w_i P_{i,\text{max}}(\lambda) \Rightarrow \hat{r} = w_{(m)}^T P_{(m)}
\]
Color reproduction

- subtractive color mixing
  ⇒ light filtered by the ink layers
- colorants with **fixed densities**
  ⇒ **halftoning**
- $m$-colorant printer → $2^m$ solid colors
The Demichel model estimates the weights $w_i$ of the NPs for a given colorant combination.

Statistical model:

$$\sum_{i=0}^{2^m-1} w_i = 1 \text{ and } 0 \leq w_i \leq 1$$

For a 2 colorants combination:

- $w_0 = (1 - c_1) \times (1 - c_2)$
- $w_1 = c_1 \times (1 - c_2)$
- $w_2 = (1 - c_1) \times c_2$
- $w_{12} = c_1 \times c_2$

For 20% of cyan and 60% of magenta:

- $w_{\text{paper}} = (1 - 0.2) \times (1 - 0.6) = 0.32$
- $w_c = 0.2 \times (1 - 0.6) = 0.08$
- $w_m = (1 - 0.2) \times 0.6 = 0.48$
- $w_{cm} = 0.2 \times 0.6 = 0.12$
Optical dot gain taken into account by the $n$ factor:

$$\hat{R}(\lambda) = \left( \sum_{i=0}^{2^m-1} w_i P_{i,\text{max}}^{1/n}(\lambda) \right)^n$$
Spectral printer model (summary)

- Cyan → LUT(c)
- Magenta → LUT(m)
- Yellow → LUT(y)
- Black → LUT(k)
- Red → LUT(r)
- Green → LUT(g)
- Blue → LUT(b)

Demichel → Neugebauer
Demichel → Yule-Nielsen
## Comments on model based approach

### Lack of accuracy in the dot gain modeling:
- Each colorant: same optical dot gain
- Colorant overlapping: same mechanical/optical dot gains
- Each dot: uniform spectral color/spectral reflectance

### To improve the NG model:
- More LUTs
- Spectral cellular NG model
- To use a more physical model for the ink drops non-uniformity

- **Forward printer model**
  trade-off: accuracy/complexity ⇔ **ability to be inverted**
  (we are interested in the inverse spectral printer model!)
Spectral colorant separation

forward spectral printer model

colorant combination

print

spectral reflectance

inverse spectral printer model
Spectral colorant separation I

- Inversion of the forward printer model
  = optimization problem

  \[
  \min_c F(c)
  \]

  \[
  F(c) = ||R_\lambda(c) - r_\lambda||^2
  \]

  \(r_\lambda\): spectral reflectance target
  \(R_\lambda(c)\): estimated spectral reflectance
  (spectral NG equations and Demichel equation)

  \(c\): colorant combination for \(m\) colorants:

  \[
  c = [c_1 \ldots c_m]^T, \quad c_i \in [0, 1] \text{ for } i = 1, \ldots, m,
  \]
Example of halftoning by error diffusion I
Example of halfoning by error diffusion II

\[ \text{out}(x, y) = 1 \text{ if } \text{mod}(x, y) \geq 0.5, \text{ else } \text{out}(x, y) = 0 \]

- \textit{in}(x,y): pixel at position \((x,y)\)
- \textit{mod}(x,y): modified pixel
- \textit{out}(x,y): binary colorant output value
- \textit{err}(x,y): error to diffuse after the thresholding
Example of halftoning by error diffusion III

- Jarvis, Judice and Ninke’s filter:

\[
\begin{bmatrix}
  w_{2,1} & w_{2,2} & w_{2,3} & w_{2,4} & w_{2,5} \\
  w_{3,1} & w_{3,2} & w_{3,3} & w_{3,4} & w_{3,5}
\end{bmatrix}
\begin{bmatrix}
  \bullet & w_{1,4} & w_{1,5} \\
  1/48
\end{bmatrix}
= \left(\frac{1}{48}\right) \times
\begin{bmatrix}
  \bullet & 7 & 5 \\
  3 & 5 & 7 & 5 & 3 \\
  1 & 3 & 5 & 3 & 1
\end{bmatrix}

\text{mod}(x + i, y + j) = \text{mod}(x + i, y + j) + w(i, j) \times \text{err}(x, y)
Spectral vector error diffusion I

- [Kouzaki et al. 1999, Kawaguchi et al. 1999]

\[
\text{out}(x, y) = \arg \min_{p_k} \| \text{mod}(x, y) - p_k \|
\]

- \text{in}(x,y): spectral reflectance at the pixel position \((x,y)\)
- \text{mod}(x,y): modified spectral reflectance
- \text{out}(x,y): binary colorant combination (selected NP)
- \text{err}(x,y): error to diffuse after NP selection \text{out}(x,y)
Spectral vector error diffusion II

▶ D50 color rendering of the MacBeth ColorChecker (CC) spectral image
Halftoning by sVED of the CC spectral image
’Slowness’ of vector error diffusion:
⇒ visibility of the error accumulation

Improvement of vector error diffusion:
⇒ increasing resolution
⇒ pre-processing by gamut mapping
⇒ new filter design
Effect of resolution on sVED I

- left patch: 64 × 64 pixels, right patch: 128 × 128 pixels
Effect of resolution on sVED II

- left patch: 256 $\times$ 256 pixels, right patch: 512 $\times$ 512 pixels
Spectral gamut mapping is performed before halftoning
⇒ inversion of the printer model for the weights only
Original CC spectral image
sVED with pre-processing III

- gamut mapped CC spectral image
sVED with pre-processing IV

- Halftoning by sVED of the spectrally gamut mapped (sGM) CC spectral image
We design new filters such that:

\[
\sum_{k=1}^{n} w_k = 1
\]
Weights related to the distance from selected NP to pixel’s neighbors:

\[ d_k = \| \mathbf{p} - \text{mod}(x + i, y + j) \| \]

To have weights values \( \in [0, 1] \):

\[ d'_k = \frac{d_k}{\max_k (d_k)} \]

Maximum = 1 on the farthest neighbor
⇒ we want the **inverse relation**
⇒ remove the pixel contribution: \( d''_k = 1 - d'_k \)

To normalize the weights:

\[ w_k = \frac{d''_k}{\sum_k d''_k} \]
Halftoning by sVED of the sGM CC spectral image
sVED with new filters - New filterS by distances III

- Halftoning by sVED and new filters by distance of sGM CC spectral image
Comment on the vector error diffusion approach

- Spectral color reproduction by sVED works
- Slowness of error diffusion still present
- **Reduction of error visibility**
  - $\Rightarrow$ spectral gamut mapping before sVED
  - $\Rightarrow$ new filters design keep details in the image but bring noise
Comparison of the two approaches

1. Introduction to spectral color imaging
2. Spectral color reproduction pipeline
   - Model based approach
   - Vector error diffusion approach
3. **Comparison of the two approaches**
4. Conclusions and perspectives
Experimental setups I
Experimental setups II

- Colorant separation (CS)
- Halftoning by error diffusion (ED) by colorant channel

- Halftoning by sVED
Result sample II

CS + ED

sVED
Result sample III

CS + ED

sVED
Result sample IV

CS + ED

sVED
Result sample V

CS + ED

sVED

Sample S

![Graph showing wavelength vs. intensity](image)
Result sample VI

CS + ED

sVED

Sample 6

wavelength (nm)
Result sample VII
Result sample VIII
Result sample IX

CS + ED

sVED

Sample 9
Result sample X

CS + ED

sVED
Result sample XI
Result sample XII
Results analysis

- Similar performance for both approaches in terms of spectral differences
- Main difference in the final dot distribution
Conclusion and perspectives

- **Model based approach**
  - difficulties to model the dot gain
  - use cellular YNSN model/physical model

- **Vector error diffusion approach**
  - sVED works and gives more pleasant dot distribution
  - promising results with new filter design/spectral gamut mapping

- **Challenges remain:**
  - practical use in real applications
  - spectral gamut mapping

- ‘ICC’ approach using LABPQR
merc...
Towards a new image quality model for color prints

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³ University of Oslo, Oslo, Norway.
Contents

- Motivation
- Image quality
  - Subjective
  - Objective
- Image quality attributes
- Image quality models
  - Existing image quality models
  - New image quality model
- Conclusion
- Future work
Motivation

- Link between subjective and objective image quality
  - Improve or develop new and better objective measures
- Better understanding of the complexity of image quality
Quality

- Definition: A degree of excellence
- What is quality?
  - When the customer returns and the product doesn't
  - Conforms to standards
- Depends on the situation
Image quality

- Refers to an objective measurement or a subjective rating of the quality of an image
  - Two different ways to judge image quality
    - Subjective
    - Objective

- Image quality is depends on the intention:
  - Accurate
  - Preferred
  - Natural
  - Useful
Definition:
- The subjective impression found in the mind of the observer relating to the degree of excellence exhibited by an image
- Restricted by the human visual system (HVS)
Subjective evaluation

- Carried out by observers
Complexity of image quality

- Image quality depends on
  - The observer
    - HVS
    - Cultural differences
    - Preference
  - Viewing conditions
    - Distance
    - Illuminant
  - Intent
  - Instructions
Is the degree of compliance of a process or its outcome with a predetermined set of criteria
Objective quality

- Carried out in many different ways
  - Measurements
  - Algorithms
- Two groups
  - Simulation of the HVS
  - Do not simulate the HVS
Image quality attributes

Terms of perception¹, such as:
- Contrast
- Sharpness
- Color
- Artifacts
- Details
- Uniformity
- Saturation
- Etc.

Image quality is composed of ‘n’ attributes
- ‘n’ dimensions of quality

Attributes can be represented in an image quality model
  ◦ A theory of perception that enables the prediction of image quality

Intention
  ◦ Describe the overall quality of a system
  ◦ Show which attributes that are important for image quality
  ◦ Show how attributes influence overall image quality

Spatial relationships between attributes can be quantified
  ◦ Relationships in ‘n’ dimensions
Models

- Models used for different purposes
  - Image quality models
    - S–CIELAB model (Zhang & Wandell, 1996)
  - Color appearance models
  - Image difference models
    - iCAM (Fairchild & Johnson, 2004)
    - CVDM (Jin et al., 1998)
  - Image attribute systems
    - Document Appearance Characterization (Dalal et al., 1998)
    - A set of image quality attributes that provides a means of describing the overall image quality of printing systems
Document Appearance Characterization System (DAC)

- Proposed by Gruber 1992–1993
  - Refined by Dalal et al. in 1998
- Two-sided
  - Printer
  - Materials and stability
  - Each side has 10 attributes
- Advantages:
  - High level descriptors
  - Separation of printer from materials and stability
- Disadvantages:
  - Mixed subjective and objective evaluation
  - Complex

E. N. Dalal; D. R. Rasmussen; F. Nakaya; P. A. Crean & M. Sato.
Evaluating the Overall Image Quality of Hardcopy Output. PICS, 1998. 14
Advantages of image quality models

- Defined quality attributes
- Tool for observers
  - Experts and non-experts
- Better understanding of image quality
- A link between objective and subjective image quality
  - Improving objective image quality metrics
- Allows a comparison of experiments
A theoretical image quality model for color prints composed of attributes based on human perception

Approximation of image quality, and it aims to provide a representation of image quality

The model uses five defined image quality attributes

- Sharpness
- Color
- Artifacts
- Details
- Contrast
Sharpness

- Described as the clarity of detail and edge definition of an image

Contrast

- There is not a clear and shared definition
- The difference, globally and locally, in both lightness¹ and chromaticity of an image

Details

- Defined as small features and fine lines in the image in mid to high frequencies, as hair, leaves, feathers and so forth
Color

- Color is a sensation. It is the result of the perception of light by the human visual system\(^1\).
- By color we include color related issues, as for example hue shift, saturation and color rendition.

Artifacts

- Error or misrepresentation introduced in the image
  - Noise introduced by the halftoning algorithm
  - Banding caused print head defects

Abstract Illustration of the model

- Simple Venn ellipse diagram with a five fold rotational symmetry
- Overall image quality can be influenced by:
  - one (yellow),
  - two (red),
  - three (blue),
  - four (green),
  - five (grey) attributes
Attributes might influence quality differently.
Shape and position for the attributes can vary.
Attributes can also be divided for adaptation to specific issues.
We have proposed a new image quality model for color prints composed of attributes based on human perception.

Still ongoing work towards obtaining a complete image quality model.

The proposed model has several advantages making it valuable in quality evaluation:
- Defined quality attributes
- The influence of attributes on image quality
- Appropriate for subjective and objective evaluation
- A link between subjective and objective image quality

Conclusion
Future work

- Quantification of spatial relationships
  - Distribution of importance of the different attributes
- Evaluation of the image quality model
  - How?
    - Psychophysical experiments?
    - Comparison to existing models?
- Showing how subjective and objective measures can be linked with the model
Thanks for your attention

- Any questions or comments?
  - E-mail: marius.pedersen@hig.no
  - Website: www.colorlab.no
Reproducing Spot Colors

• Different set of goals from reproducing colors in images
• ICC profiles typically optimized for images
  – Rendering of spot colors may not be as good as it could be
• Will look at some of the goals for rendering colors for images and spot colors
• Will recommend the use of the new floating point tags and some changes to ICC profiles
Goals for Rendering Colors for Images

• Some of the many goals for rendering colors to a printer
  – Preserve Detail
    • Highlight detail
    • Shadow detail
    • Detail in saturated colors
  – Preserve Appearance
    • Make the reproduced image look as close as possible to the original
  – Maximize Appearance
    • Make the image look as good as it can
Preserve Shadow Detail Example

• Using a simple gamut compression algorithm that only reduces color difference can result in the loss of shadow detail

• Two profiles created
  – One produced using a very simple min delta E algorithm
  – One produced with a commercial gamut compression algorithm

• Looking at Relative Colorimetric for Fogra 42 in order to exaggerate the differences
FOGRA 42 Gamut
Images

Original
Images converted to CMYK

Simple Min DeltaE  Complex Gamut Compression
Gamut Compression

Simple Min DeltaE  Complex Gamut Compression
Goals for Spot Colors

• Minimize the color difference for individual colors
  – Just minimizing the difference is analogous to the absolute intent of ICC profiles

• Maintain distinctions between colors
  – Do not want individual colors mapping to the same color on the printer
  – Analogous to Perceptual intent of ICC profiles

• Many other possible goals
  – Preserve hue, preserve spacing of colors, etc.
Example

- Consider Pantone 232C & 225C
- Similar colors

Well distributed colors

- 5,100,0,0 CMYK
- 0,100,5,0 CMYK

Best Visual Match: 0,100,0,0 CMYK
Achieving our goals

- Could create one set of device values that balances visual difference and differentiation
- Create multiple sets of device values
  - One for minimizing visual difference
  - One that preserves the difference between the colors
- Create a transform that provides multiple levels of differentiation
- Both goals can be achieved with either LUT based or named color profiles
Goals for Named Color Profiles

• Support of tints in a new version of named color profiles is desired by Pantone
• A named color could be specified at 100%, 75%, 50%, & 25%
• The CMM would use 1D interpolation to find the named color for any tint value
Tint gradation for out of gamut colors

• When the color is out of gamut at 100%, could want at least two different results
  – Might want each color along the gradation to be the closest visual match
    • This could result in undesirable hue shifts as the colors move from out of gamut to in gamut
  – Might want the gradient to not have any hue shifts even if each individual color is not the best match
  – Might want the gradient to maintain differentiation
Possible Gradations

Preserve Hue  Visible Match
Implementing Spot Color Rendering in ICC Profiles

- Profiles could be built for either images or spot-colors
- The floating-point absolute tags could be used for spot-colors
  - B2D0, B2D1, B2D2 for images
    - Relative with black-point compensation would not be affected
  - B2D3 for spot colors
    - Still only allows one rendering for spot colors
Future Directions

• New named color profiles with multiple rendering intents
• More flexible rendering intent support for future ICC profiles
Questions?
Application of ISO 12647-7

Fons Put

VIGC - 4 March 2009
Introduction

• Flemish Innovationcenter for Graphic Communication
Introduction

- ISO print standardization (ISO 12647)
  - Produce predictable color
    - substrate
    - Ink
    - Dotgain
    - Result: reliable proof/print match
  - ...Increasing use of these standards
    - “craftsmanship” versus “Industrialization’
    - Customer communication
    - Globalization
    - Certification
    - ...

Contents
- Introduction
- normative
- informative
Introduction

Contents
• Introduction
• normative
• informative
Introduction
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Introduction

- ISO 12647-7
  - “Simulate the visual characteristics of the finished product as closely as possible”
  - Proof/print match in ISO 12647-2
    - Paper: $dE < 3$
    - Solids: $dE < 5$
    - Average color deviation 50 patches: $dE < 4$
    - Maximum color deviation 50 patches: $dE < 10$

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Introduction

- How do proofs match with prints?

### Marié avec votre banquier?

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Introduction

• How do proofs match with prints (2)?
ISO 12647-7 requirements
ISO 12647-7 requirements - normative

• Test Page
ISO 12647-7 requirements - normative

- **Proofing Substrate**
  - **Color variability in dark keeping conditions**
    - 24h at 25 °C and a relative humidity of 25%
    - 24h at 40 °C and a relative humidity of 80%
    - One week at 40 °C and a relative humidity of 10%
  - **Light fastness**
    - ISO 12040
    - Blue Wool scale
    - >= 3
ISO 12647-7 requirements - normative

- **Proofing Substrate**
- **Results**

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#### Application of ISO 12647-7

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ISO 12647-7 requirements - normative

- Color
  - Process colors
    - Deviation
      - CIELAB dE
      - CIELAB dH
    - Variation
    - Light fastness
  - Stabilization
  - Control Strip
  - Repeatability
  - Outer gamut patches
ISO 12647-7 requirements - normative

• Color

• Process colors

Application of ISO 12647-1: D50 verlichting, 2° observer, 0/45 or 45/0 geometry, white backing.
ISO 12647-7 requirements - normative

• Color
  • Control strip
    • Simulated print substrate color
    • Solids and overprints (CMYRGB)
    • mid-and shadow tones (CMYRGB)
    • Black half-tone scale
    • CMY half-tone scale
    • Critical colors
ISO 12647-7 requirements - normative

- **Color**
  - **Control strip (CMY halftones)**

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ISO 12647-7 requirements - normative

- **Tone value**
  - Tone value reproduction limits
  - Tone value deviation
- **Reproduction of Vignettes**
  - Visual according to ISO 3664
- **Image register and resolving power**
- **Margin information**
  - Date/Time
  - Proofing system
  - Substrate/colorants
  - Simulated print condition
  - ...

Contents
- Introduction
- Normative
- Informative

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ISO 12647-7 requirements - informative

- Data delivery
  - PDF/X, TIFF/IT
  - Color information
- Screening
  - Frequency, Angle, Dot shape
- Substrate
  - Gloss, UV-response
- Rub resistance
- Ink gloss
Thanks :-)
Working together toward greater efficiency
Strategic partners VIGC
Attendees?...

- Digital Press Only
- Digital and Sheetfed Press
- Digital and Web Offset Press
- Digital and Screen Press
- Combination of 3 or more
Type of Digital Press?...

- Xerox iGen
- Xerox Other
- HP Indigo
- Xeikon
- Kodak NexPress
- Canon
- Combination of above
Goals for Digital Press?...

- Make match existing Presses
- Make match to existing Proofer
- Make match other Digital presses
- Make match Customer proof
- Make match Industry Standard
Agenda

- Describe available Color Options
- Understand what each Option provides
- Benefits of each in a Digital Press environment
- New ways to use Color Options to Optimize Results
How many paper stocks?

■ 1-3
■ 4-6
■ More than 6
Two Main Questions

- What is Your Target?

- What is Your Tolerance
What are you AIMing at?

- Target Reference?
- What are devices attempting to match?
- How well do devices match?
- Is this different for different substrates?
- Do you communicate this to customers?
Potential Aim References

- Customer Proof
- Shop Proof
- Industry Specification?
  - ISO 12647 (ISOcoated, ISOuncoated…)
  - GRACoL 6 and or 7
  - SNAP
  - FIRST (Flexo) etc.
Print on Different Substrates

- Generally difficult to Proof
- Difficult to make Images consistent
- Different Dot Gain (TVI)
- Different Gray Balance
- Images do not match proof or other presses
- Not a good scenario - but typical
What is your shop Tolerance?

- First Ring?
- Second Ring?
- What does this mean?
- Wide Field, or Narrow field
- What Metric to Use?
- Differentiator
What your Color Tolerance Determines:

- How often to Calibrate
- How many substrates to profile?
- How many presses to profile
- If Calibration is “enough”
- What you can do in addition to calibration
What Metric?

- Density?
  - No, Density is NOT color, reflected light
  - Can Match Density and NOT match color

- Need to Define Color Difference
  - Based on COLOR
  - Different formulas based on how perception works
How to Determine Your Color Tolerance?

- Color Tolerance Exercise
- Qualify Color Difference in delta E (\(\Delta E_{76}, \Delta E_{94}, \Delta E_{2000}, \text{CMC}\)...)
Starting Point:

- Have to know what you want to Match To:
  - Your Aim point(s)- How Many Configurations
  - Determines level and type of Color Control to use

- Have to know the Tolerance of acceptability
  - Allowance for variability
  - Determine type and time of Process control tools to use
What Constitutes a Match?

- Tonality, Weight of Highlights vs Midtones
- Matching Gray Balance, tonal and color
- Match Color
  - *Primaries, Overprints and in between colors*
  - Grays
How to Match Tonality

Traditionally with Dot Gain Curves
What Curves alone Do Not Do

- Compensate for Gray Balance
  - Unless using some intelligent software
- Change the color of primaries and overprints
- Required to have Inks verified to ensure color match
  - ISO Inks have defined Lab values primaries and overprint
Order of Implementation-Traditional Press

■ Define TRC Curves
  ■ Done via linear plate curves
  ■ Determines Dot Gain and Potentially Gray Balance

■ Calibration - Get Press to ISO
  ■ Verify Densities match ISO Lab values
  ■ Ensures that Press is printing to ISO TVIs

■ Ideally Optimize files received by customers
  ■ Ensure the correct TAC and Consistent Separations
Digital Press Color Tools

- Tone Reproduction Curves
- Calibration Tools
- ICC Profiles
- ICC Static Device Links
- ICC Dynamic Device Links
Follow Traditional Procedure?

- Define Tone Reproduction Curves?
  - Some Press', too variable, cannot get consistent
  - If Colorants are not correct, no use

- Calibration
  - Most presses drift within a calibration tolerance
  - Peak of 6 delta E across the same sheet

- Reference Profile- Your Aim Point
  - Use ICC Profile,
  - Static DeviceLink,
  - Dynamic DeviceLink
Why Digital Presses handled differently

- TRC Curves do not work very well
  - Inconsistency on Press
  - Digital press and TVI

- Colorants do not match ISO Colorants
  - Igen off - blue overprint off by 11 dE
  - Xeikon - blue overprint off by 11 dE
  - Indigo - blue overprint off by 8 dE
  - NexPress
ICC Device Profile Transformation

Reference Condition
- ISOcoated
- SWOP3
- ISOuncoated
- SWOP5
- GRACoL7
- SNAP

Destination Gamut
- ISOc 300
- SWOP3
- GRACoL7
- ISOwebctd
- SWOP5
- SNAP
ICC Device Profile Transformation

**Pro**
- Ease of use
- One profile per device or color space
- Adding new devices requires only one new color transform

**Con**
- Depend on quality CMM
- Two applications can give different results
- Less accurate
- No control separations
- Pure colors contaminated
- Black generation destroyed
How to Reference Digital Presses

- Color Match via ICC Profiles

**Pro’s**

- Fixes Colorant issues, Primaries and Overprints corrected
- Fixes Tonality and Gray Balance per “Source” profile

**Con’s**

- Potentially have different Conversions due to CMM
- Potentially have colorant contamination issues
  - Single Black converts to Four Color Black- Tints Issues
ICC DeviceLink Profiles (Static)

ISOcoated
SWOP3
Cust Proof1
SWOP5
GRACoL7
SNAP

Digital Press
Silk
Coated
Uncoated
Matte

■ 24 Device Links for 1 Digital Press, 4 substrates
Static ICC DeviceLink Profiles

Pro

- Transformations have both source and destination information (gamut, viewing conditions)
- Less Conversions, less rounding errors
- Control on output separations characteristics

Con

- More profiles needed
- Adding a device requires multiple new color transforms
- Conversion not optimized for different content
One Conversion does not fit all…

One Page, Multiple Images

- TAC 380 Default CMYK
- TAC 228 SNAP
- TAC 300 SWOP
- TAC 320 Gracol7
- TAC 310 Japan
- TAC 360 G7 Uncoated

- TAC 300 USWebSWOP
- TAC 280 DigitalPress
One Conversion does not fit all...

One Page, Multiple Images

- TAC 380 Default CMYK
- TAC 228 SNAP
- TAC 300 SWOP
- TAC 320 Gracol7
- TAC 310 Japan
- TAC 360 G7 Uncoated

Resultant TAC 300

- TAC 300 USWebSWOP
- TAC 280 DigitalPress
One Conversion does not fit all…

One Page, Multiple Images

TAC 380 Default CMYK
TAC 228 SNAP
TAC 300 SWOP
TAC 320 Gracol7
TAC 310 Japan
TAC 360 G7 Uncoated

Resultant TAC
300
148
One Conversion does not fit all...

■ One Page, Multiple Images

TAC 380 Default CMYK
TAC 228 SNAP
TAC 300 SWOP
TAC 320 Gracol7
TAC 310 Japan
TAC 360 G7 Uncoated

Resultant TAC
300
148
220
One Conversion does not fit all…

■ One Page, Multiple Images

<table>
<thead>
<tr>
<th>TAC 380</th>
<th>TAC 228</th>
<th>TAC 300</th>
<th>TAC 320</th>
<th>TAC 310</th>
<th>TAC 360</th>
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</thead>
<tbody>
<tr>
<td>Default CMYK</td>
<td>SNAP</td>
<td>SWOP</td>
<td>Gracol7</td>
<td>Japan</td>
<td>G7 Uncoated</td>
</tr>
</tbody>
</table>

Resultant TAC

| 300 |
| 148 |
| 220 |
| 240 |
One Conversion does not fit all…

■ One Page, Multiple Images

TAC 380 Default CMYK
TAC 228 SNAP
TAC 300 SWOP
TAC 320 Gracol7
TAC 310 Japan
TAC 360 G7 Uncoated

Resultant TAC
300
148
220
240
230
One Conversion does not fit all...

One Page, Multiple Images

- TAC 380 Default CMYK
- TAC 228 SNAP
- TAC 300 SWOP
- TAC 320 Gracol7
- TAC 310 Japan
- TAC 360 G7 Uncoated

Resultant TAC
- 300
- 148
- 220
- 240
- 230
- 280
Dynamic ICC DeviceLink™ Profiles

- Dynamic Link Creation
- Dynamic TAC Reduction
- Dynamic visible color
- Better color accuracy
- More Ink Savings
Dynamic Device Link Profiles

**Pro**
- All Benefits of Static DVL
- Do NOT need multiple
- No Loss of Contrast-Dynamic TAC on the fly
- Optimum Quality- Builds on-fly based on Color
- Looks inside images for Optimization- Toner Savings
- Vector and Special color handling- PMS, Named

**Con**
- Some Workflows do not support
Optimum Configuration with Digital Press

- Calibrate at least daily to ensure consistency
- Use Dynamic DVLs for Color Conversions
  - Control the Color Reproduction
  - Matching your Reference printing condition
- Use Color Server for Multiple Press Conversions
  - Eliminate CMM differences between different DFEs
- Use Tone Reproduction Curves
  - Accommodate drift after calibration
Optimum Configuration with Digital Press

- Calibrate at least daily to ensure consistency
- Use Dynamic DVLs to Match Reference Condition
  - Control the Color Reproduction
- Use Color Server for Multiple Press Conversions
  - Eliminate CMM differences between different DFEs
- Use Tone Reproduction Curves
  - With Curve Software accommodate drift after calibration
  - Force Device back to Gray Balance condition
Conclusion

- Know Your Targeted Reference Condition
- Define Your Tolerance
- Implement Process Control procedures accordingly
- Use Optimum Color Conversion for your Press
  - Separate differently for iGen versus Indigo
  - Honor embedded profiles
  - Design Queues to accommodate different References
- Satisfy Color Requirements with Digital Presses
**Impact of Luminance Environment in Preferred Tonal Reproduction**

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**Abstract**

In this study, we propose to use the tools of sensimetry and psychosopic to characterize a color appearance phenomenon. We will ask experienced observers to adjust a digital picture corpus in a variable luminance environment. These adjustments will be made on extended information files, through a console. The collected data should allow us to determine a function we could apply to a model to obtain preferred tonal reproduction according to the luminance environment.

**Context**

There is one known color appearance phenomenon we are particularily interested in, Bartelson-Breneman Equations. It specifies that image contrast changes according to surrounding luminance environment. These adjustments will be made on extended scale. We must select a monitor which could display high luminance and could have a high contrast ratio.

**We can illustrate that effect with this example:**

This is the same image duplicated, the left one has a white background and the right one has a black background. Observers do not have the same perceived tonal rendition for these two images. Pictures come from Adobe Photoshop.

**References**


**Psychophysical Experiment**

In this study we will only change the amount of light. Therefore, the quality of the light source will have to remain constant. We will be running our experiments on complex photographs. We have studied only preferred tonal reproduction, on B&W and colour pictures which are representative of a standard photographic production.

We will show pictures on a monitor with a field illuminated by a filtered tungsten source with a Correlated Colour Temperature equal to 5000 Kelvin. Therefore, the field has continuous spectral properties and its luminance could vary on an extended scale. We must select a monitor which could display high luminance and could have a high contrast ratio.

Images have already been equalised, by expert people who work on images, in a predetermined environment. Next, we will change the environment and will allow observers to adjust the images by using a rendering function. They will have some cursors at their disposal, one for each parameter, and they may change parameters in any way. We will keep the final result and log these modifications.

**Principle of the experiment**

We have determined a three-parameter function to act on the image displayed:

- Brightness B.
- Contrast C.
- Tonal rendition G.

Therefore, The function must offer the following possibilities:

- To translate movement along the abscissa axis. This is for brightness B.
- To change the ratio between extreme values. This is for contrast C.
- To change slope value. This is for tonal rendition G.

Moreover, the function must have two asymptotes.

**Selected function**

We have used a function based on Weibull distribution:

\[ N_{\text{VOut}} = C_1 - C_2 e^{- (N_{\text{VIn}} R)^{C_3}} \]

- Threethree: C_1 variation
- Continuous/discontinuous: C_2 variation
- Gradient/flat: C_3 variation
- Purple lines: C_1 and C_3 variation

**Finding & Future work**

We will study results of the test. If they are statistically representative, we will:

- Compare our results with existing Color Appearance Models or equations.
- Design a model for preferred tonal reproduction.
- Examine the data for both B&W and colour images and visual correspondences in order to differentiate between these two picture families.
Does the use of Perceptual Reference Medium Gamut improve image quality in colour management of printing systems?

Nicolas Cardin et al.

The International Colour Consortium (ICC) has published three fourth version of their specifications. In these specifications a new key feature is the introduction of the Perceptual Reference Medium Gamut (PRMG) in the ICC profile workflows. The PRMG is used as a target colour gamut for perceptual intent in order to improve the quality of the reproduction. To investigate the possible improvements when using the PRMG we consider the following criteria: the perceptual quality of resulting printed images, the evaluation of colour reproduction quality and the improved coherence of image rendering when using different printing systems. To do so, we define two perceptual workflows, one using the PRMG and the other not using it. In this study we propose a psychophysical experiment to compare the printing images resulting of these two workflows.

Abstract

The PRMG is represented in the CIELAB colour space. The reference medium is defined as a hypothetical print on a substrate. The PRMG is based on a superset of different color gamuts among which several printer profiles. To determine the impact of the use of the PRMG in an ICC perceptual workflow we define two workflows to convert an image from an input colour space to an output colour space (e.g. a printer CIELAB colour space). The version 2, it will use the PRMG and the other, the version 4, will not. The two workflows are figured below.

In particular, for the forth situation we apply Black Print Compensation (BPC) following the gamut mapping algorithm to ensure that the PRMG contains the target gamut in CIELAB colour space. The two workflows are figured below.

The Perceptual Reference Medium (PRM) and the Perceptual Reference Medium Gamut (PRMG)

We have chosen the Epson R800 because of its similar gamut with the PRMG and the Océ Color Wave 600 because it is a printer with a smaller gamut.

Set of images

We have chosen 128 RGB images from the GO 1040+2.004 set of images and from personal photographs. The set of RGB images are chosen because they mostly belong to the sRGB gamut. The personal photographs are chosen because their colour content is less standardized.

Viewing conditions

Glittery and non-glittery reflectors prints (215x267 mm) are placed on a rack mounted on a drafting table which was angled to produce a +40° Illumination angle and a perpendicular viewing angle. Viewing distance of printed images was recorded at 750 mm under the centre of the spot. The illumination of the place is a 6500 K bulb and a cold light illumination.

Monitor features

We use the NEC Color Edge CG221 monitor to display the reference images because we can calibrate it to reproduce the official colour space (sRGB) with an accuracy of ±0.5 ΔE. It is equipped with the Colour Appearance Model (CAM) version of the CIECAM02 CIE colour appearance model.

Experiment setup

Printing systems

We have chosen two different printing systems:

- Epson R800
- Paper: Premium Glossy Photo Paper Art:
- Perceptual render intent

- Océ Color Wave 600
- Paper: Océ Real Label UH 600
- Perceptual render intent

Subjective experiment to assess the impact of the use of PRMG on the given printers

Task to perform

This psychophysical experiment is based on a pair comparisons of images between prints produced from the ICC version 4 perceptual workflow and from the ICC, version 2, perceptual workflow.

Future works

- Introduction of a workflow with ROM images in input.
- Psychometric studies

Bibliography

Perception of the Printer Modulation Transfer Function by the Human Visual System

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Abstract

Experiments have shown that the quality of printed images depends on the capacity of the printing system to accurately reproduce details.

We propose to measure the Modulation Transfer Function (MTF) of the printing system. The MTF is first measured using a modified version of the method proposed by Jang and Allebach. The MTF is then assessed visually by a group of observers in a psychophysical experiment which consists in determining a threshold of pattern perception on test charts, where test charts have been printed with two different print quality modes. Results show the need for a measurement method based on the human visual system.

Motivation

The motivation of the work is to obtain an accurate measure of the ability of printers to reproduce details. In this study we consider the relationship between the use of the threshold by a subjective observer and the perception of the MTF by the human visual system.

Scanner-based Measure of the Printer Modulation Transfer Function

Jang and Allebach's Method

The test page is printed, scanned and analyzed.

MTF values for the 11 bands (lower and upper frequencies) are taken with Jang and Allebach's test page, even of 11 scans.

Results show two important limits

For both cases, and for each lower frequency patterns are optimally perceived. Observers perceive less modulation when frequency is lower. The frequency is lower when the modulation is lower and this is not modulated. The higher the frequency at which the signal is not seen, the lower the frequency that is seen.

Perception by the Human Visual System, Psychophysical Experiment

Introduction

MTF measurements show differences between these three modes MTF for lower Y values and higher frequencies are more attenuated with Production and Draft modes. Ideally, the MTF should approach zero at low and high frequencies. The quality of the reproduction is far less than the lowest bias. The MTF is higher when the difference reaches 0.5. A different threshold for the low band is used. To assess this threshold, we propose a psychophysical experiment to assess the limits of the human ability to detect patterns on printed paper.

Protocol

Ten observers consider the test chart. The observers are presented with two test images: Jang and Allebach's test chart with a uniform modulation value with a half-tone pattern and with different print quality modes (Presentation and Draft).

The observers can observe the test chart for 10 minutes with a darkened room.

The observers view the prints from a distance of 50 cm.

The observers were asked to circle the points where they perceived modulation.

Results

MTF measurements vs. Perception

In this study we propose a comparison between different print quality modes. First we use scanner-based MTF measurements and then we have proceeded with a psychophysical experiment. We actually measured a correlation between scanner-based and perceptual measurements for most frequencies and biases but more information, particularly perceptual amplitudes, are needed to link and compare the two measurements.

Conclusions and Future Work

In this study we have proposed a comparison between different print quality modes. First we use scanner-based MTF measurements and then we have proceeded with a psychophysical experiment. We actually measured a correlation between scanner-based and perceptual measurements for most frequencies and biases but more information, particularly perceptual amplitudes, are needed to link and compare the two measurements.

That is why we propose to extend this study to several printing systems and modes and to proceed with a broader psychophysical test to assess the differences between the perception of one printed sinusoidal patch and its scanner-based measurement.

Observations

Scanner-based measurements give an indication about the quality of the reproduction of details by the printer in these print modes, which capture better with a known number of detail per inch.

MTF measurements of the printer in Presentation and Production modes are similar. Océ Colorwave in these print modes produces prints in MTF. Océ Colorwave in these print modes produces prints in MTF. Océ Colorwave in these print modes produces prints in MTF. Océ Colorwave in these print modes produces prints in MTF. Océ Colorwave in these print modes produces prints in MTF.

MTF measurements of the printer in Draft mode appear very different, presenting lower values and strong variations, particularly for the highest frequency (150 cpi) and the lowest bands. It can be explained that the MTF is the number of dots per inch the printer in Draft mode is capable of.

All differences between Presentation and Draft MTF are less than 0.1 (absolute values) whereas differences between Presentation and Draft charts above 0.2 (absolute values), except for 150 cpi where the difference reaches 0.5.

Conclusions and Future Work

In this study we have proposed a comparison between different print quality modes. First we use scanner-based MTF measurements and then we have proceeded with a psychophysical experiment. We actually measured a correlation between scanner-based and perceptual measurements for most frequencies and biases but more information, particularly perceptual amplitudes, are needed to link and compare the two measurements.

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Bibliography