ICC DIGITAL PRINT DAY

Paris, March 4 2009

Océ

Digital Color Printing @ Océ

océ
Printing for Professionals

Raymond Balmès

ICC DIGITAL PRINT DAY

Welcome in Paris !

Océ Print Logic Technologies

Site d'Océ Print Logic Technologies, Créteil (Ile de France)

University of the Arts London
London College of Communication

TELECOM ParisTech

There should be smarter color management !

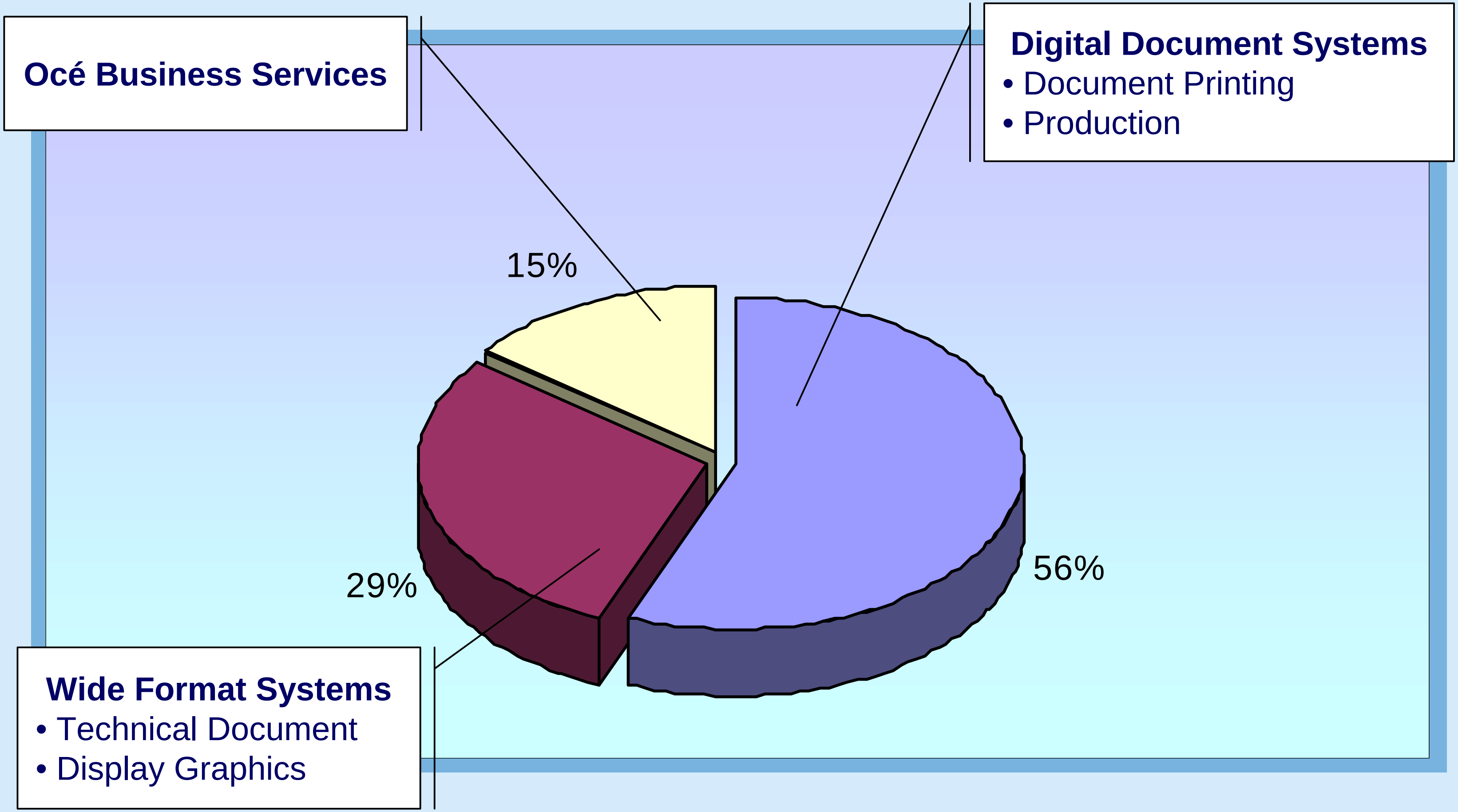
Color management in Wonderland

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 ColorWave 600

- **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

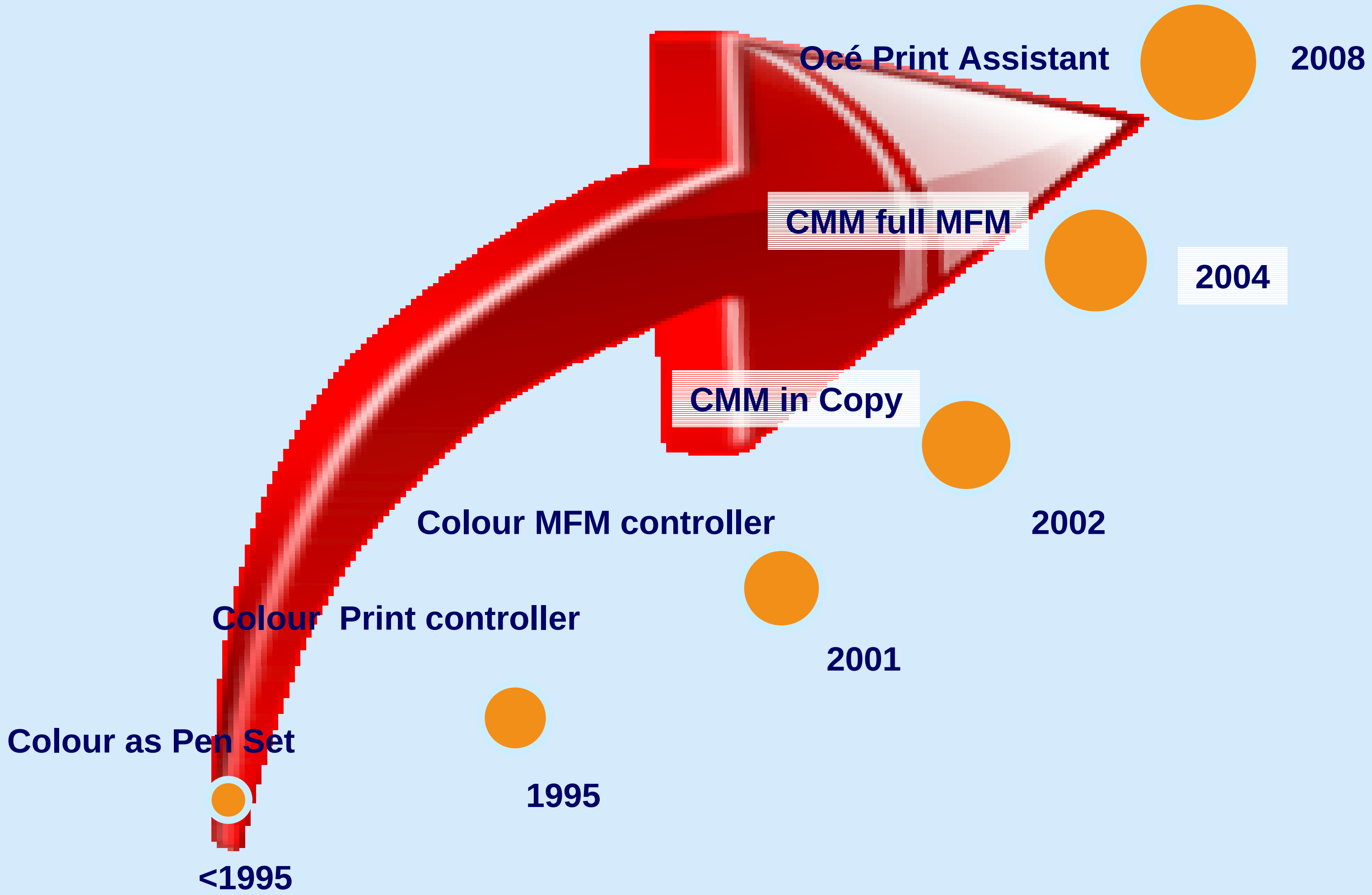
- **High speed printers of exceptional quality**
  - The Océ JetStream 2200 is a digital, full-color printing system capable of producing exceptional quality full-color data at high speed.
  - Océ JetStream technology uses a high speed paper path to produce CMYK full-process color output at a speed of 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

Innovation @ Océ

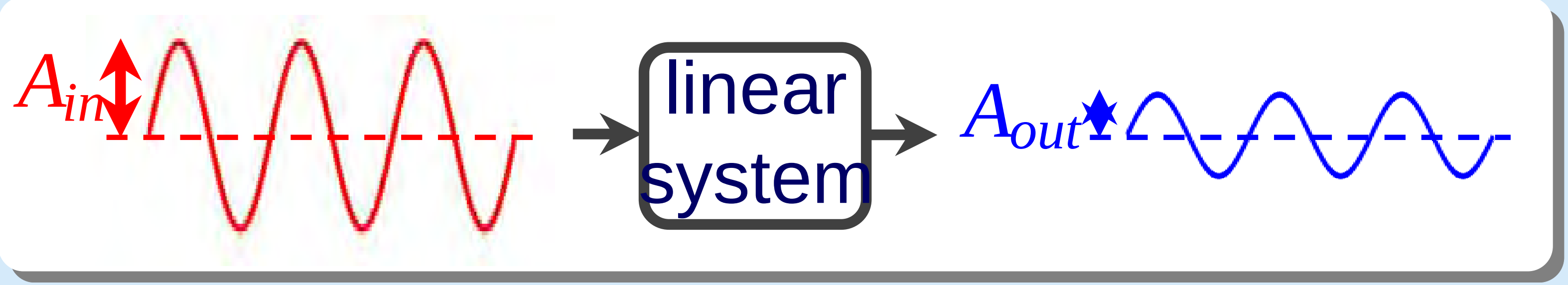
Océ

Printing for Professionals

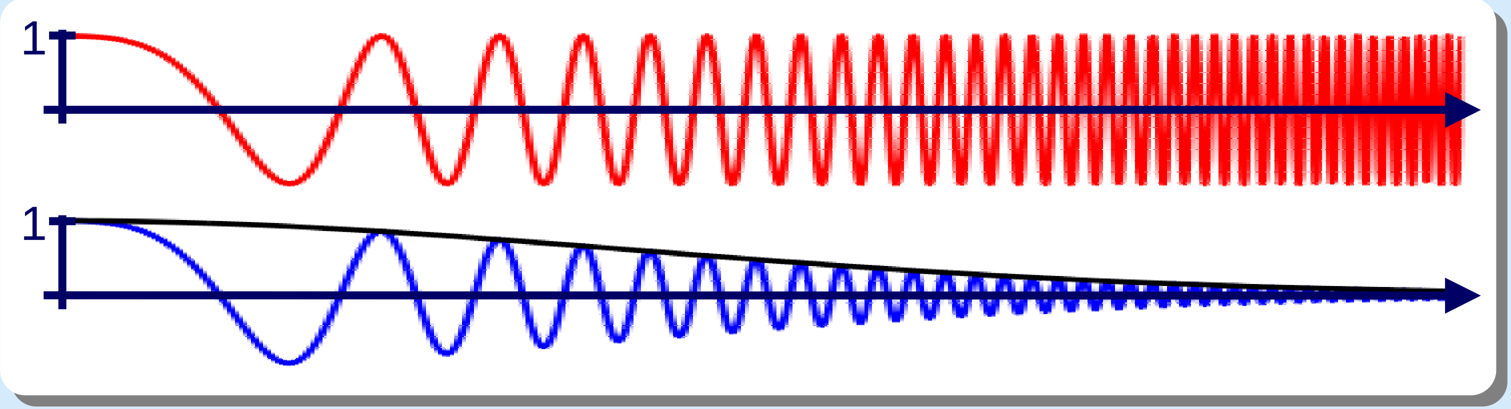
Color and image processing

- 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
  - …

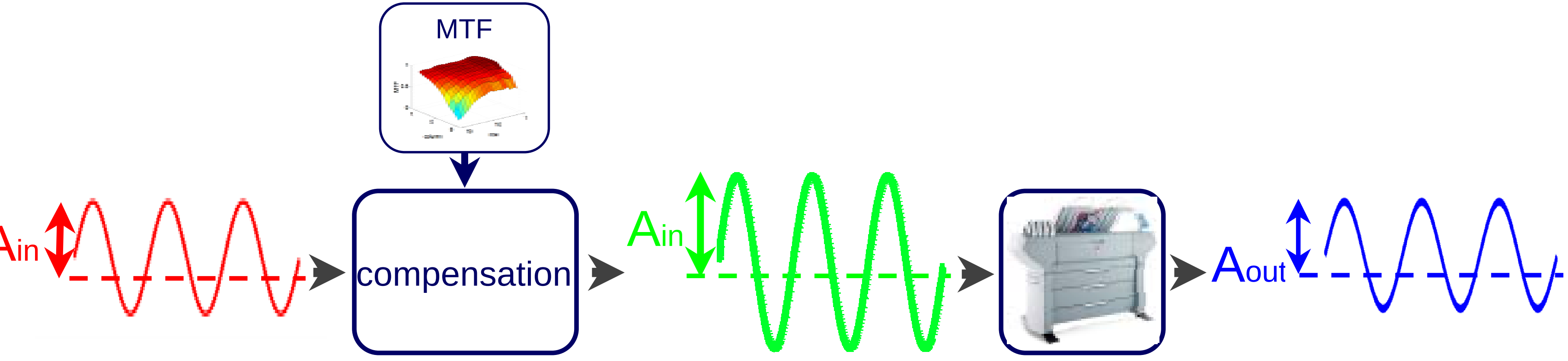
Enhance Prints by Modulation Transfer Function



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



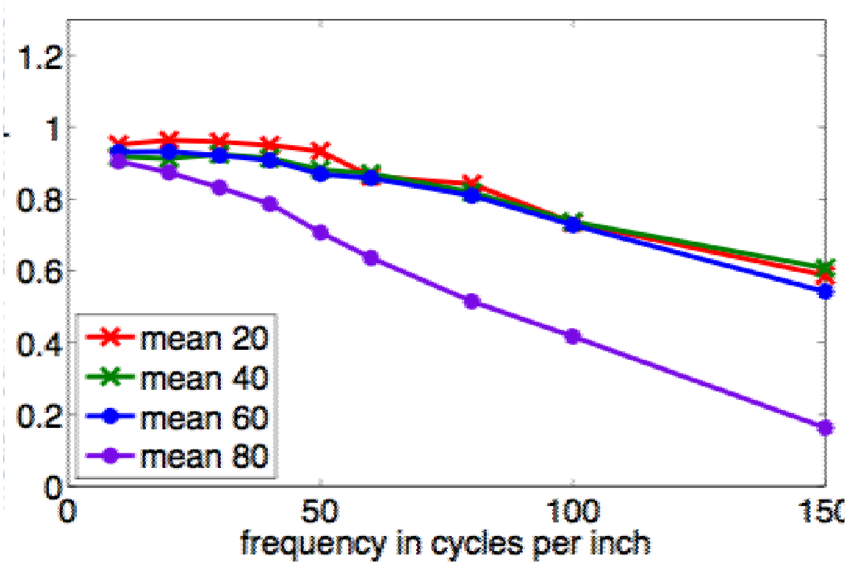
Compensation of the printer MTF



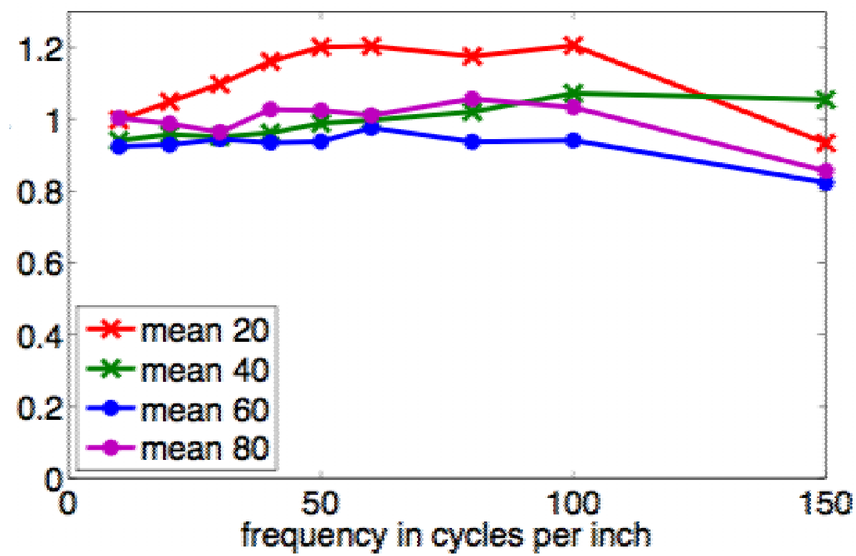
- Our goal is to maintain the high-frequency content in the output print and produce a printed image with a constant *MTF=1*
- We compensate for the degradation due to the printer by boosting the amplitude of the input signal

Impact of the compensation on the MTF of the printout

Without compensation

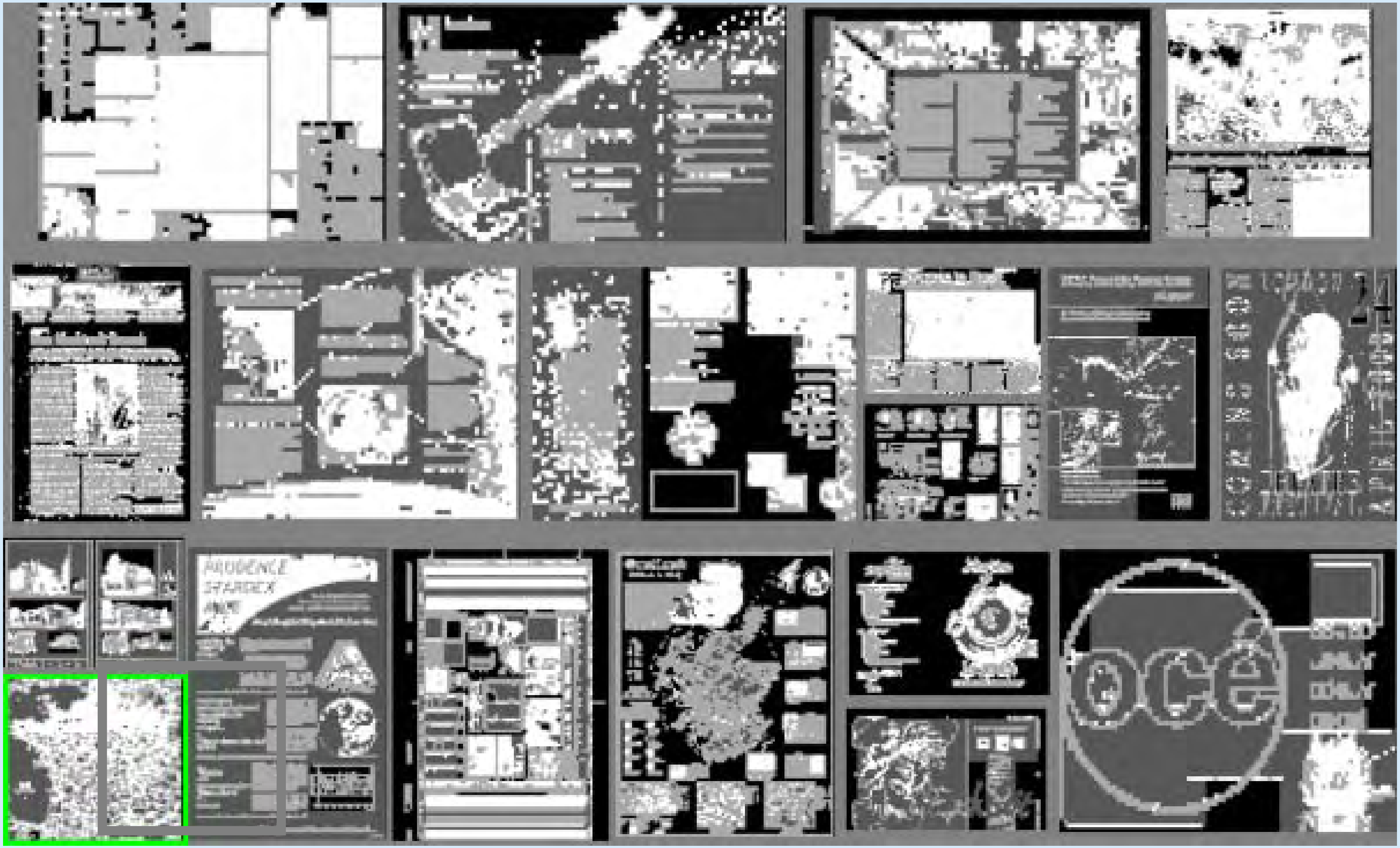


With compensation



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

Classify documents to automate printer systems



PHOTO

LINE/TEXT

COLORED UNIFORM AREA

WHITE UNIFORM AREA

Documents classified as mixed content

Documents classified as photos

Documents classified as Text/CAD

Memory Colors

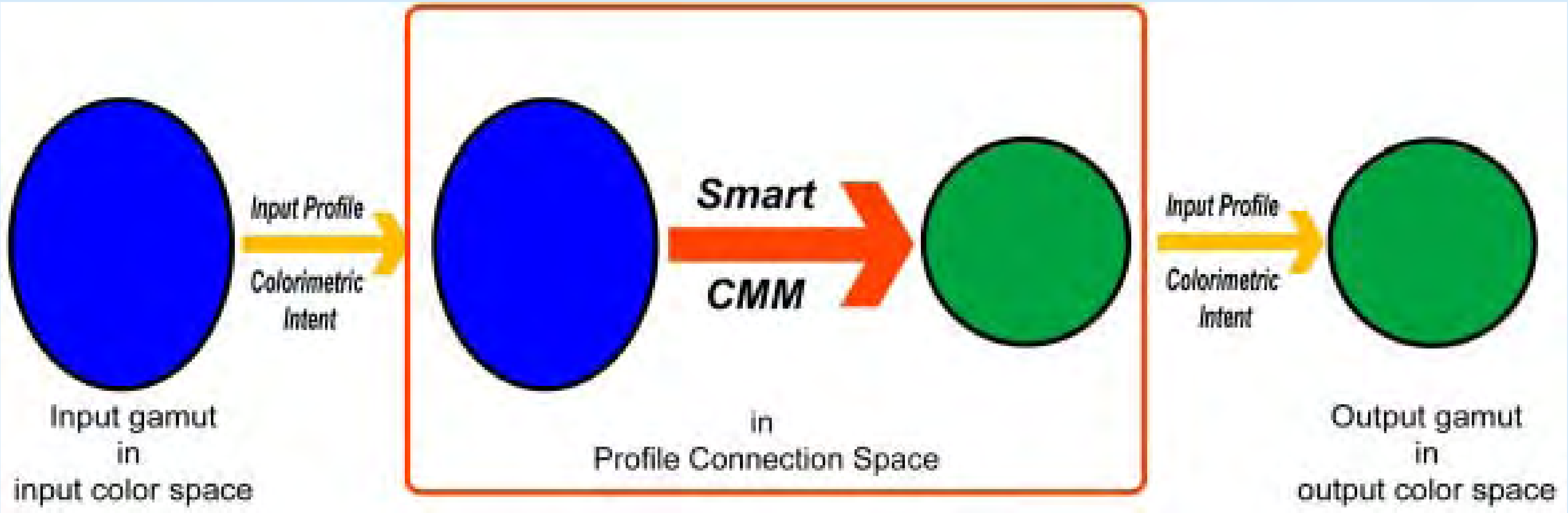
Memory Colors

Improving Gamut Mapping

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

Printing for Professionals

Using the sRGB v4 profile in digital print workflows

prepared by Jack Holm

for the ICC Digital Print Day

4 March 2009

Paris, France

TARKUS IMAGING

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

SWOP preview examples

v2 or v4 sRGB
MRC+BPC

v2 sRGB
MRC

v4 sRGB
MRC

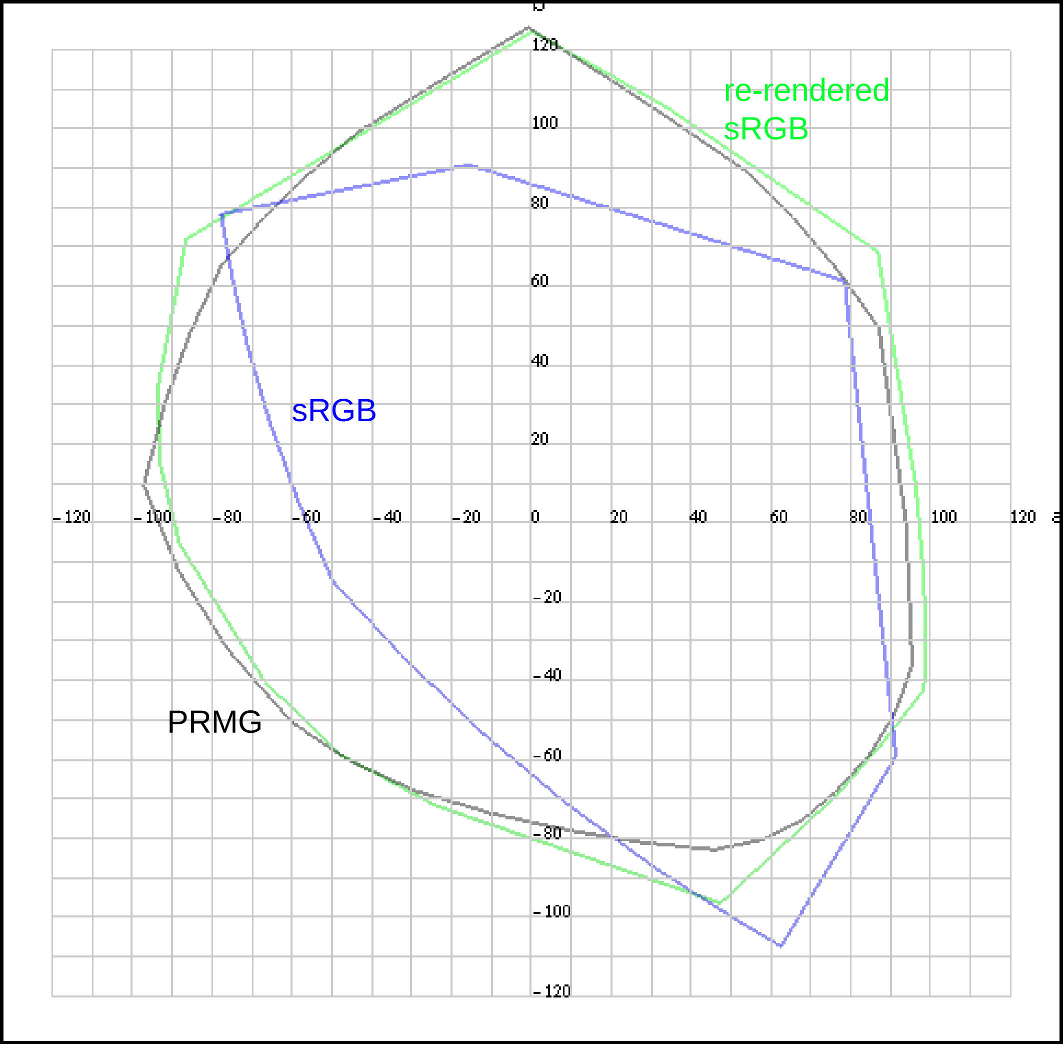
The v4 sRGB profile

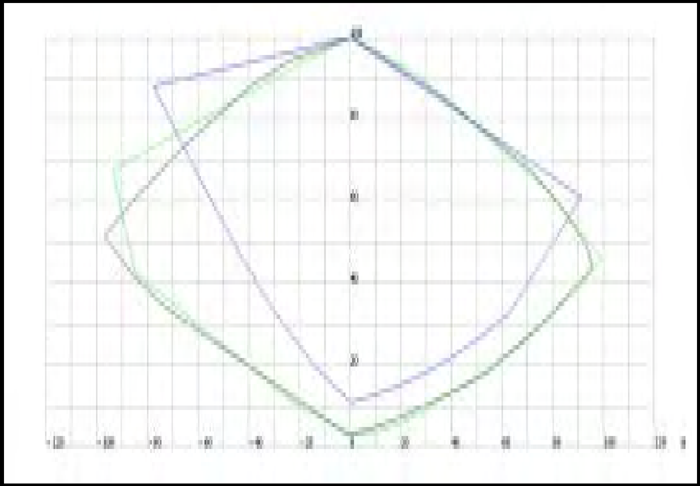
- The colorimetric intent transforms in the v4 sRGB profile do not include black scaling
  - If a display is calibrated to sRGB, and the print viewing conditions are such that the desired white point matches the display white point, the colorimetric rendering intent of the v4 sRGB profile can be used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

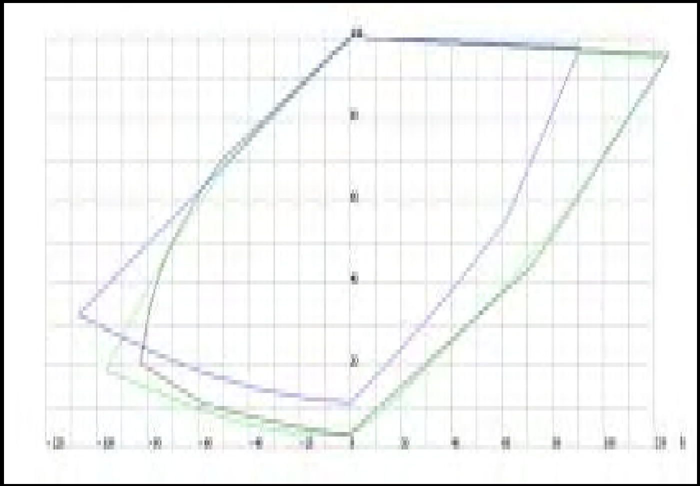
What is color re-rendering?

- 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







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

ROMM RGB image
(gray:colors outside sRGB)

sRGB image
sRGB v4 ICC profile

ROMM RGB image
(gray:colors outside sRGB)

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

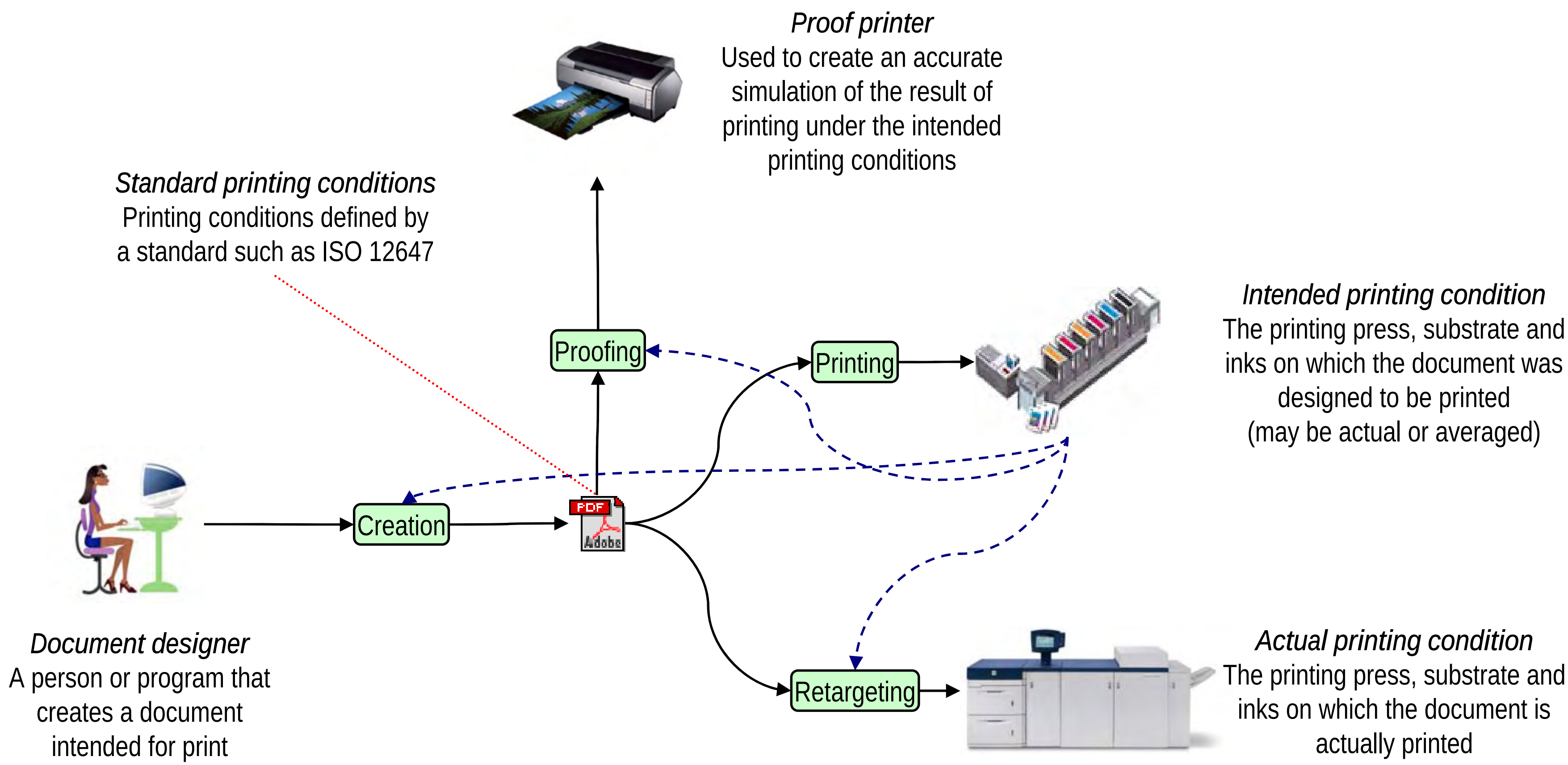
- The v4 sRGB profile supports several new use cases for digital printing
  - But some behaviors are different from existing use cases
- The v4 sRGB profile is designed to be used with other v4 profiles, but can be used with v2 profiles with similar care as is required when using v2 profiles in general
  - 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

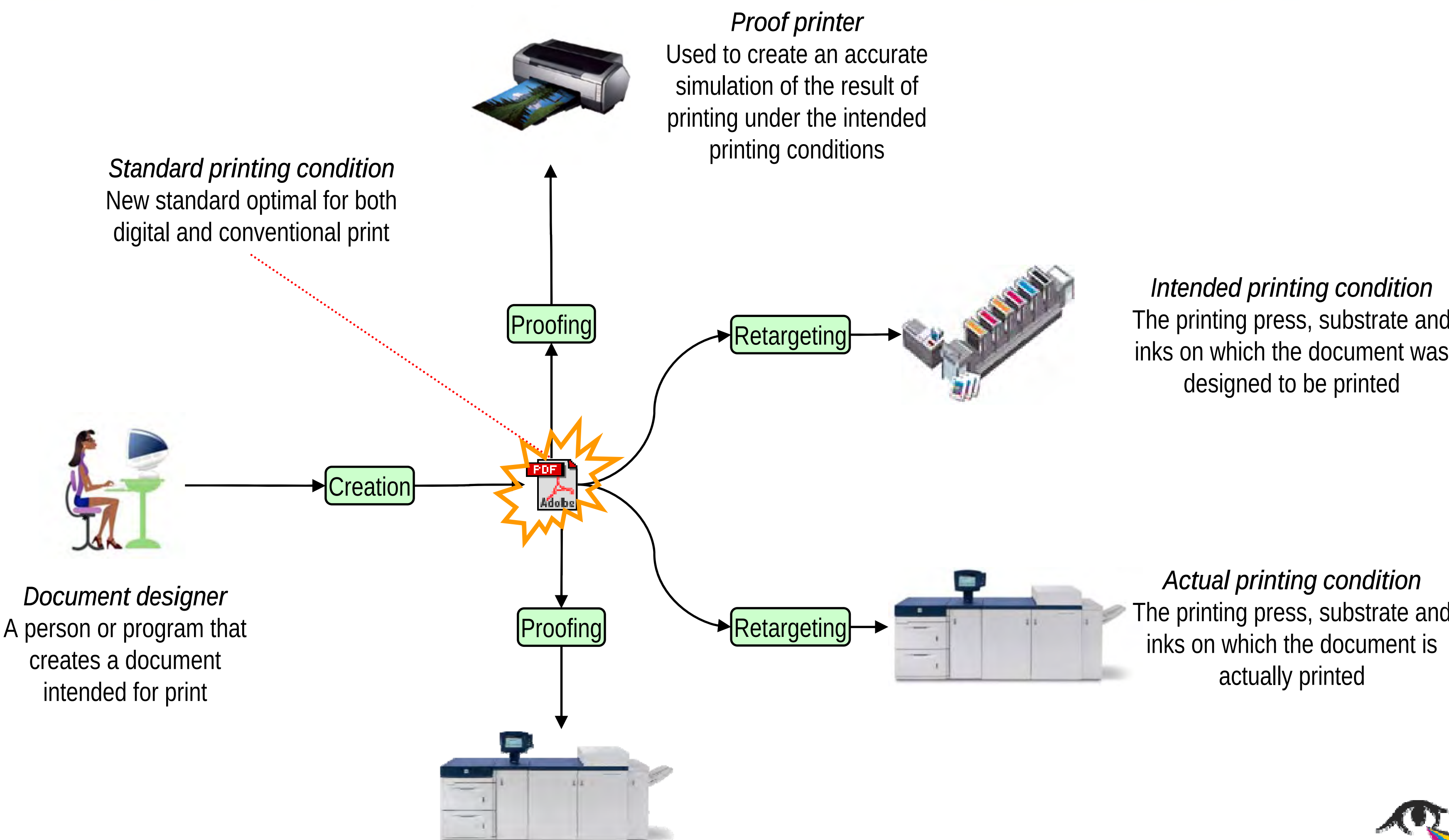
Current workflow for conventional and digital print



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



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**

✓ Print
? Proof
? Retarget

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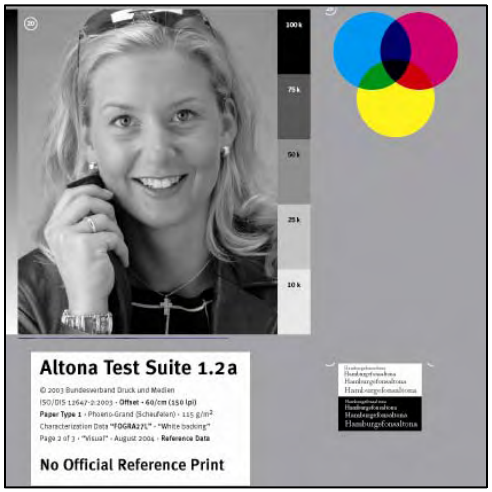
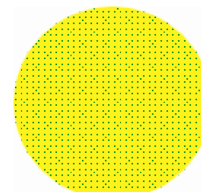
CMYK, grey and black elements

✓ Print
✓ Proof
? Retarget

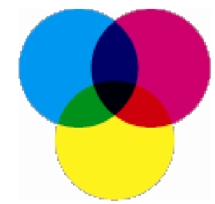


Objective
Define elements in printing space for print production reasons

Avoid fuzzy edges by using black only



Avoid 'scum dots' by using device yellow only



Overprinting effects (trapping, small text…)

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

‘RGB’ Images and other content

✓ Print
✓ Proof
? Retarget

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

✓ Print
? Proof
? Retarget

Objective

Use special ink for corporate brand or for special design effect

Spot colour name

Alternate ColorSpace ← Usually provides 'process equivalent' CMYK values

Tint transform

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…

✓ Print
? Proof
? Retarget

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

Similar problem predicting colour when spot colour overprints other document elements

Proof and Retarget

- No standard way to communicate the colour of ink combinations – it is usually impractical to create ICC Profiles for each combination

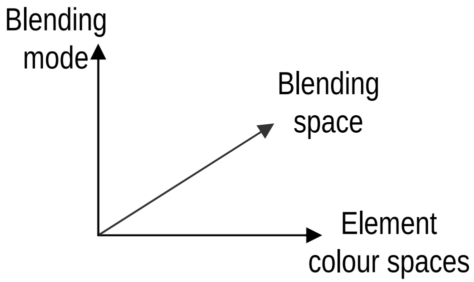
Transparency

✓ Print
✓ Proof
? Retarget

Objective

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

Determining the colour of elements that use transparency is a multi-dimensional problem



Print and Proof

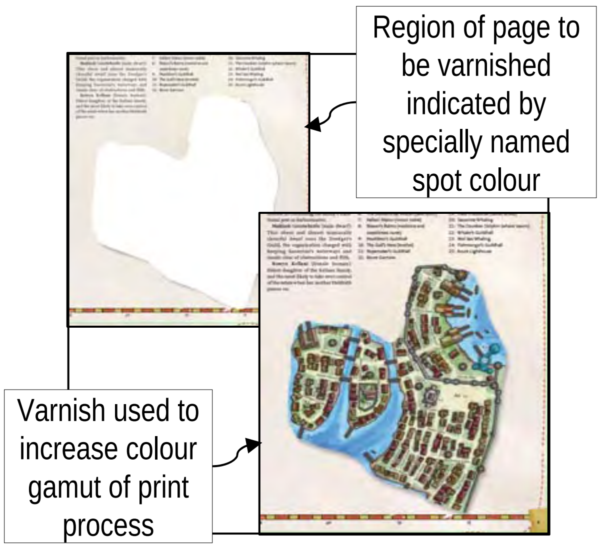
- Some RIPs (not PDF/X-4 compliant) do not handle transparency correctly

Retarget

- In some cases the result of transparency blending may be slightly different due to change in blending space

Varnish and special inks

✓ Print
? Proof
? Retarget



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

Metallic ink

Fluorescent ink

Pearlescent ink

Colour matching of special inks on hard copy proof not usually practical

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

Ink Properties

How to Store and Preview in PDF

Leonard Rosenthol
PDF Standards Architect
Adobe Systems

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??

Adobe

Special Ink Properties

- 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.

Ink Order & Opacity - Possible Solution - NChannel Color

- 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

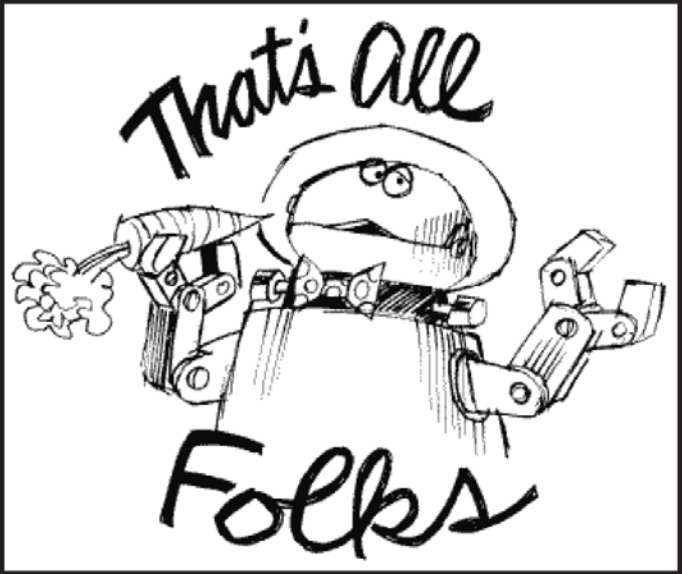
Ink Order & Opacity - Possible Solution - ICC Profiles

- 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/CMYK 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

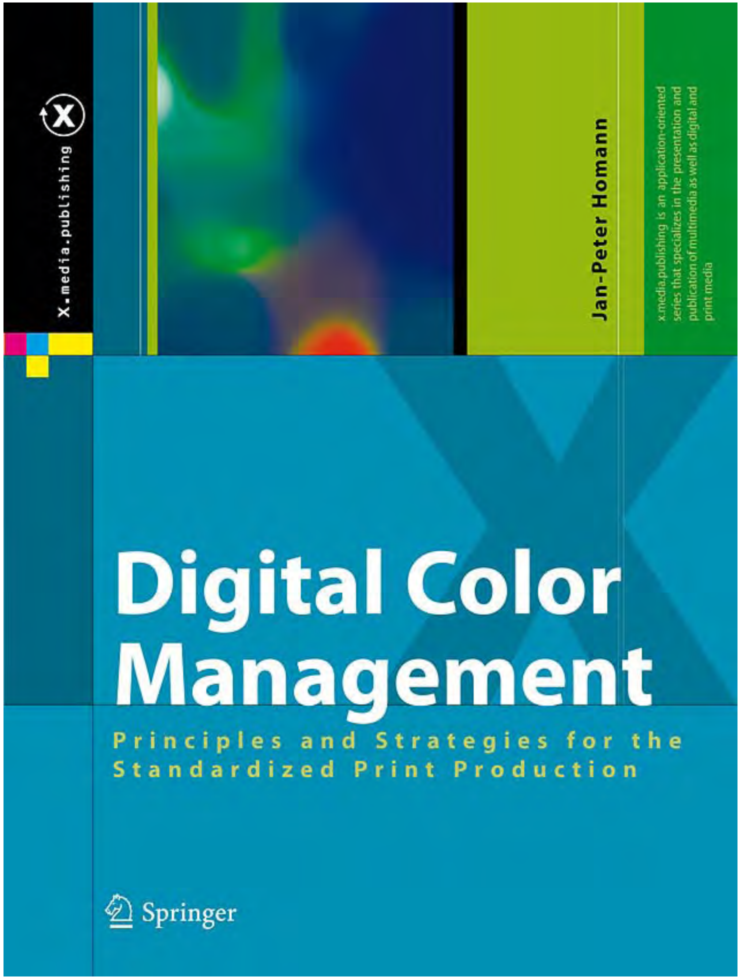
Matching GRACoL / TR 006 and FOGRA39 in Digital Printing

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 adresses 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.
- See also

http://www.color.org/TAGA_2007_Neutral_Scales_Press_Calibration.pdf

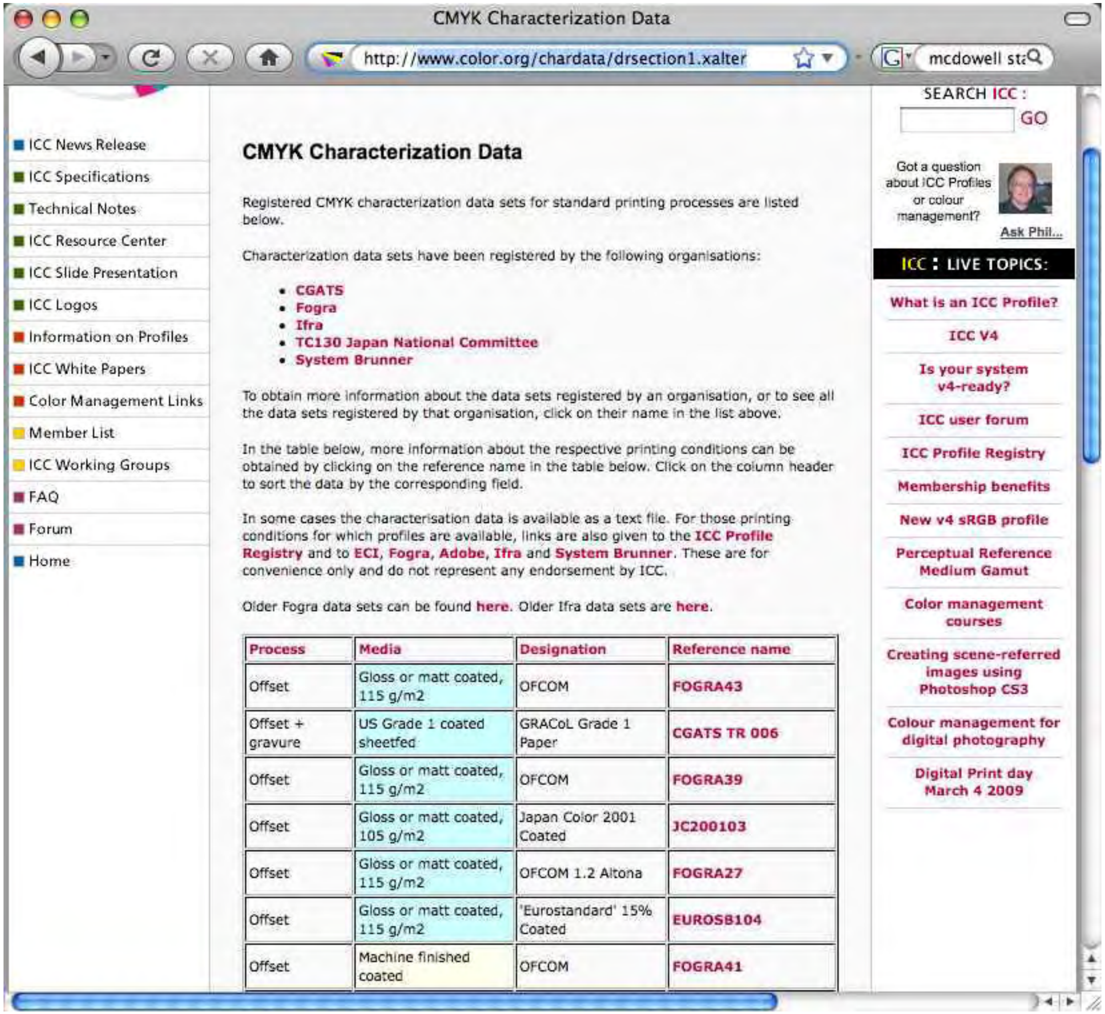
ISO 15930 PDF/X

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 th print provider, PDF/X recommend to agree on reference printing conditions like e.g. FOGRA39 or GRACoLcoated / TR 006 hosted at the ICC

The Ghent Workgroup www.gwg.org backed by all relevant vendors works on workflow specificatios for PDF/X in practice including recommendations for ICC profiles

ICC characterization-data registry



CMYK Characterization Data

http://www.color.org/chardata/drsection1.xalter

mcdowell st

- ICC News Release
- ICC Specifications
- Technical Notes
- ICC Resource Center
- ICC Slide Presentation
- ICC Logos
- Information on Profiles
- ICC White Papers
- Color Management Links
- Member List
- ICC Working Groups
- FAQ
- Forum
- Home

CMYK Characterization Data

Registered CMYK characterization data sets for standard printing processes are listed below.

Characterization data sets have been registered by the following organisations:

- **CGATS**
- **Fogra**
- **Ifra**
- **TC130 Japan National Committee**
- **System Brunner**

To obtain more information about the data sets registered by an organisation, or to see all the data sets registered by that organisation, click on their name in the list above.

In the table below, more information about the respective printing conditions can be obtained by clicking on the reference name in the table below. Click on the column header to sort the data by the corresponding field.

In some cases the characterisation data is available as a text file. For those printing conditions for which profiles are available, links are also given to the **ICC Profile Registry** and to **ECI, Fogra, Adobe, Ifra** and **System Brunner**. These are for convenience only and do not represent any endorsement by ICC.

Older Fogra data sets can be found **here**. Older Ifra data sets are **here**.

Process	Media	Designation	Reference name
Offset	Gloss or matt coated, 115 g/m2	OFCOM	FOGRA43
Offset + gravure	US Grade 1 coated sheetfed	GRACoL Grade 1 Paper	CGATS TR 006
Offset	Gloss or matt coated, 115 g/m2	OFCOM	FOGRA39
Offset	Gloss or matt coated, 105 g/m2	Japan Color 2001 Coated	JC200103
Offset	Gloss or matt coated, 115 g/m2	OFCOM 1.2 Altona	FOGRA27
Offset	Gloss or matt coated, 115 g/m2	'Eurostandard' 15% Coated	EUROSB104
Offset	Machine finished coated	OFCOM	FOGRA41

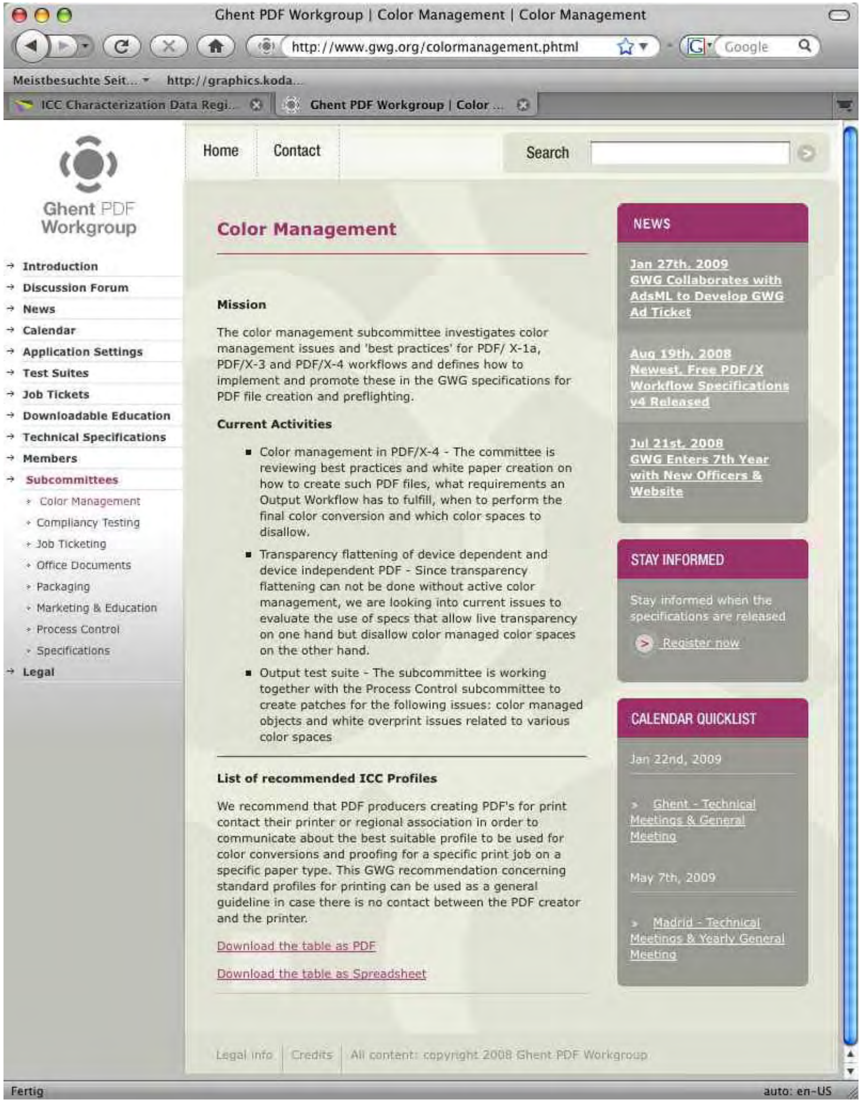
SEARCH ICC : GO

Got a question about ICC Profiles or colour management? Ask Phil...

ICC : LIVE TOPICS:

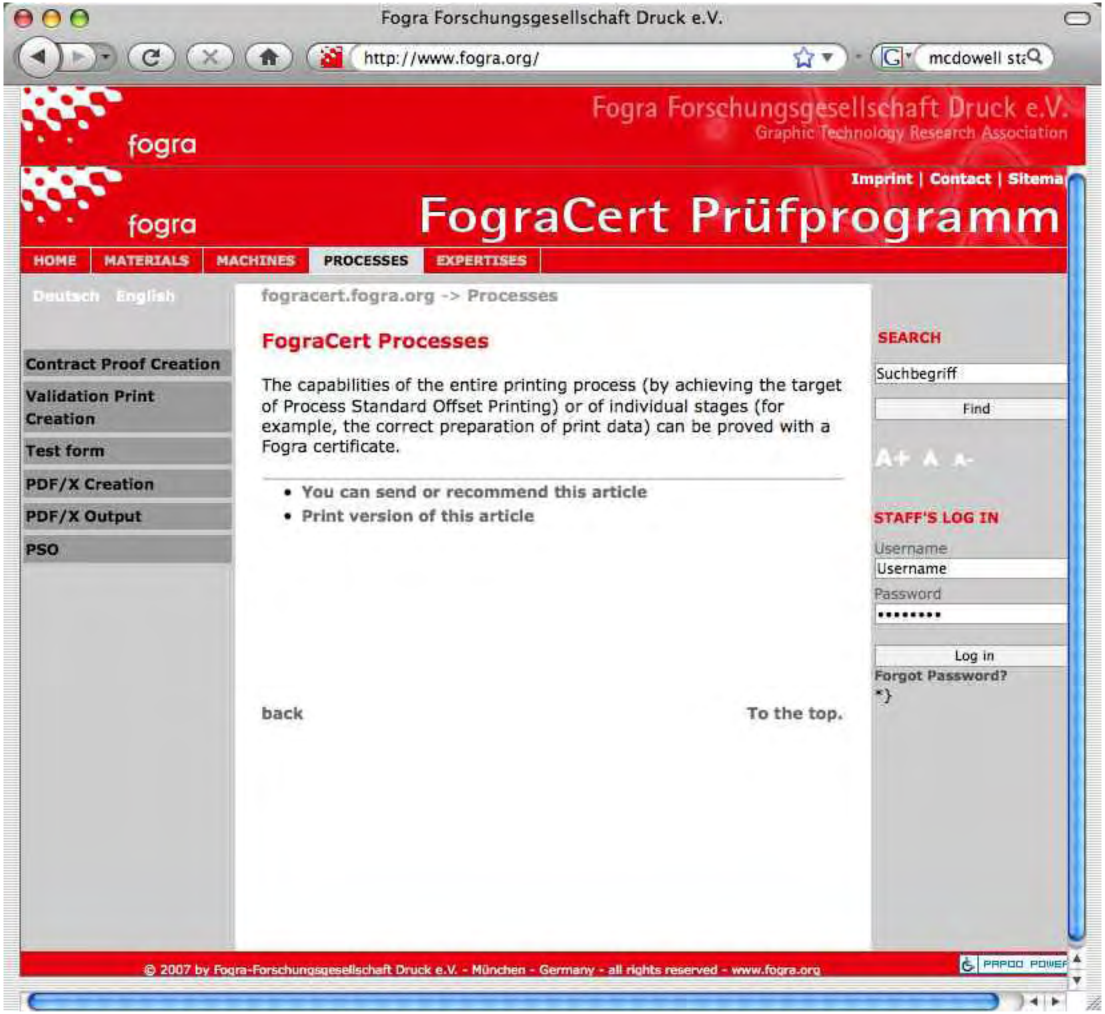
- What is an ICC Profile?
- ICC V4
- Is your system v4-ready?
- ICC user forum
- ICC Profile Registry
- Membership benefits
- New v4 sRGB profile
- Perceptual Reference Medium Gamut
- Color management courses
- Creating scene-referred images using Photoshop CS3
- Colour management for digital photography
- Digital Print day March 4 2009

GWG list of profiles

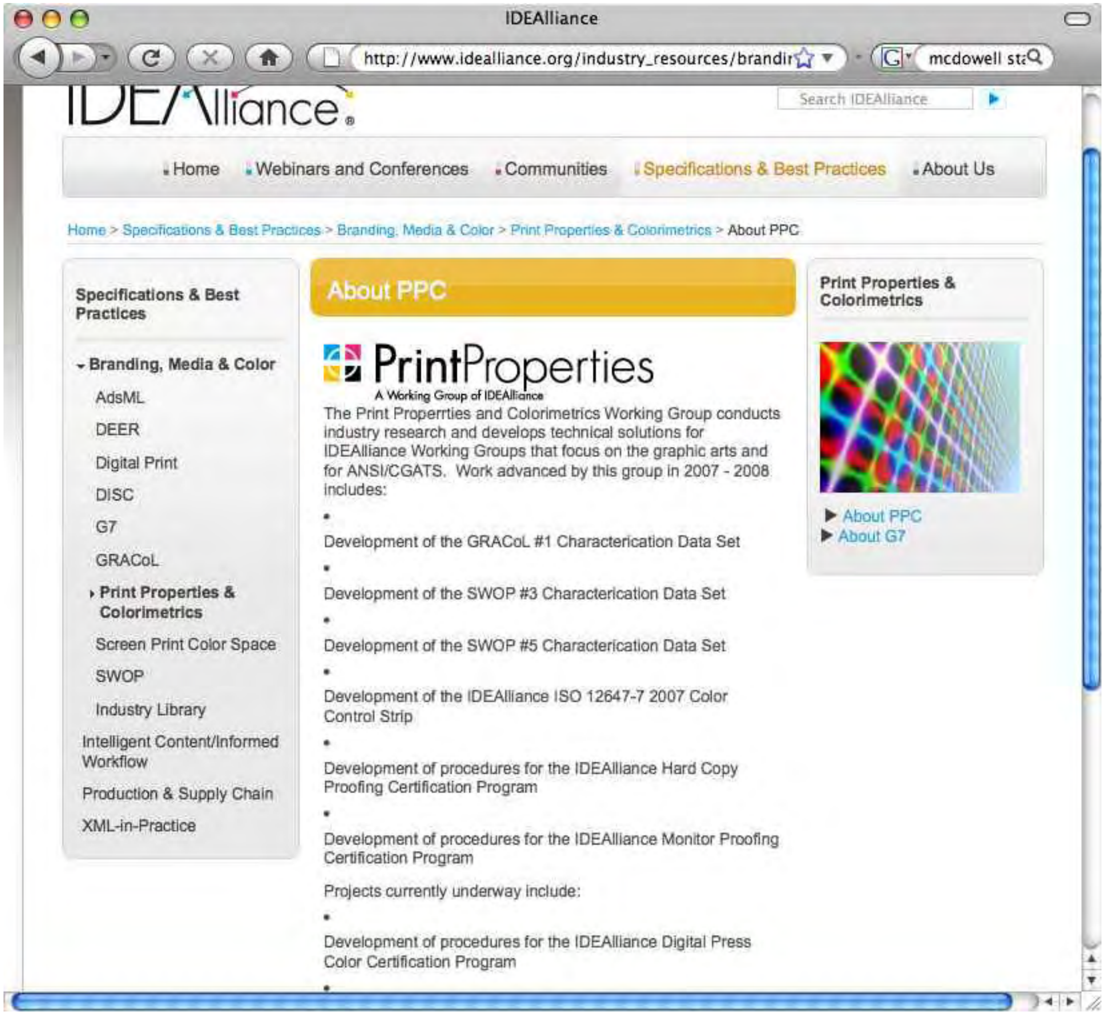


FOGRAcert machines

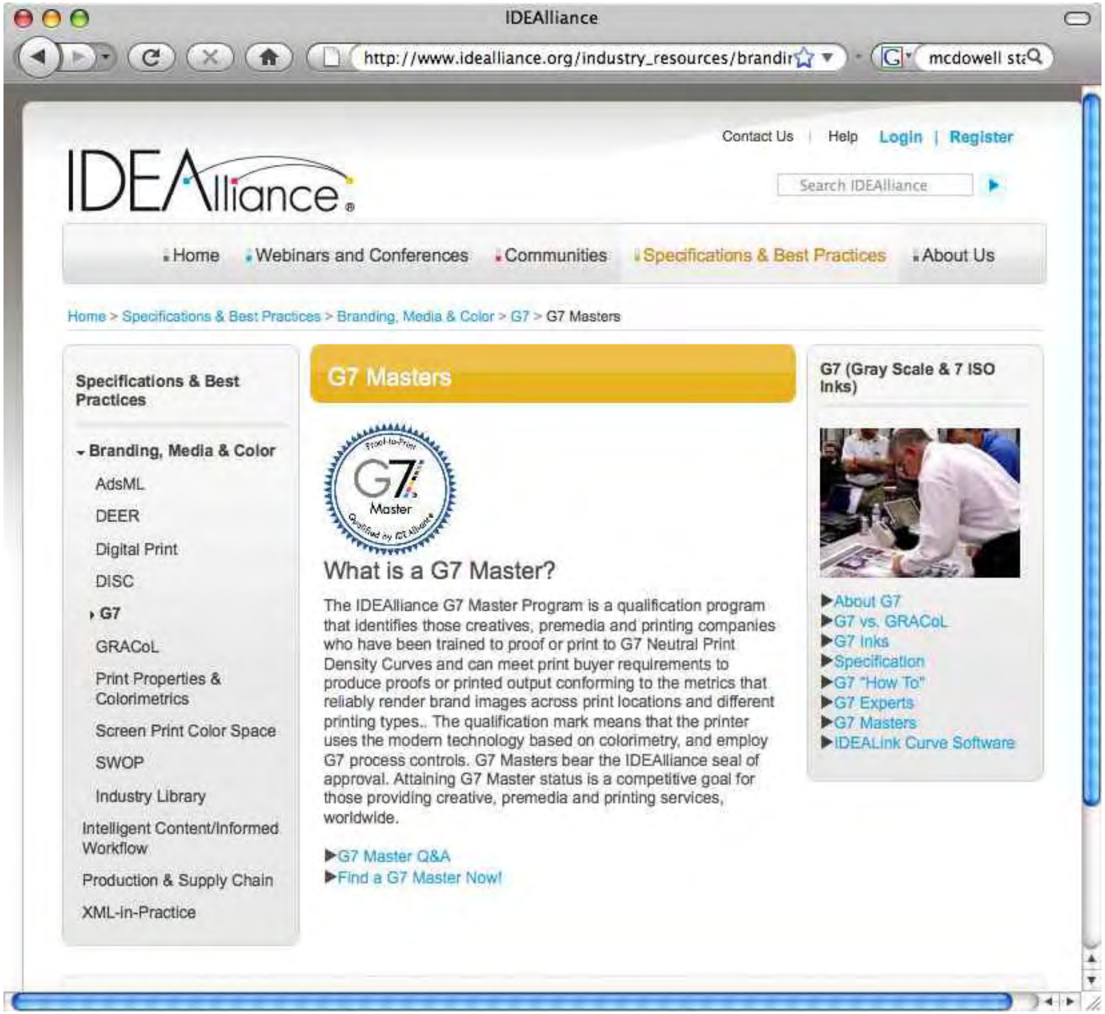
FOGRAcert processes



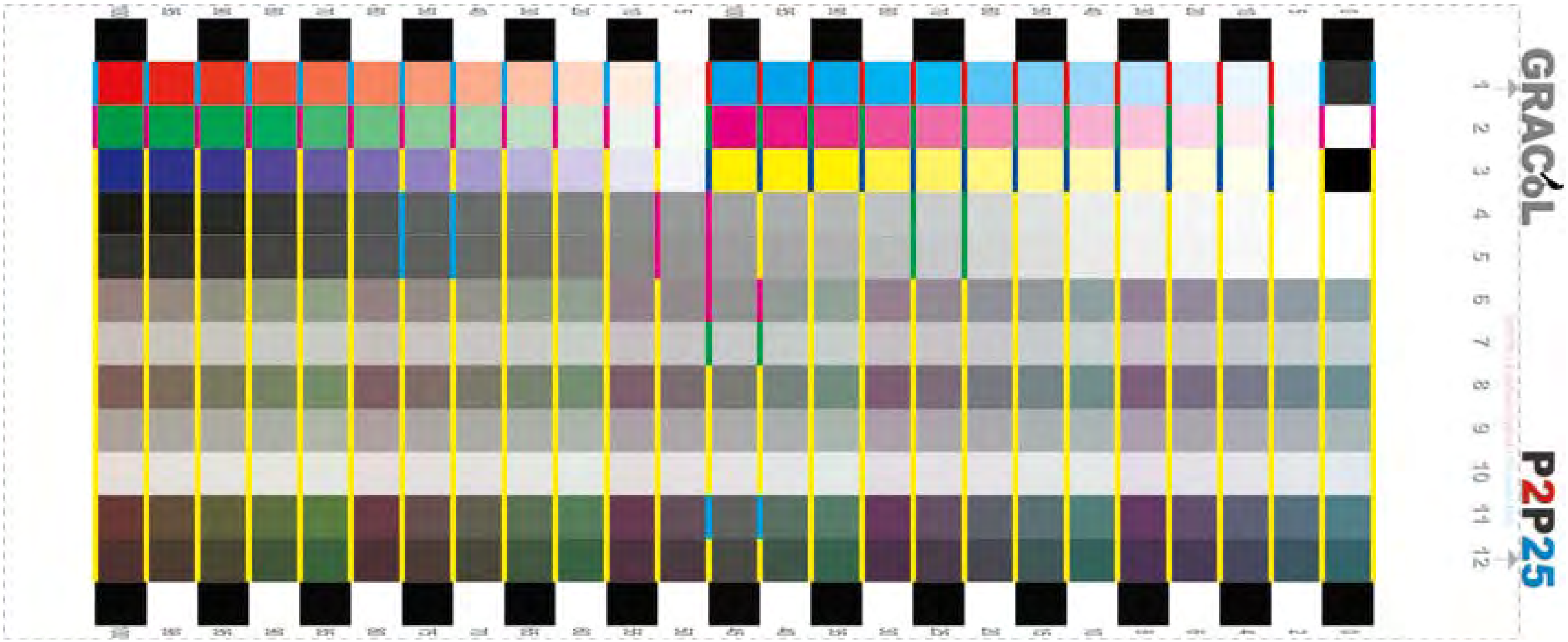
IDEAlliance Certifications



IDEAlliance / G7 Master



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 colormanagement 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 the result according ISO 12647-7

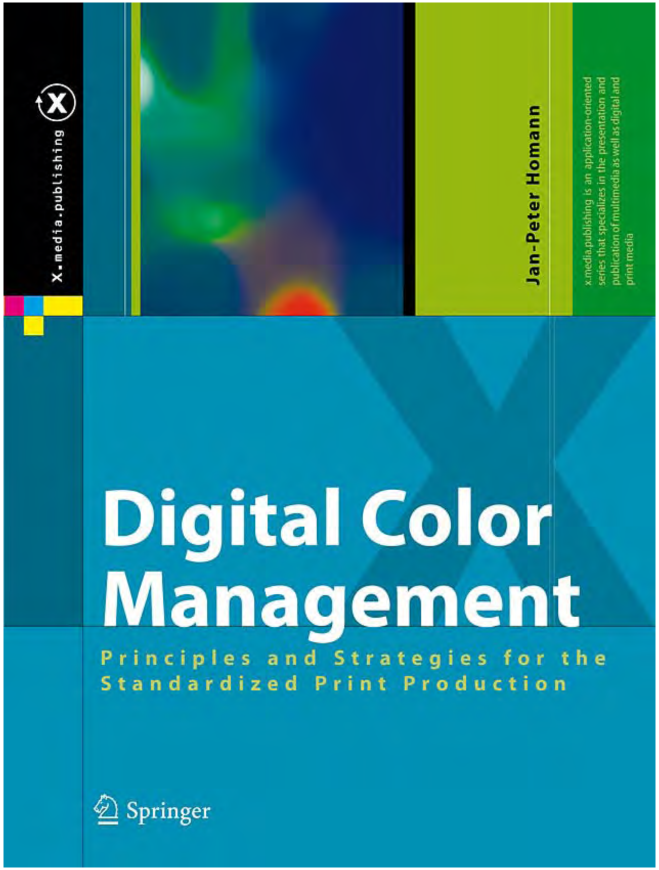
- Use a software for validating color output according ISO 12647-7
- The validation should be done on basis of an ECI 2002 or IT8/7.4 Testchart
- Several proofing vendors offering such solutions
- Certifications of FOGRA and IDEAlliance will probably make similar evaluations both for systems and print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

Rue du Rhône 114- CH-1204 Geneva - T: +41 22 849 6000 - F: +41 22 849 6001 - www.ecma-international.org

OpenXPS Standardization
Overview of progress

- 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

OpenXPS Standardization
Colour Rules

- 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**

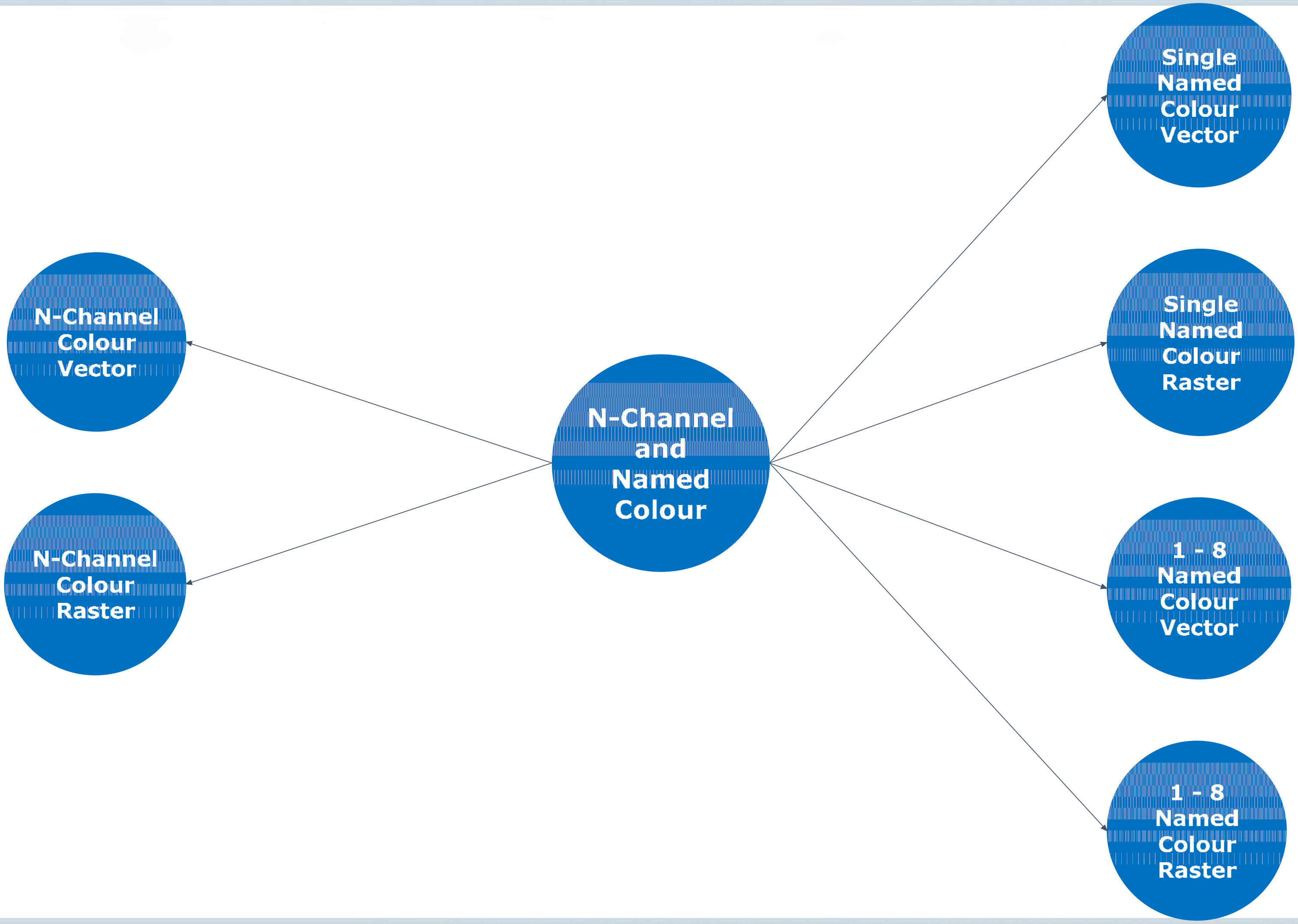
OpenXPS Standardization
ICC Source Profile Provisions

- 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

<u>XPS ICC source profile colour spaces</u>

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**

N-Channel colour with alpha*	`Color="ContextColor ProfileURI AlphaFloat, Chan0Float, ..., ChanN-1Float"`
E.g., '5CLR'	`Color="ContextColor /5nchannelprofile.icc 1.0, 1.0, 0.0, 0.0, 1.0, 0.0"`

Named colour with alpha*	`Color="ContextColor ProfileURI AlphaFloat, TintFloat"`
E.g., 'GRAY'	`Color="ContextColor /namedtintprofile.icc 1.0, 1.0"`

*AlphaFloat = 1.0 is opaque

OpenXPS Standardization
N-Channel and Named Colour

- 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:

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

    - ../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**

OpenXPS Standardization N-Channel and Named Colour

- **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

OpenXPS Standardization N-Channel and Named Colour

- 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 ⇨ 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

r	g	b	L	a	b	hue	chroma	ratio a:b
192	**253**	**255**	95.00	-19.00	-8.00	**202.8**	**21**	2.38
0	**238**	**248**	85.00	-46.00	-19.00	**202.4**	**50**	2.42
0	**221**	**231**	80.00	-43.00	-18.00	**202.7**	**47**	2.39
0	**207**	**216**	75.00	-41.00	-17.00	**202.5**	**44**	2.41
0	**187**	**196**	69.00	-38.00	-16.00	**202.8**	**41**	2.38
0	**174**	**181**	64.00	-36.00	-15.00	**202.6**	**39**	2.40
0	**140**	**146**	52.00	-31.00	-13.00	**202.8**	**34**	2.38
0	**126**	**131**	47.00	-29.00	-12.00	**202.5**	**31**	2.42
0	**97**	**101**	37.00	-24.00	-10.00	**202.6**	**26**	2.40
0	**32**	**34**	10.00	-12.00	-5.00	**202.6**	**13**	2.40

Thank You

–

Questions?

ORIS

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 %

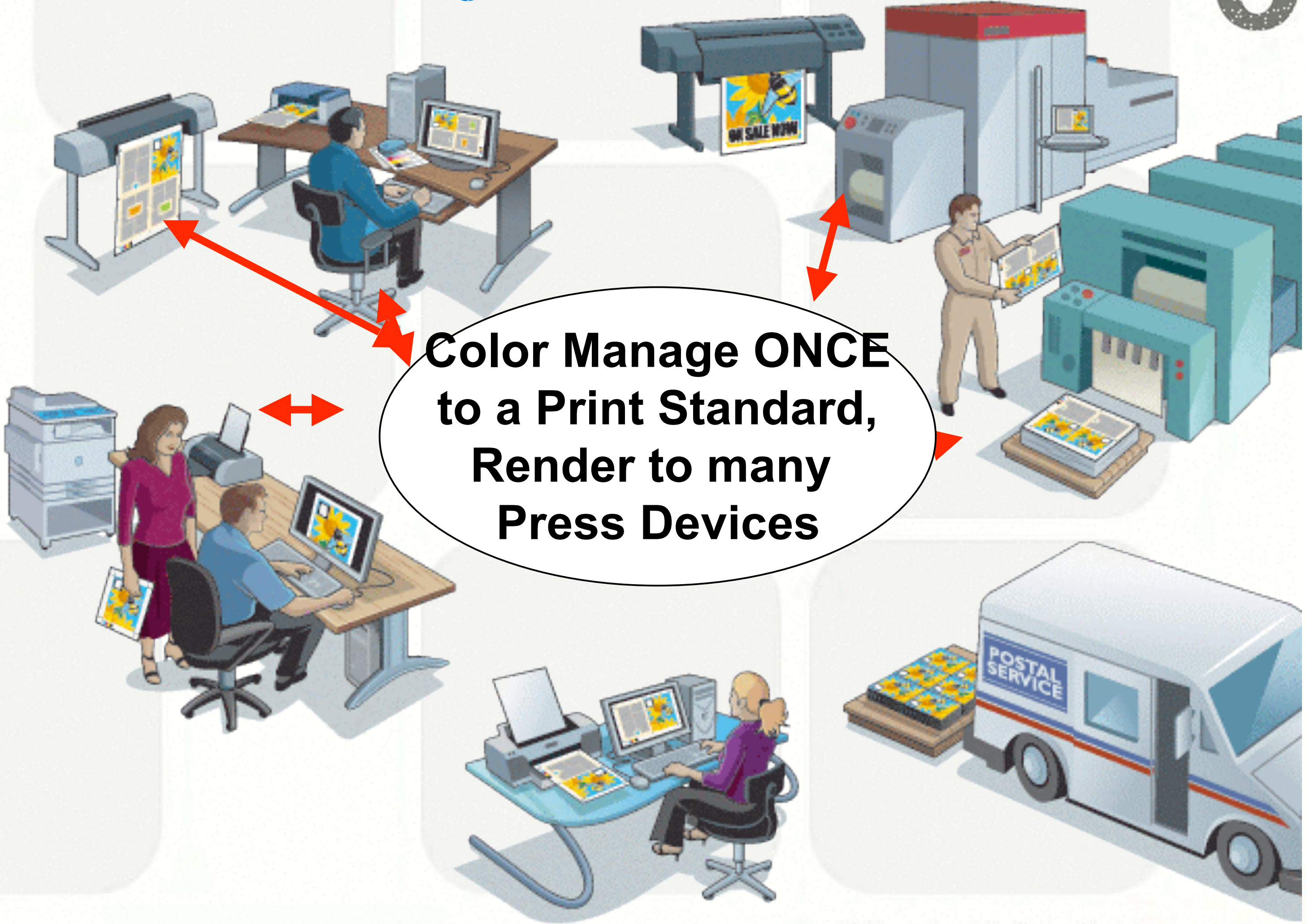
  replaced by digital printing

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



Digital Presses Matched to FOGRA ISOcoated V2 / ISO 12647

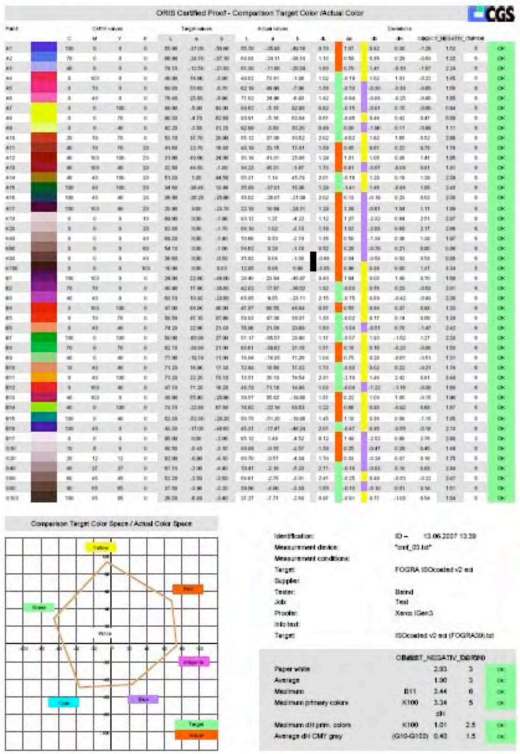
- Canon Image Press C1
- HP Indigo 3050
- HP Indogo press 5000 / 5500
- Konica Minolta C451
- Konica Minolta C6500
- Xerox iGen 3 / 4™
- Xeror DocuColor™ 242 / 252 / 260
- Xerox 700 Digital Color Press
- Xerox DocuColor™ 5000 / 5065
- Xerox DocuColor™ 7000 / 8000 Digital Press
- And so on ...

Match Results

- The result are prints within Fogra ISOcoated v2

  ΔE < 1...2 average

  ΔE < 5...8 max



Aim: ISO 12647-7

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

	ΔE^*_{ab} paper white	Average ΔE^*_{ab} of all color patches	Max. ΔE^*_{ab} of all color patches	Max. ΔE^*_{ab} of primary colors	Max. ΔH of primary colors	Average ΔH gray patches
Tolerance	3	3	6	5	2,5	1,5

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

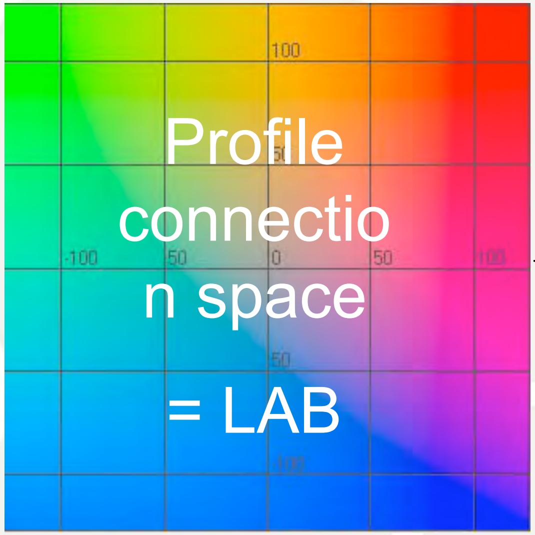
Additional advantages

Any drawbacks?

ICC based color management

RGB input profile

CMYK input profile



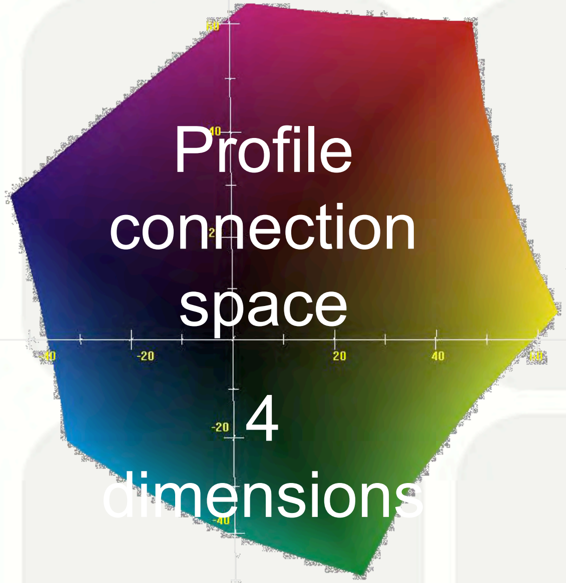
CMYK press profile

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

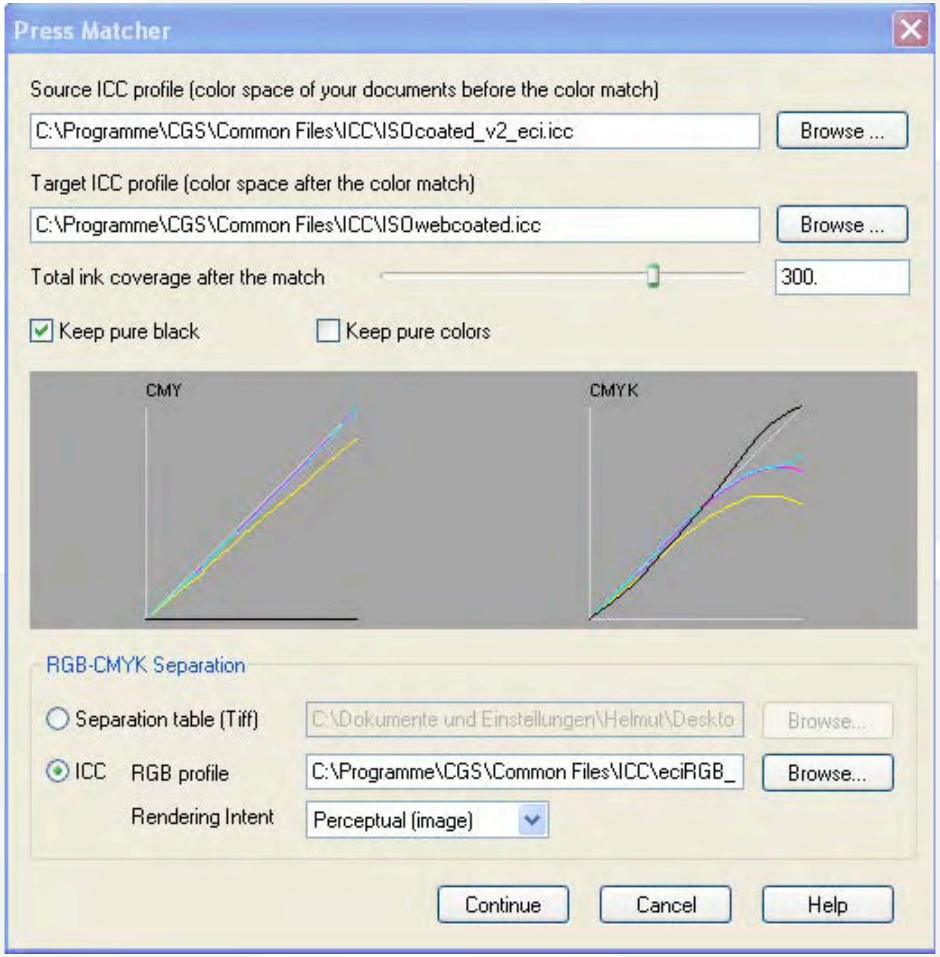
  If you use more than a few target color gamuts you need lots of device links. May be a logistic chalenge.

Creation of device links

Easy to create:

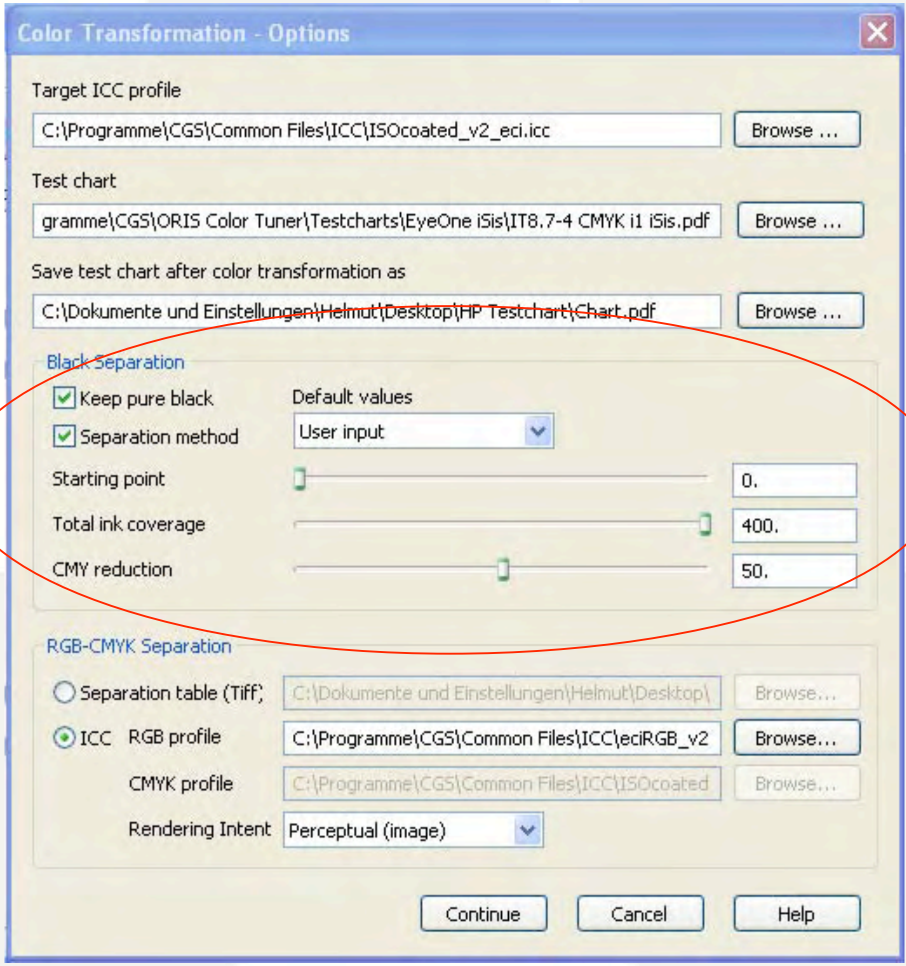
- Use of ICC profile for color matching
- Color matching with iterations

Device link creation using ICC profiles



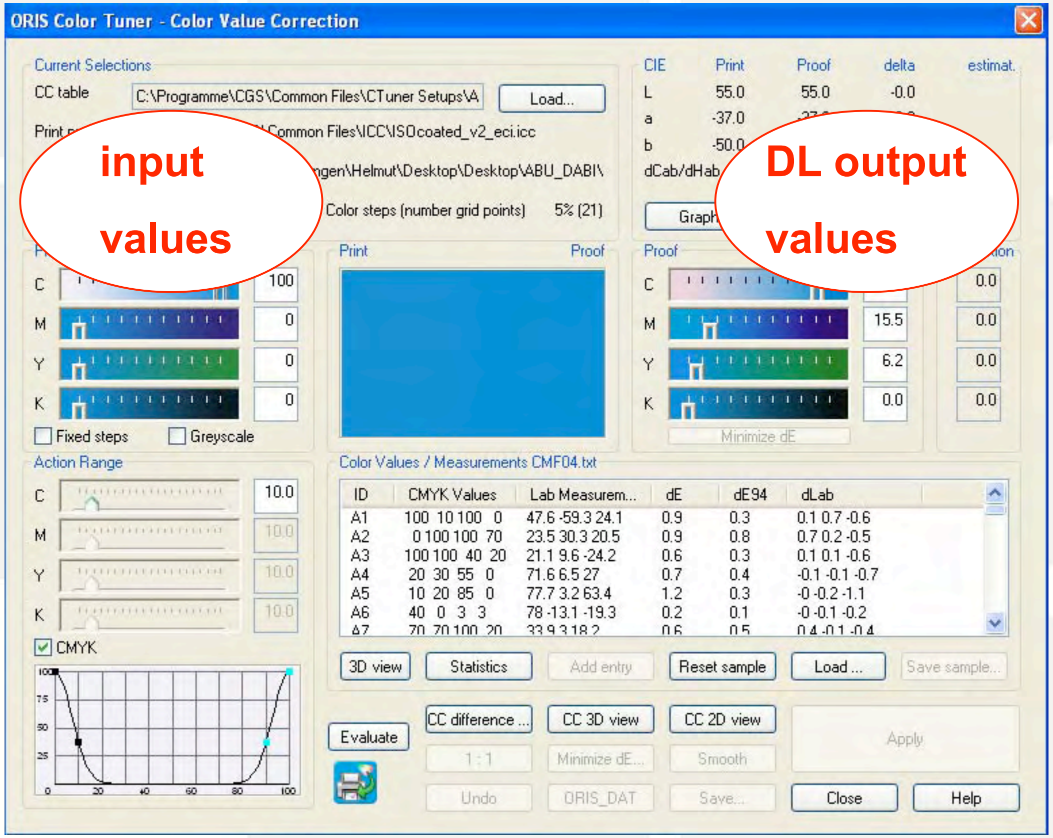
Settings for the black separation

Device link creation using ICC profiles



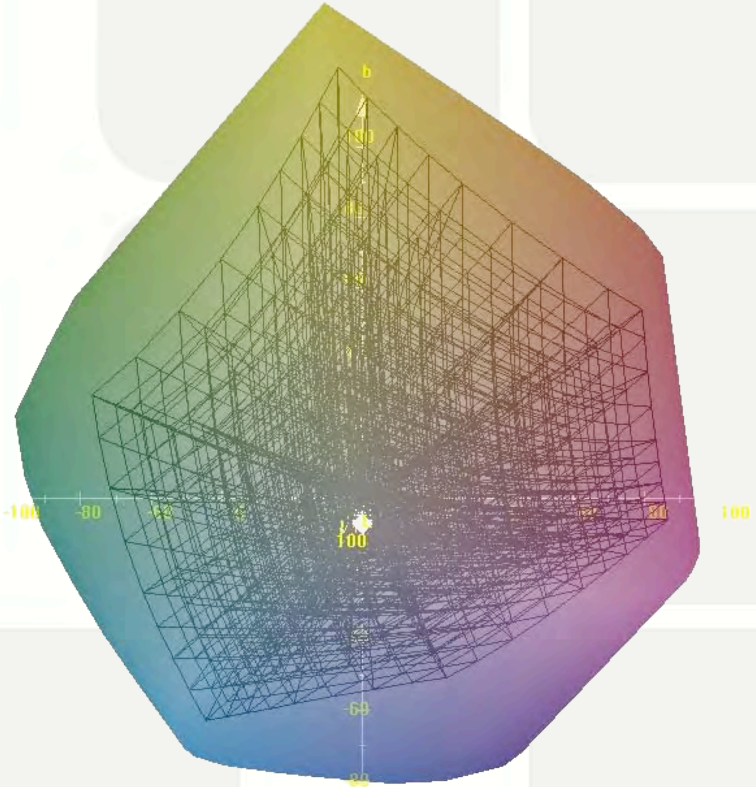
Settings for the black separation

Device link editor

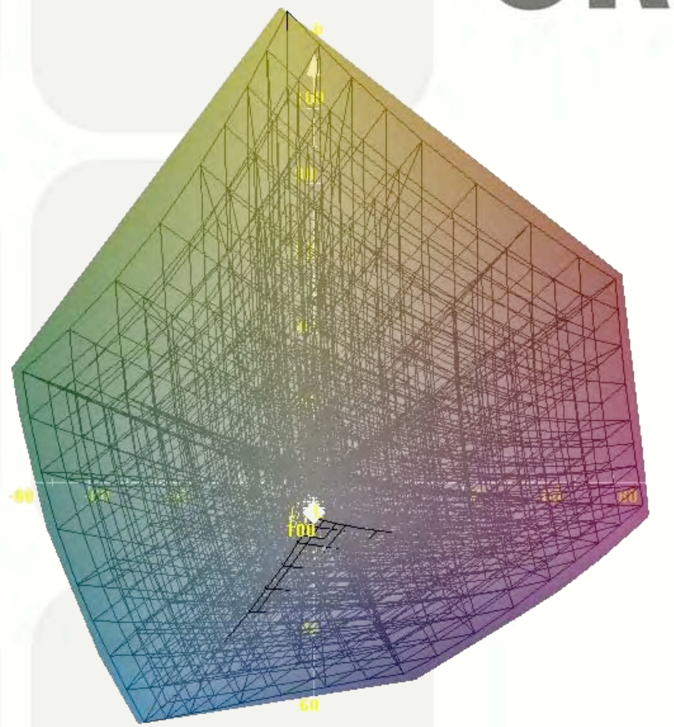


A device link profile is easy to edit

Result with ICC method



Gamut / match before

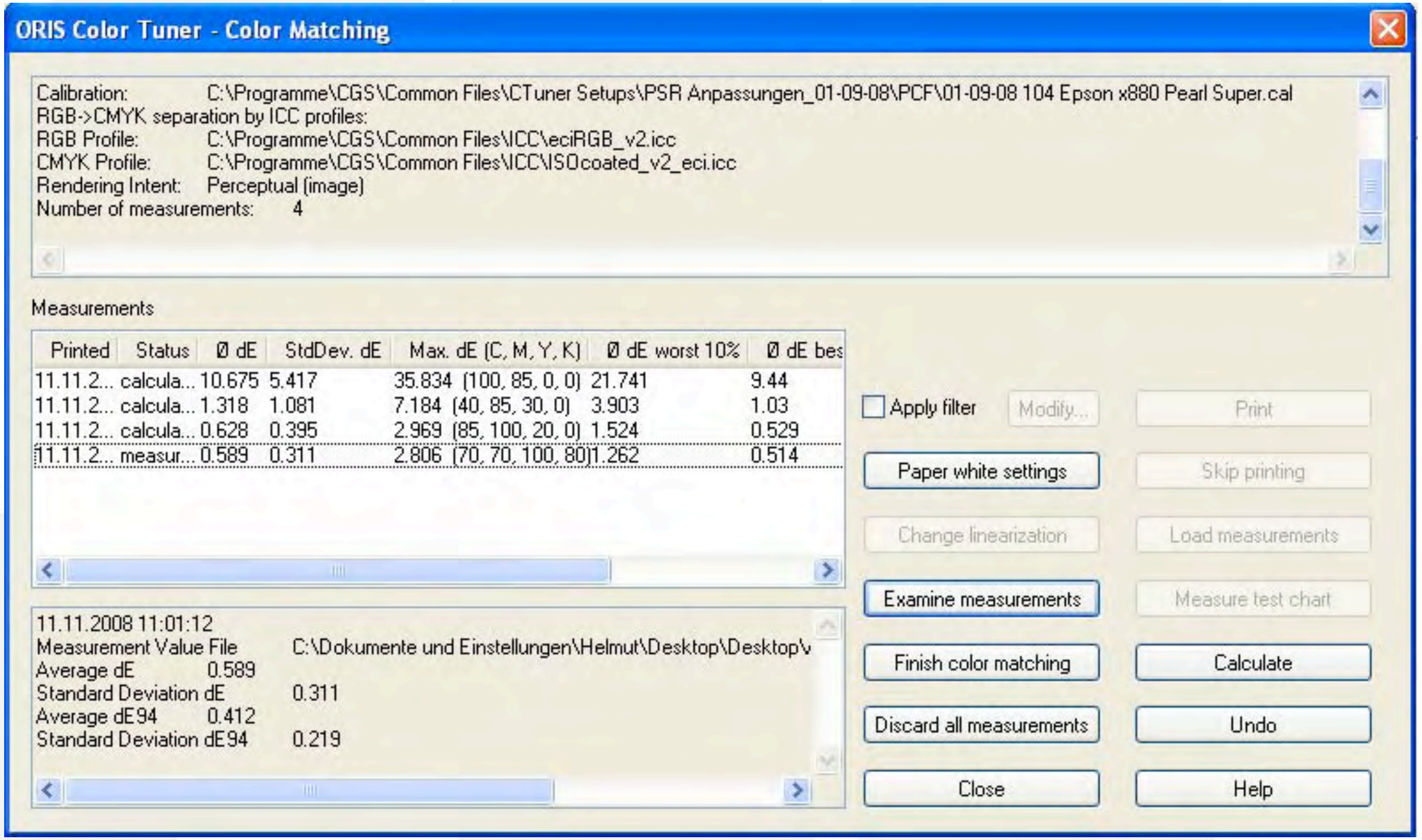


Gamut / match after

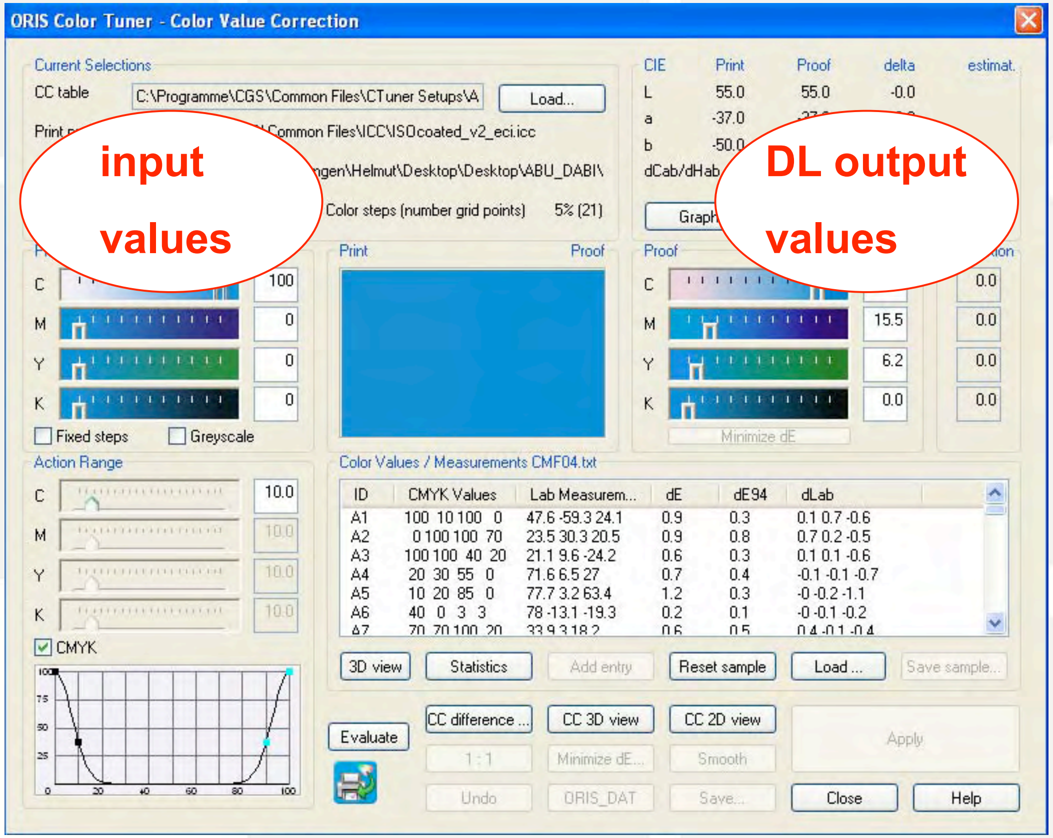
Color matching with iteration

Approach to achieve Delta E = 0

Color matching with iteration

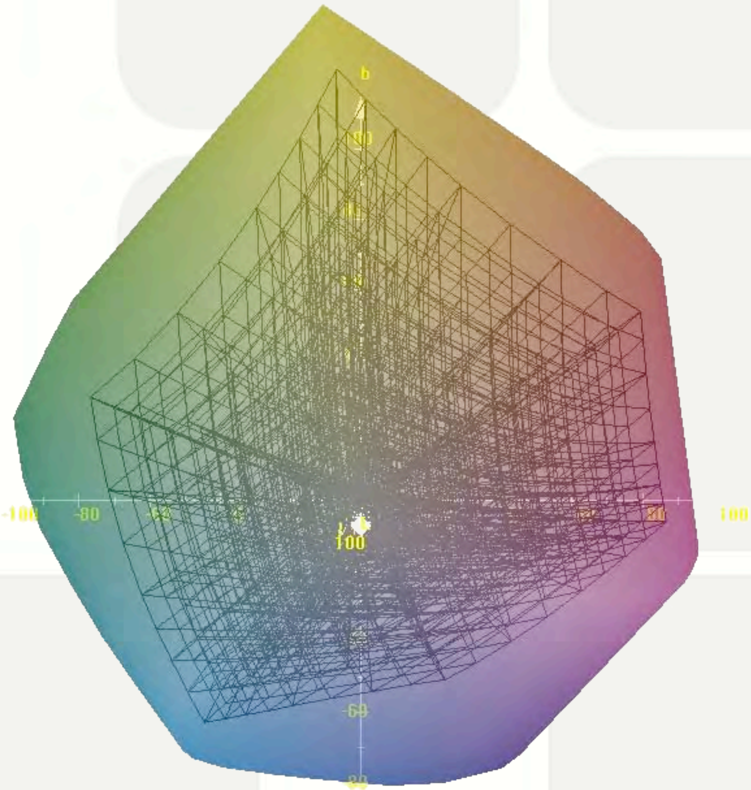


Device link editor

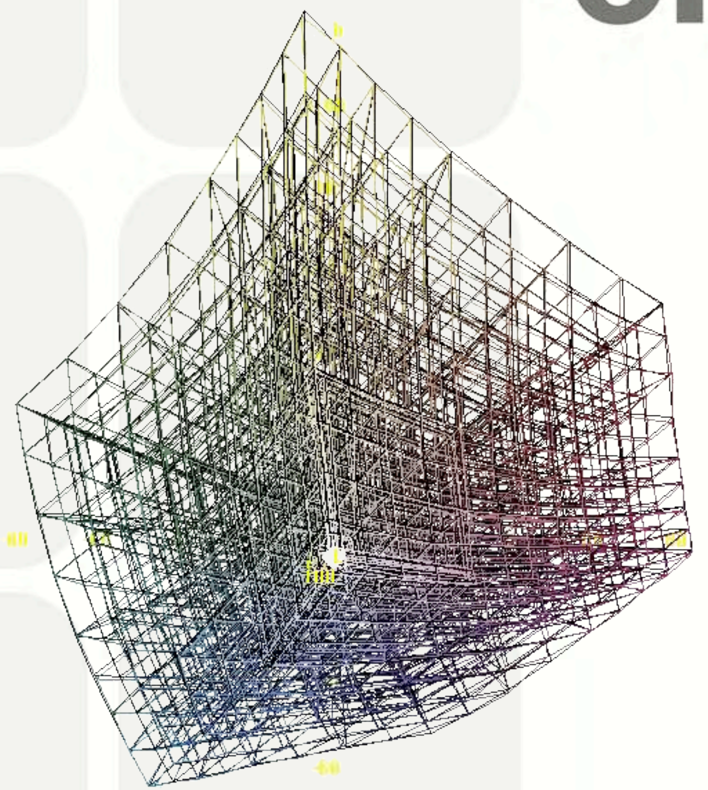


A device link profile is easy to edit

Result with iteration methode



Gamut / match before



Gamut / match after

Color Management on Digital Presses using DeviceLink Technology

Thank you for your Attention!

Who is CGS?

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Color Management Solutions

Digital Proofing Systems

Specially-formulated Media

Serving the Global Graphic Arts Market

Prepress

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Publishing

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Color management with ORIS

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ORIS MEDIA FACTORY »PRESS MATCHER«

ORIS MEDIA FACTORY »INK SAVER«

ORIS CERTIFIED SUITE »CERTIFIED PROOF«

ORIS CERTIFIED SUITE »CERTIFIED PRESS«

ORIS MEDIA FACTORY »NORMALIZER«

ORIS MEDIA FACTORY »PDF TUNER«

ORIS CERTIFIED SUITE »CERTIFIED MONITOR«

CIE Illuminant D50 Simulators: Ganz & Griesser Coefficients for UV Calibration

Veronika Lovell and Danny Rich

Sun Chemical Corporation
Color Research Lab

March 4, 2009

SunChemical
a member of the DIC group

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

- ICC White Paper 3:2004 - Reflectance and transmittance
    - 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) = $Y + 800(x_0 - x) + 1700(y_0 - y)$

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

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

$D = \delta W/\delta Y$

$P = (-\delta W/\delta S)\{\cos(\varphi + \eta)/\cos(\varphi)\}$

$Q = (-\delta W/\delta S)\{\sin(\varphi + \eta)/\cos(\varphi)\}$

$C = \{W_0(1-\delta W/\delta Y)\} - (Px_n) - (Qy_n)$

where:

$\delta W/\delta Y = 1$ (contribution of lightness to whiteness)

$\delta W/\delta S = 4000$ (contribution of saturation to whiteness)

$\delta W/\delta H = (-\delta W/\delta S)\tan(\varphi)$ (contribution of hue to whiteness; $\varphi = 15°$)

$\varphi = 15°$ (equi-chroma lines in Munsell system are parallel to the 15° curve, also white bias of most observers)

Ganz-Griesser Method of Assessing Whiteness

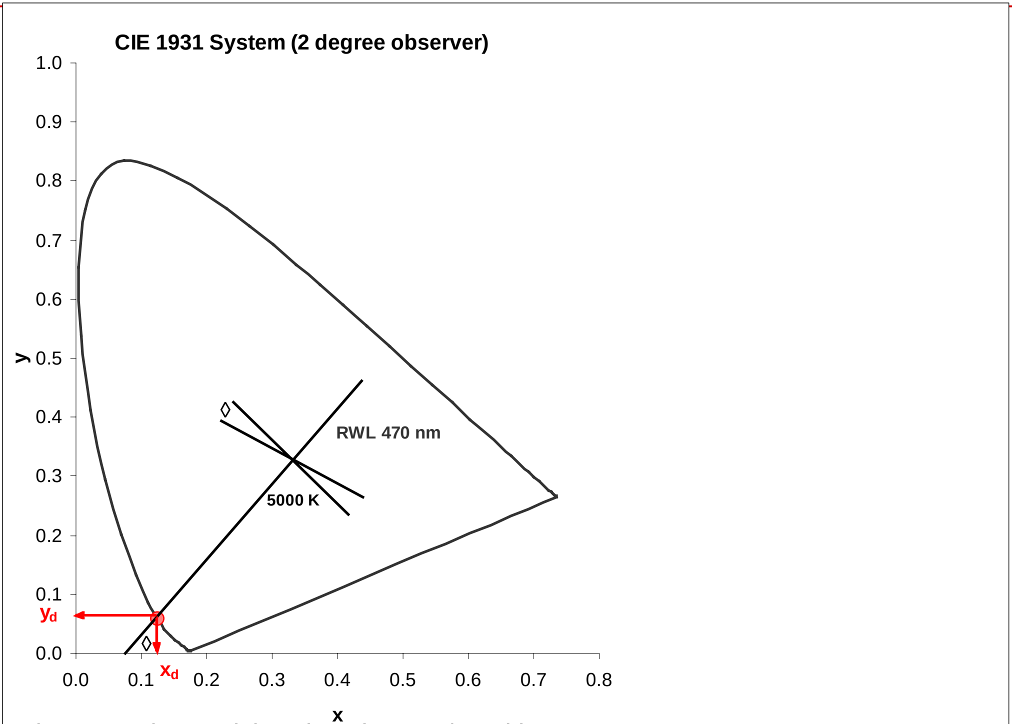


Figure 1. Chromaticity Chart for D50/2° with RWL = 470 nm.

$W_0 = 100$ (degree of whiteness of physical ideal white)

$\lambda_d = 470$ nm (dominant wavelength; RWL)

x_d and y_d (point of intersection of the RWL with the spectrum locus of CIE 1931 observer)

$\eta = \text{atan}\,\{(y_n - y_d)/(x_n - x_d)\}$ (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

$x_d = 0.1241 \quad x_n = 0.3457$

$y_d = 0.0578 \quad y_n = 0.3585$

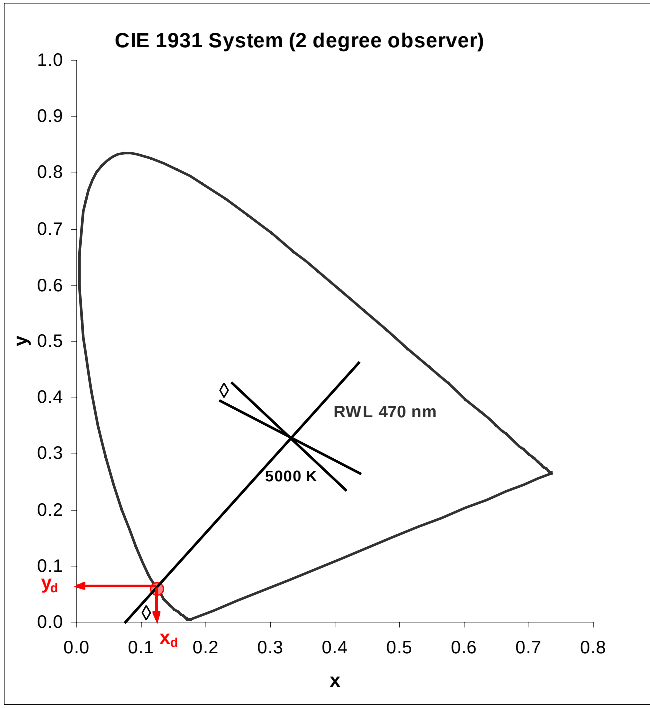
$\eta = \text{atan}\{(y_n - y_d)/(x_n - x_d)\} =$ **53.6°**

$D = \delta W/\delta Y =$ **1**

$P = (-4000)\{\cos(15+53.6)/\cos(15)\} =$ **-1511**

$Q = (-4000)\{\sin(15+53.6)/\cos(15)\} =$ **-3855**

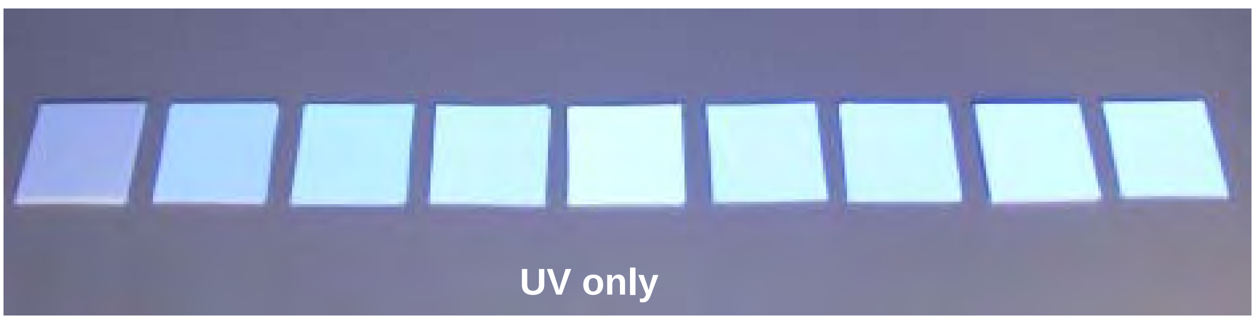
$C = \{W_0(1-1)\} - (-1511 \times 0.3457) - (-3855 \times 0.3585) =$ **1904**



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.



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

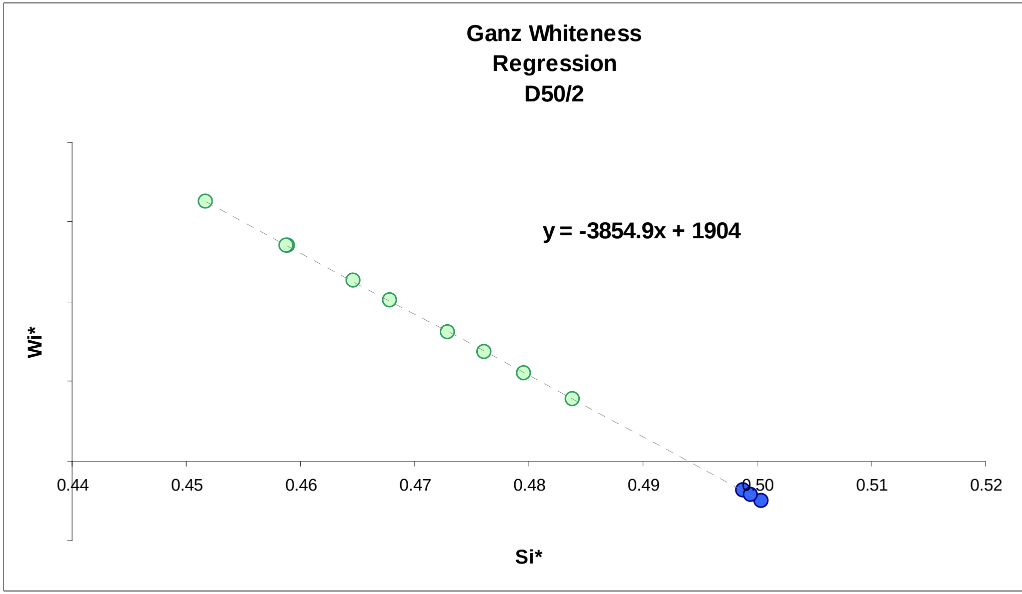
$V = 1 / \{(\tan(\varphi + \eta)\}$, and

$D = \delta W / \delta Y = 1$

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

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

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



GretagMacbeth Color i7

W_i GANZ – nominal values
W_i* - graphical adaptation method

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

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 $\delta W/\delta S$ ~ 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:

$$P = (-\delta W/\delta S)\ \{\cos(\varphi + \eta)/\cos(\varphi)\}$$

where:
$\{\cos(\varphi + \eta)/\cos(\varphi)\} = -2.647$
$\varphi = 15°$ and $\eta = 53.6°$

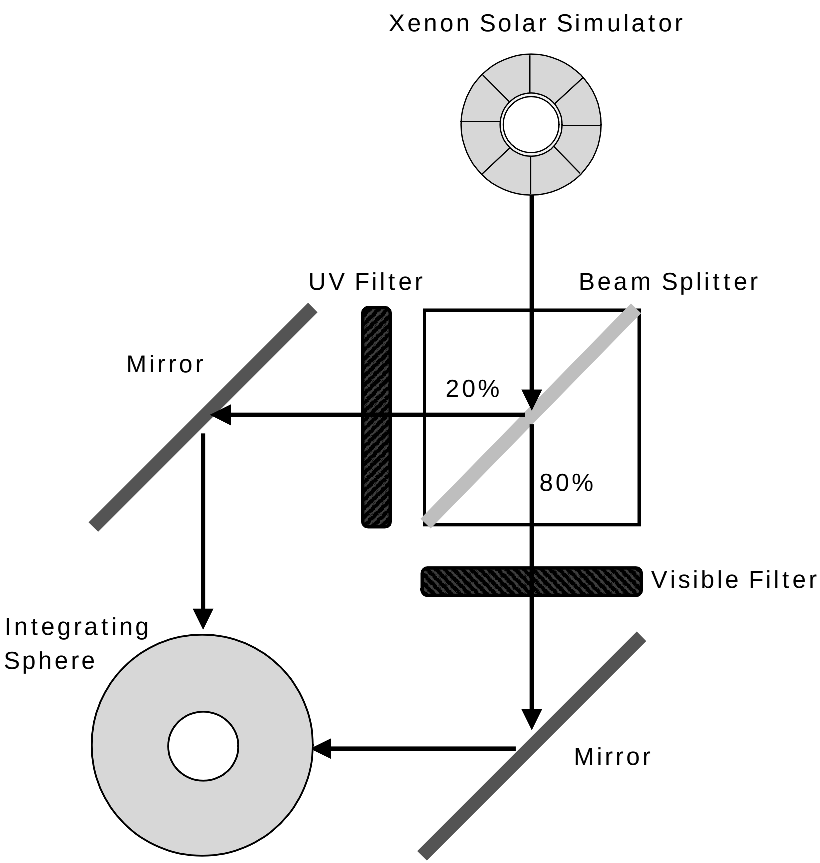
$\delta W/\delta S = P \cdot (-2.647) = (-1513.5) \cdot (-2.647)$ ~ **4000**

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

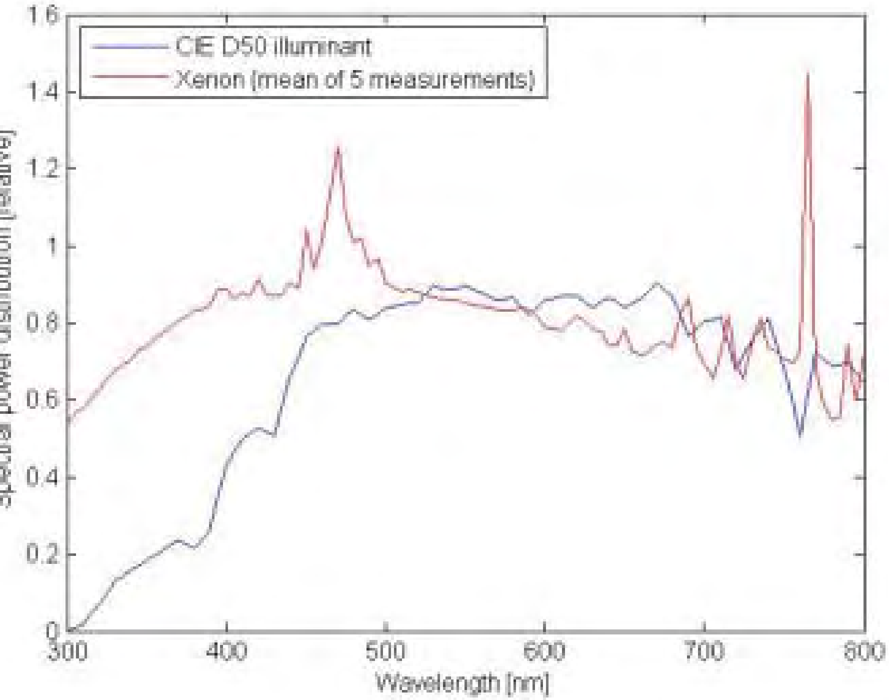


Specifications of the proposed D50 simulator

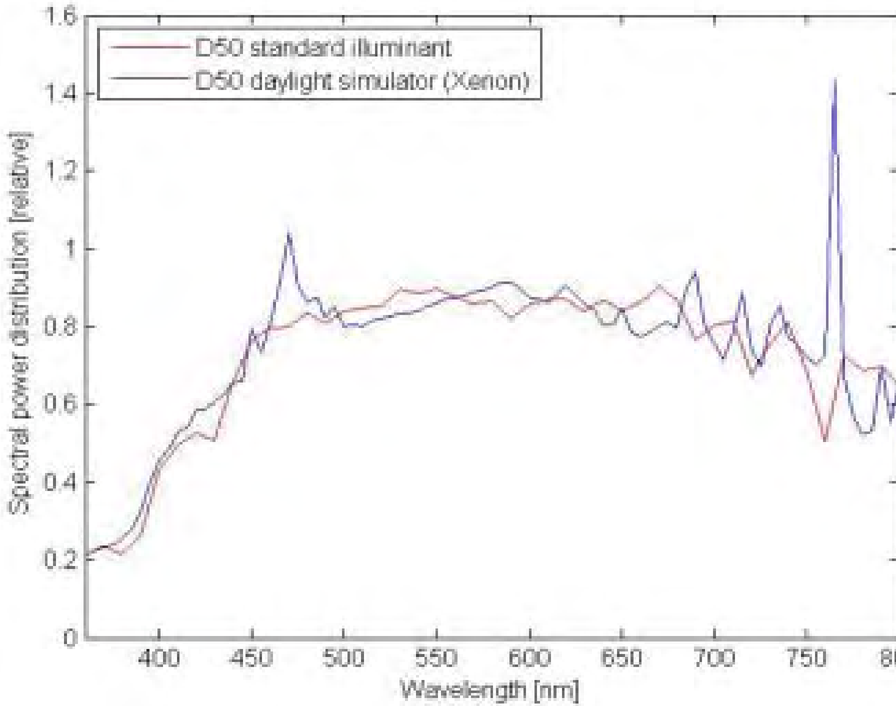
	CIE D50 illuminant		Proposed D50 simulator	
WP	u'_{10}	v'_{10}	u'_{10}	v'_{10}
	0.2102	0.4889	0.2125	0.4847
CCT	5000 K		5014 K	
M_{vis}	0		0.23 (A)	
M_{uv}	0		0.12 (A)	
CRI	100		97-98	

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.

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- Griesser R. CIE Whiteness and Tint: Possible Improvements. Appita J. 1996; 49:105-112

THANK YOU!

QUESTIONS

???

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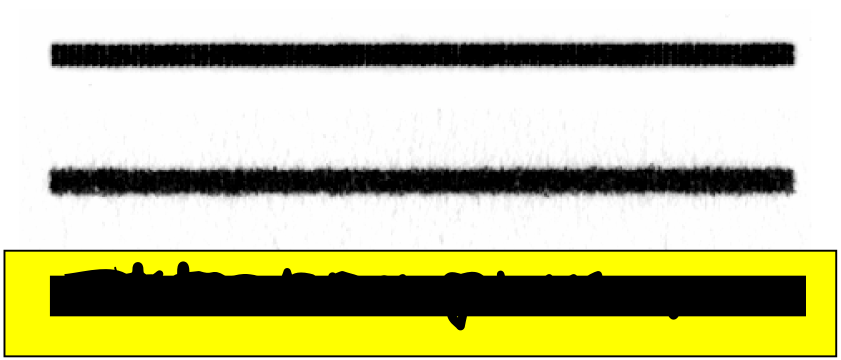
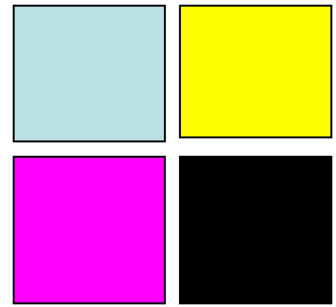
The optical interaction between ink and paper

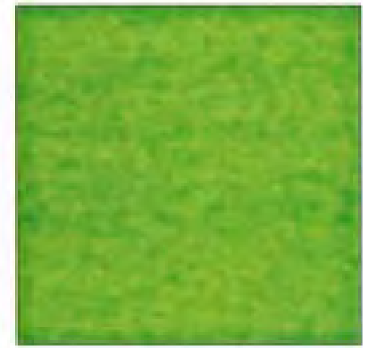
Nils Pauler

Print quality of home & office ink jet

Scanner measurements



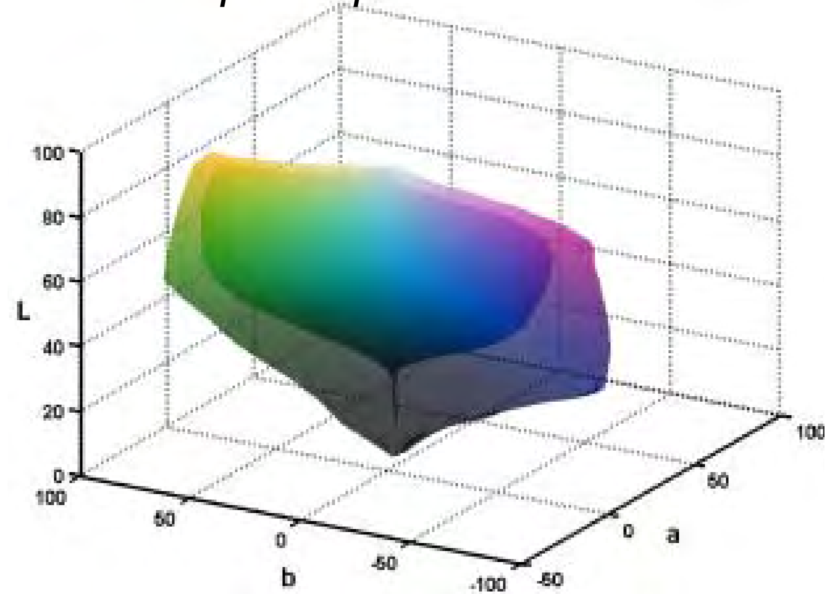




- Line: sharpness, raggedness, bleeding
- Print density
- Unevenness

- Colour gamut
  - A range of phenomenon
  - What is caused by paper?

Spectrophotometer



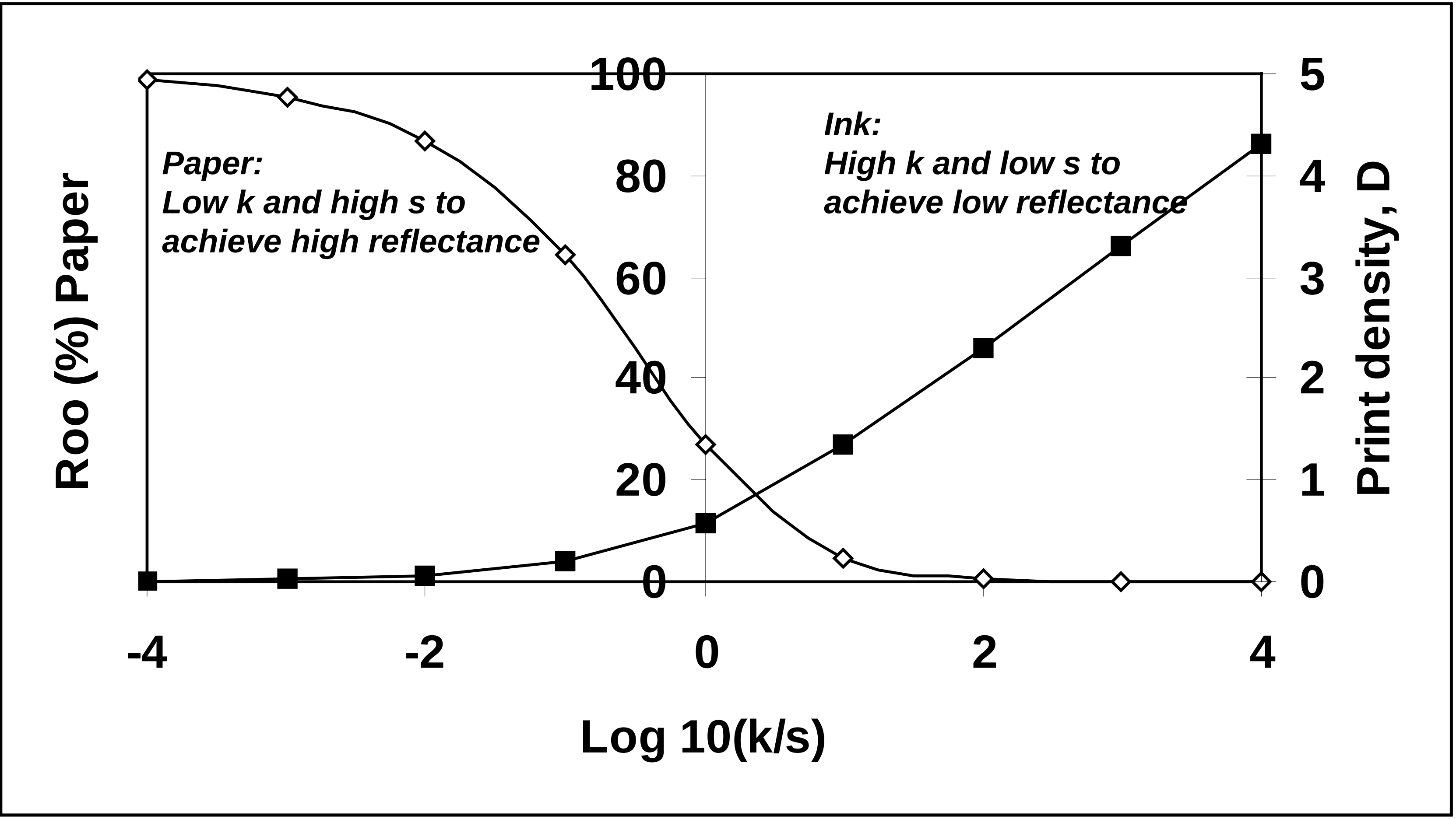
The optical interaction between ink and paper

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

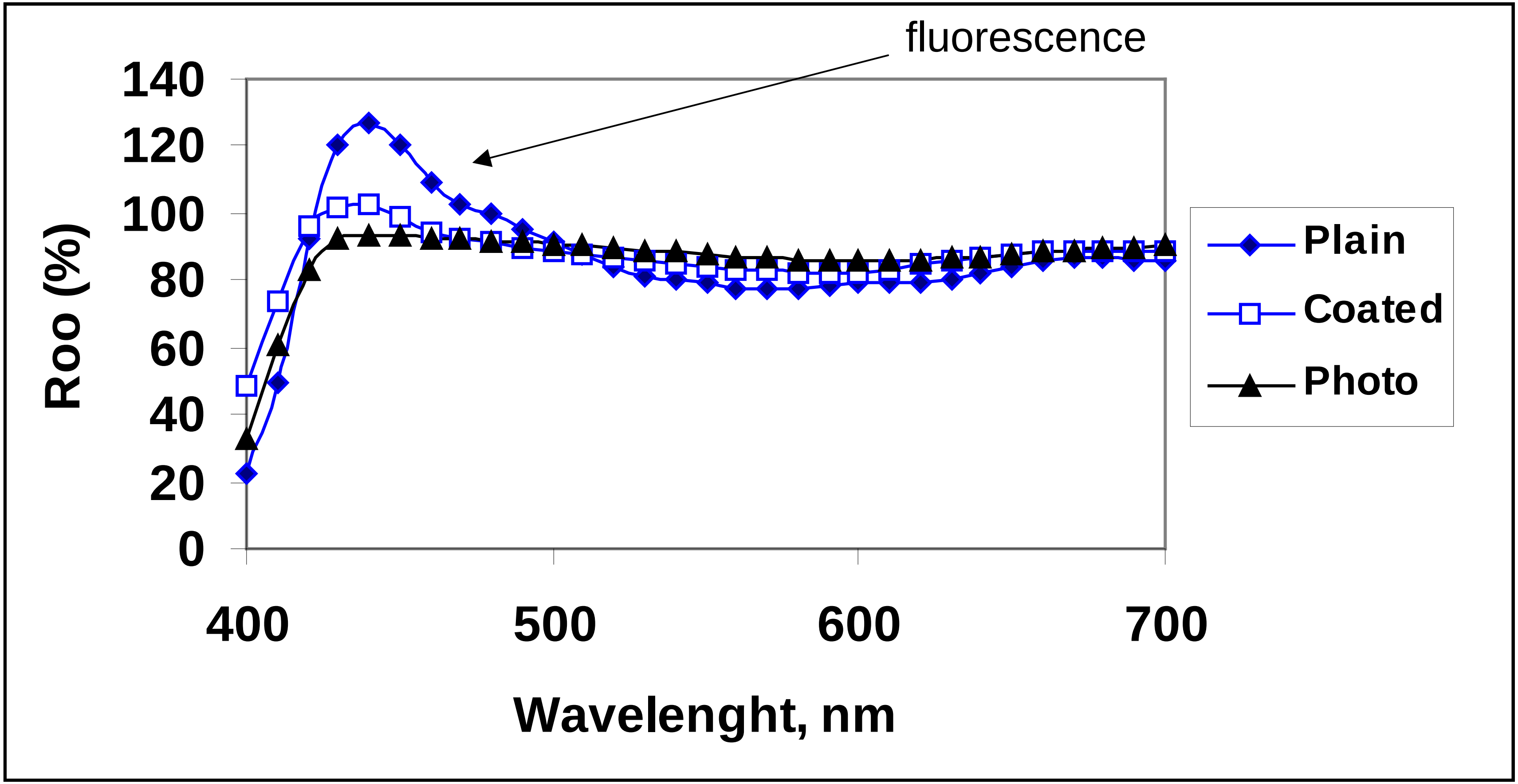
The light scattering (s) and light absorption (k) of paper and ink

Print density = Log10(Rpaper/Rprint)



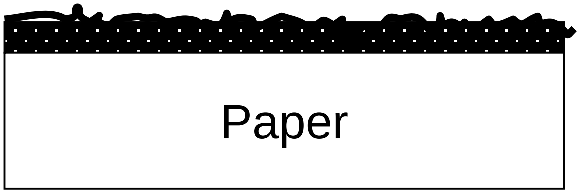
Plain paper, Coated paper and Photo paper

with fluorescence radiation of FWA

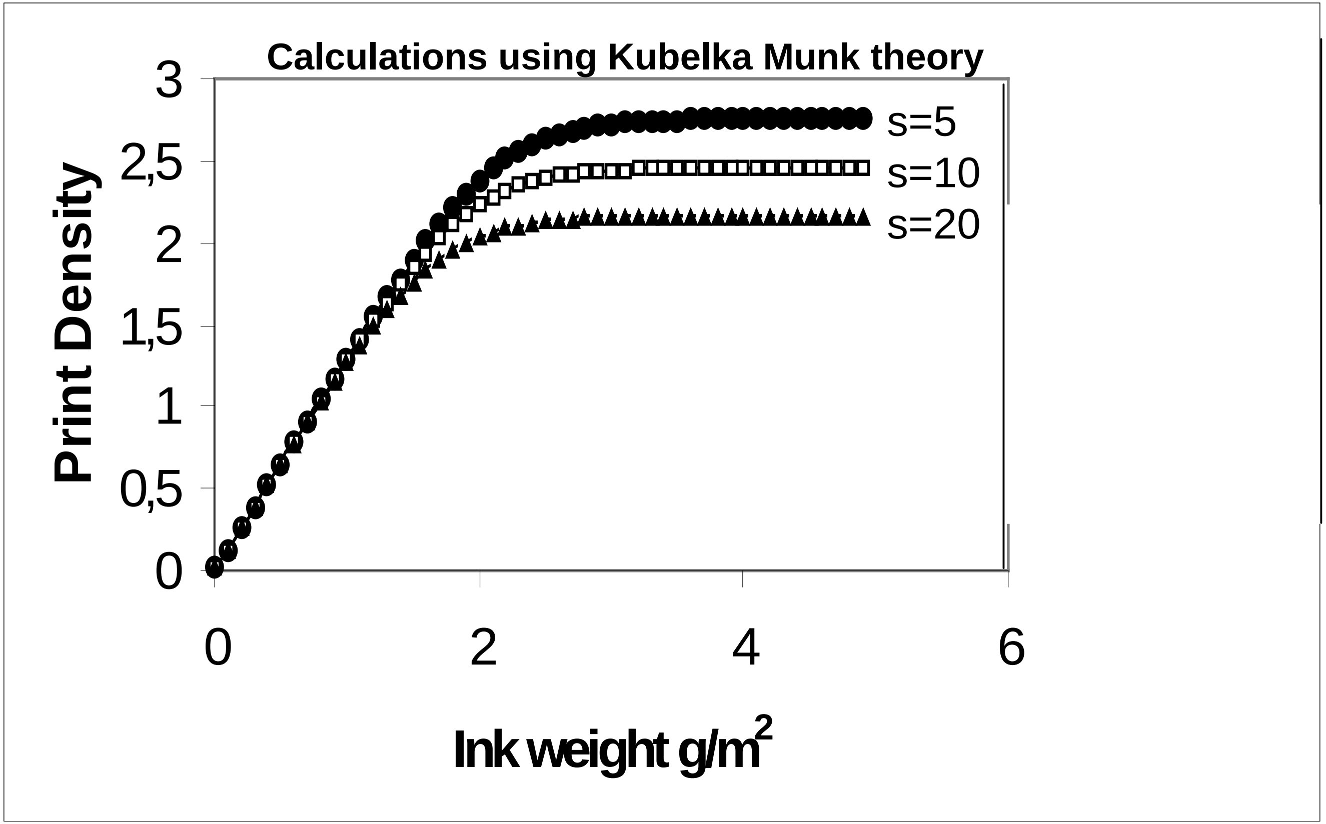


The light scattering of the ink layer

from pores, pigment or surface roughness



	D
Slides	4-5
Photo gloss	2-3
Coated paper	2-2,5
Plain paper	1-1,5



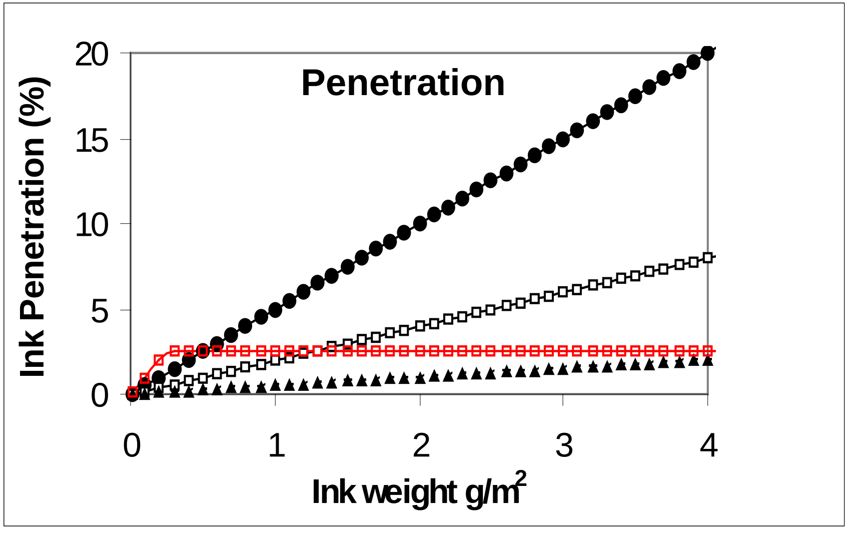
Simulation the effect of ink penetration

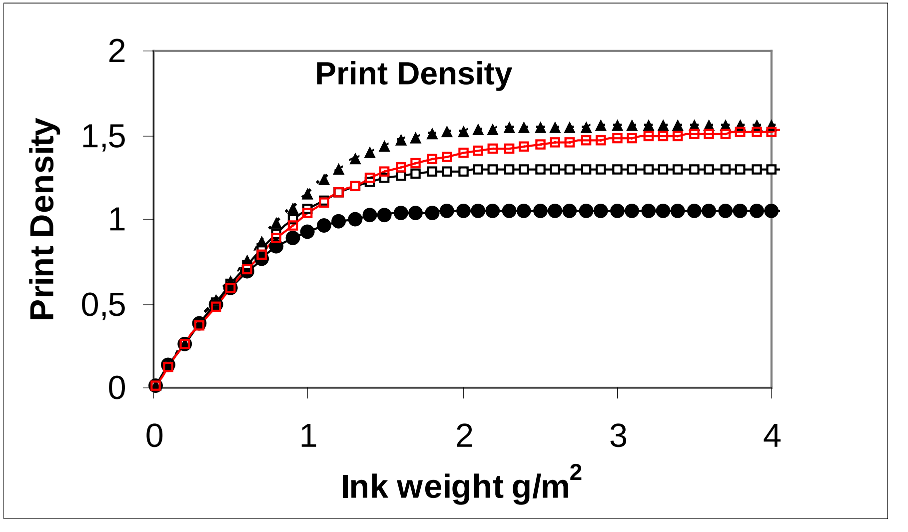
linear and with a barrier

Linear penetration with lower rate ⇨ Increased plateau value of density

Barrier ⇨ Increased density

Calculations using Kubelka Munk equations

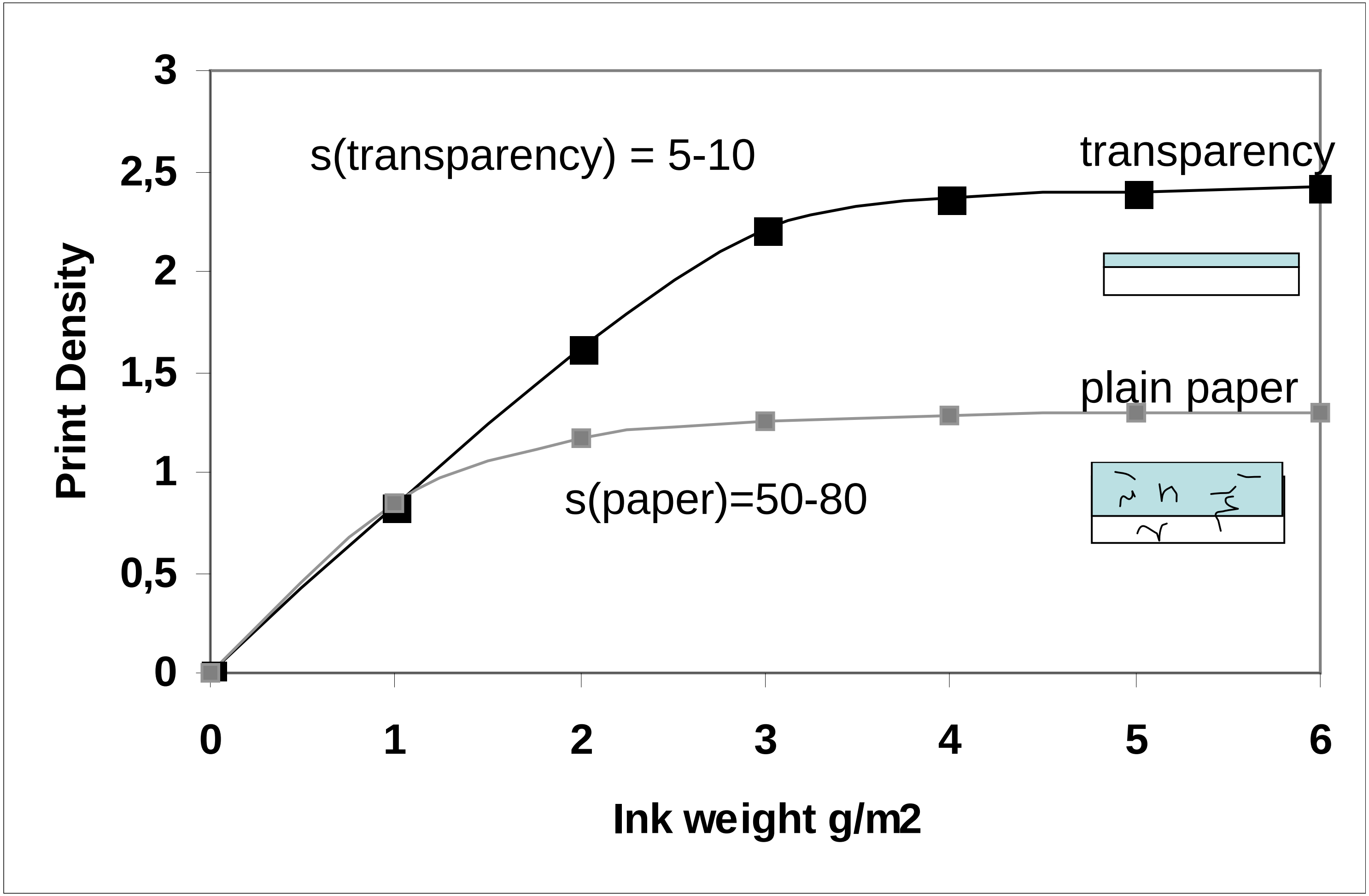




Print density vs. ink weight

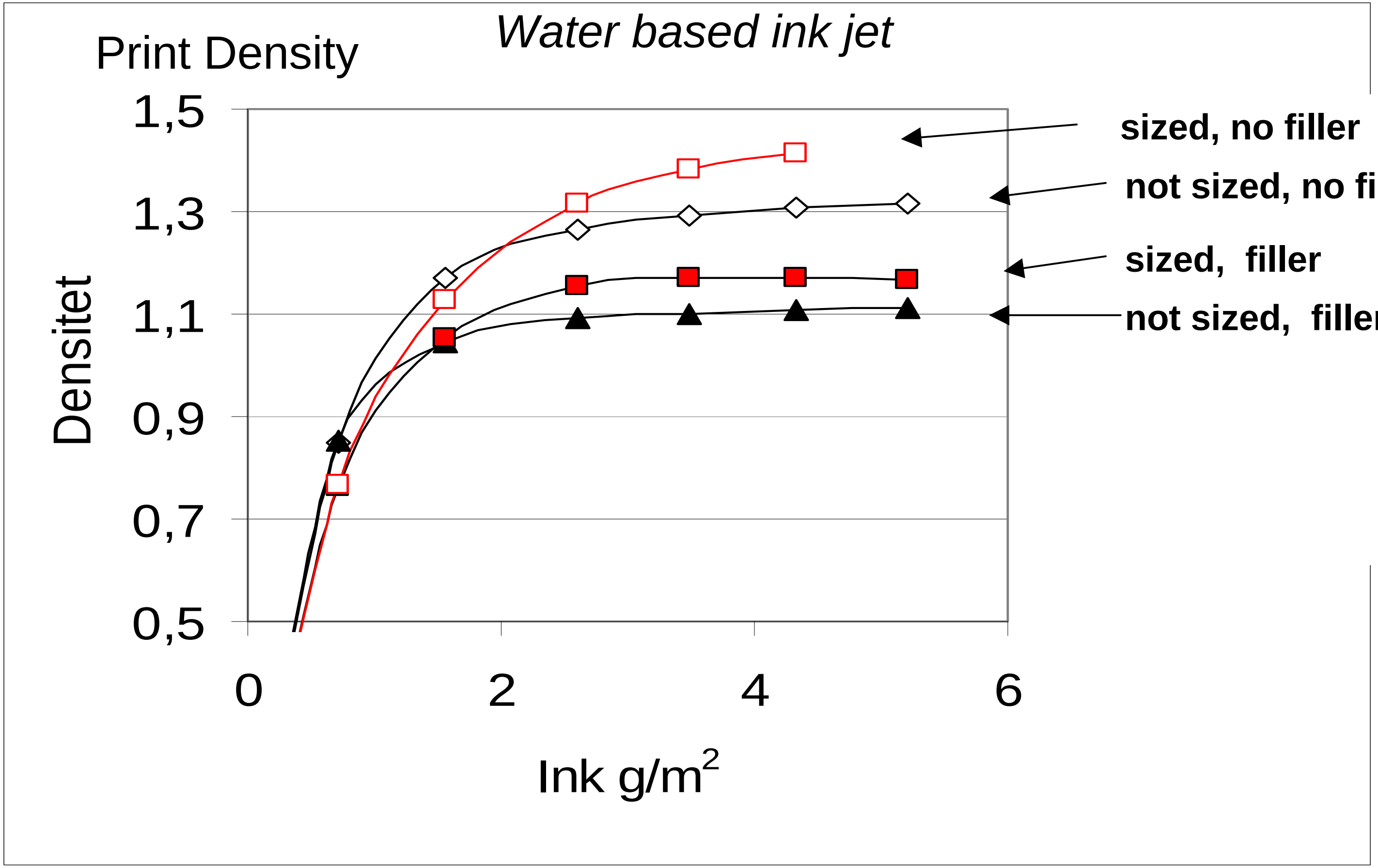
the influence of ink penetration and light scattering

Measurements with a spectrophotometer



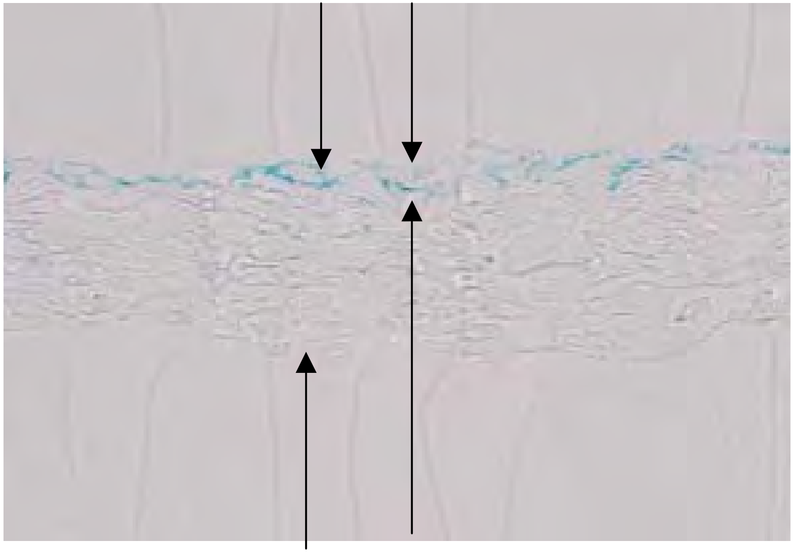
Test printing; Print density vs. ink weight

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

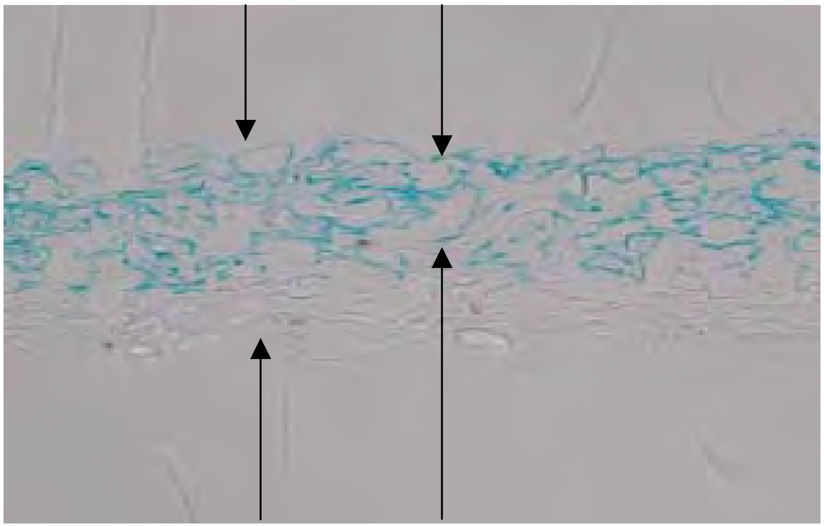


Ink jet print with ink amount 1 g/m^2 and 5 g/m^2

1 g/m^2



5 g/m^2

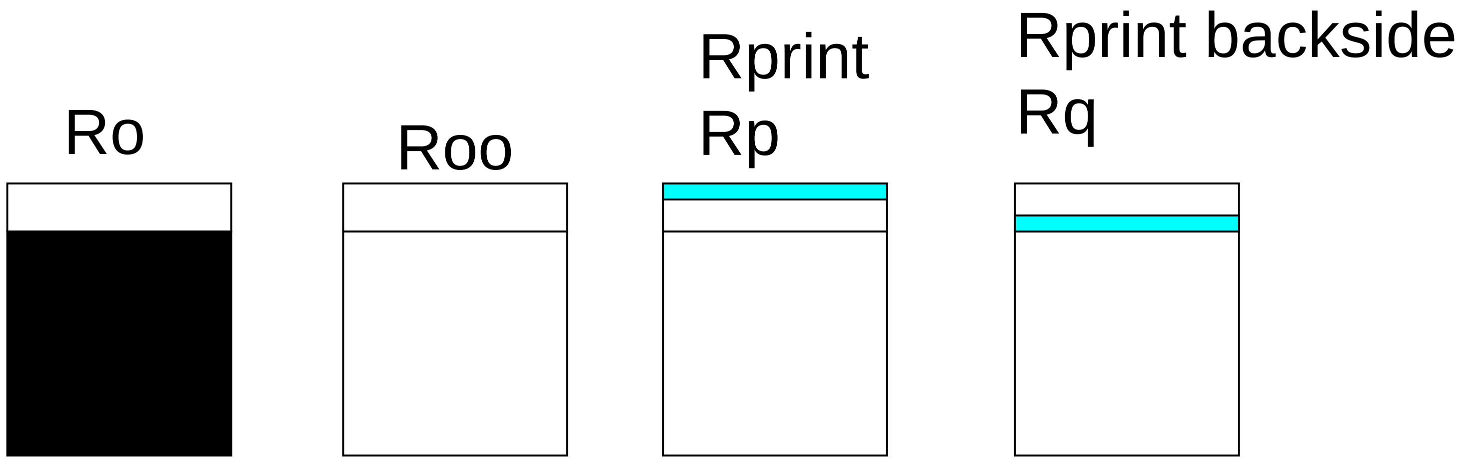


The ink adsorbs to the fibres

Penetration of ink into plain paper

determination with Kubelka Munk theory

Spectrophotometer



$$Pen\% = 100 \times \frac{\ln \dfrac{F(R_0, R_\infty) \times F(R_p, R_\infty)}{F(R_q, R_\infty)}}{\ln(F(R_0, R_\infty))}$$

Ink jet print with sex different ink amount

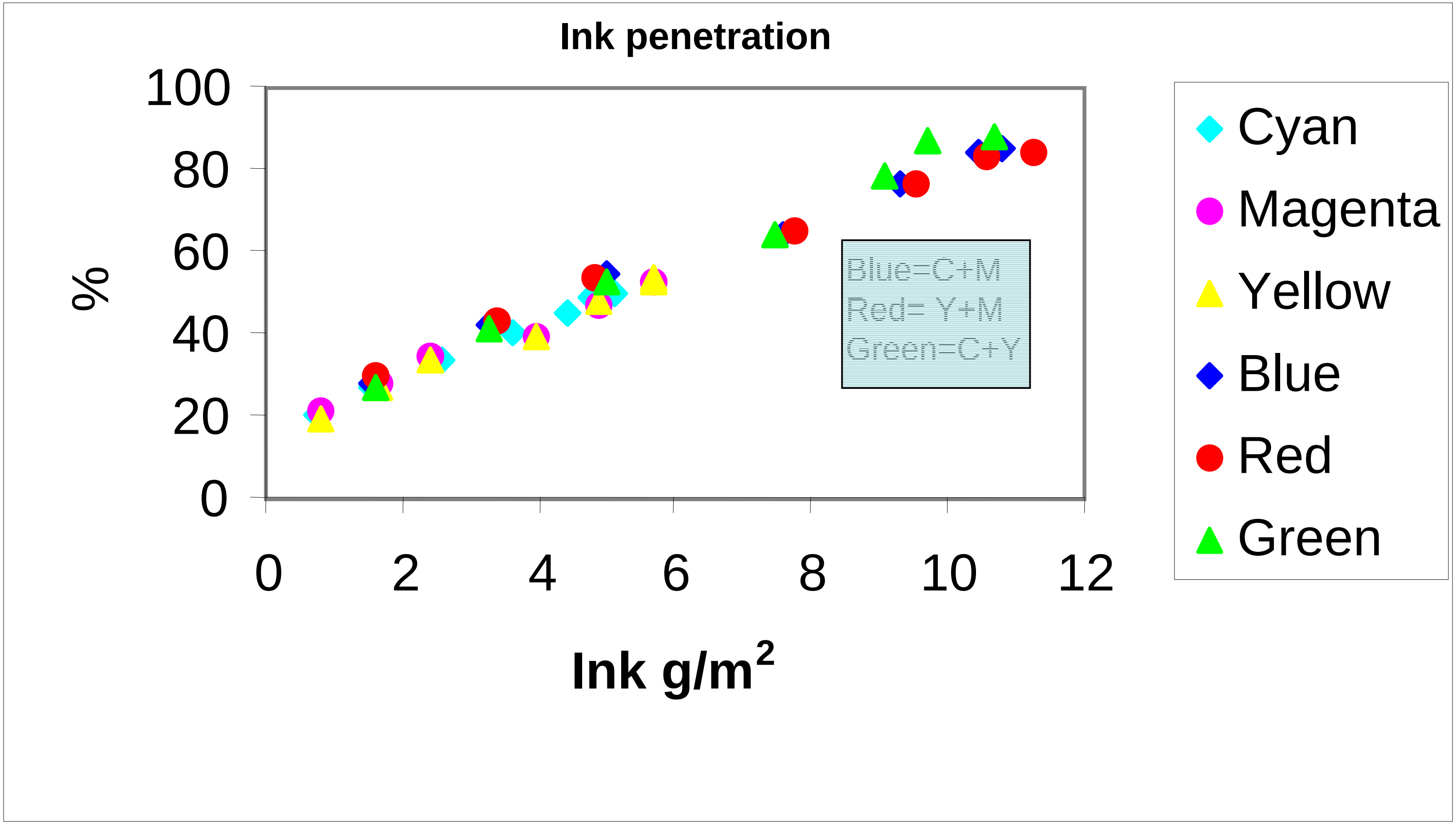
Plain paper

Printed side

Back side

Penetration of ink into plain paper

Determination based on reflectance measurements



Plain paper and Photo gloss paper

The influence of ink penetration and light scattering

Plain paper :

Low Colour Gamut

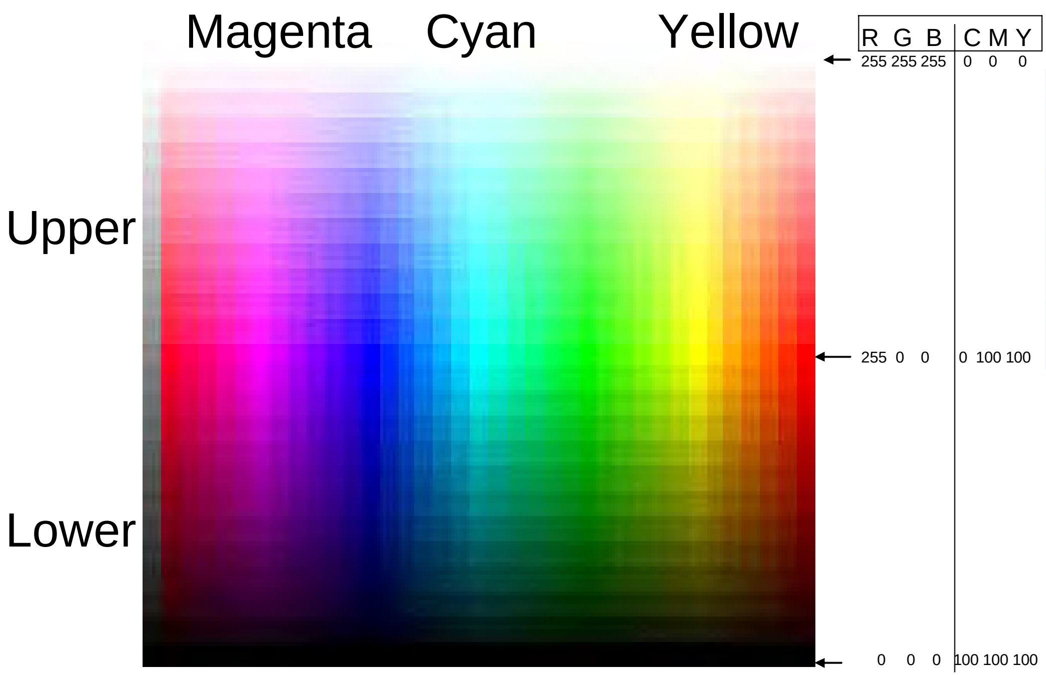
Photo Gloss paper:

High Colour Gamut

Ink jet prints

Test chart for measurement of Colour Gamut

RGB coordinates



Colour gamut of Photo gloss paper compared to plain paper

Silica gel

Measurement with spectrophotometer

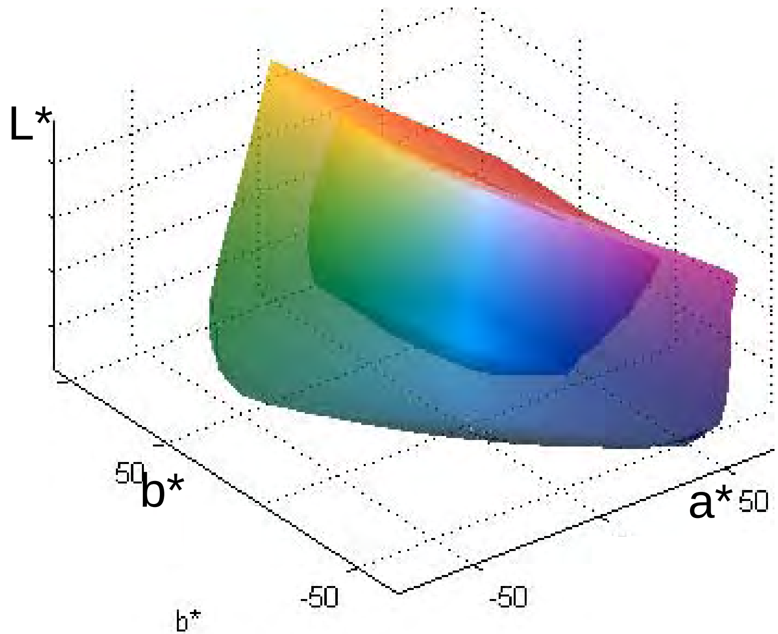
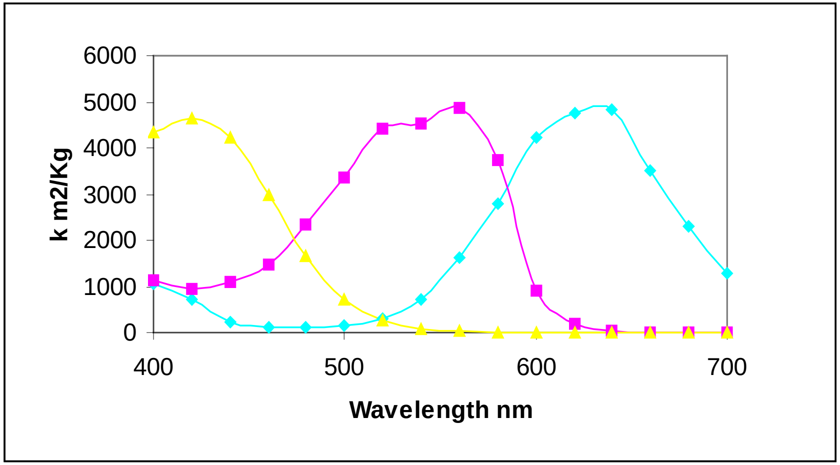


Photo gloss paper has a top layer of low light scattering

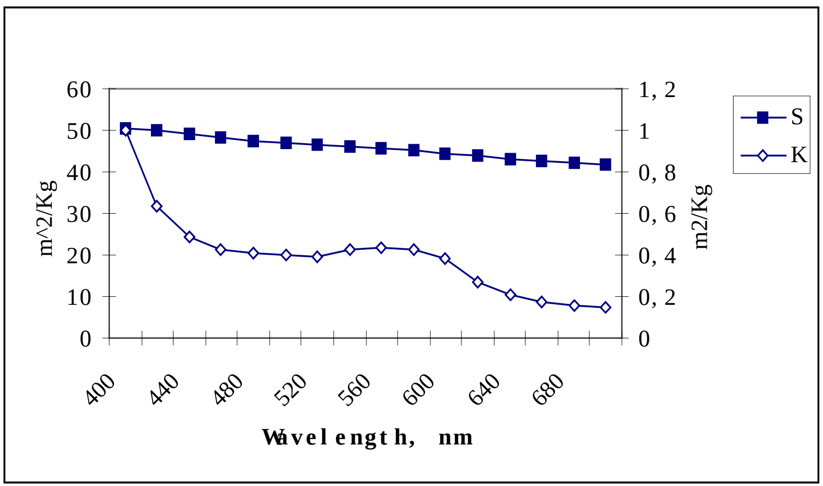
Calculation of the colour gamut

k of process inks

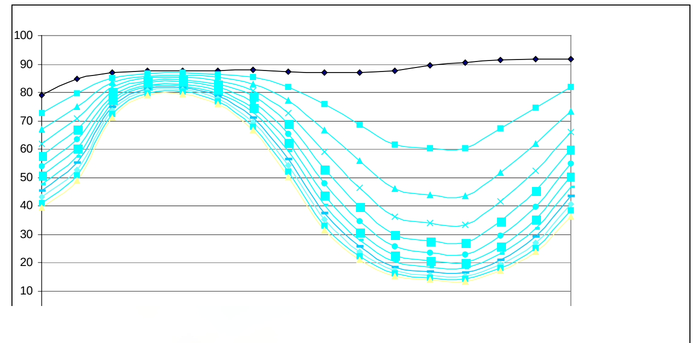


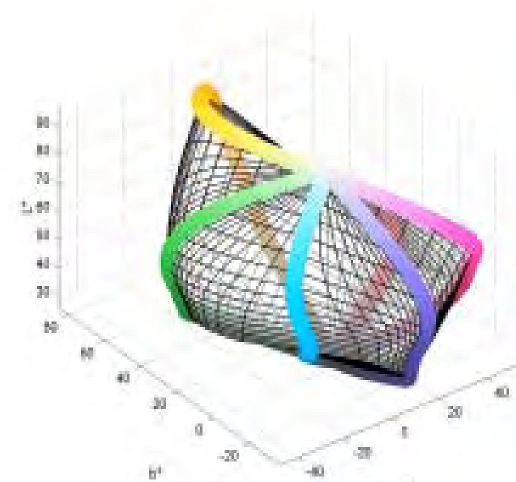
R paper+ink

s and k of paper

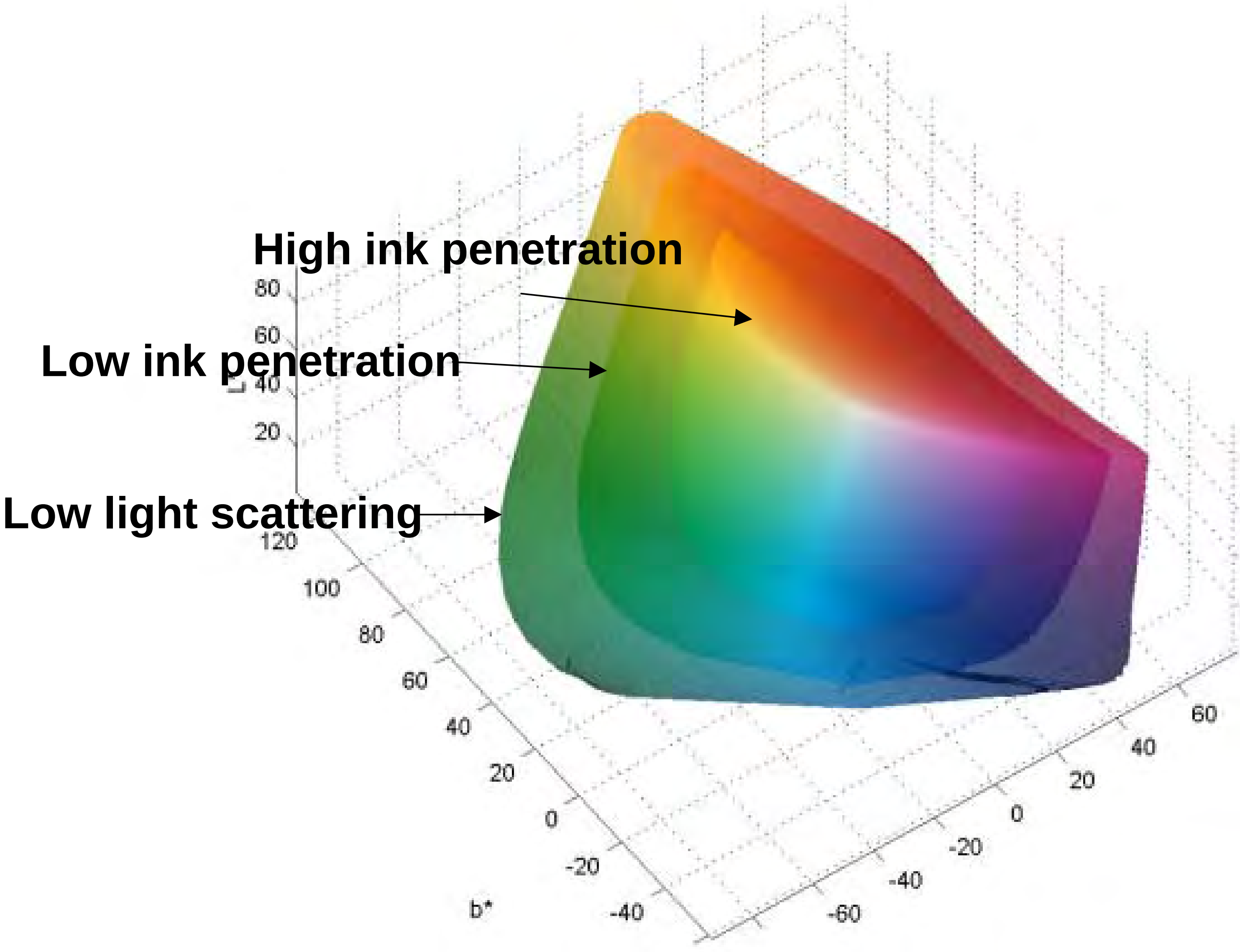


R printed paper





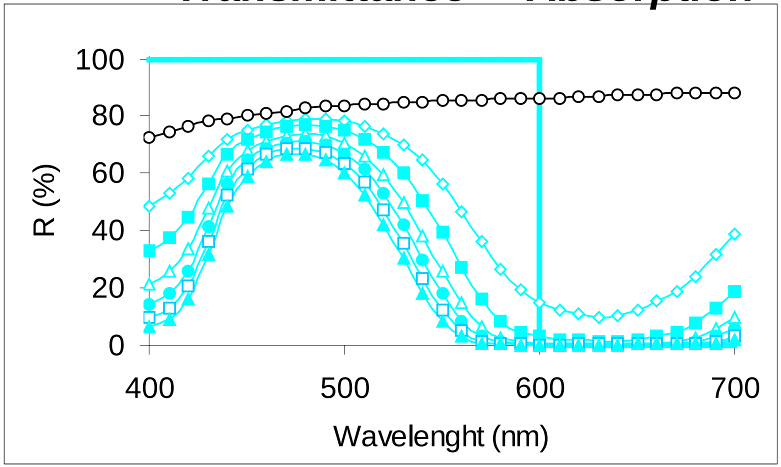
Calculated colour gamut

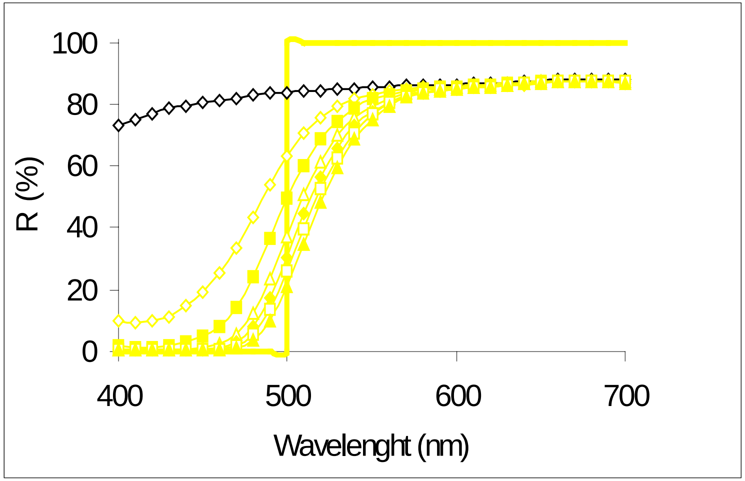


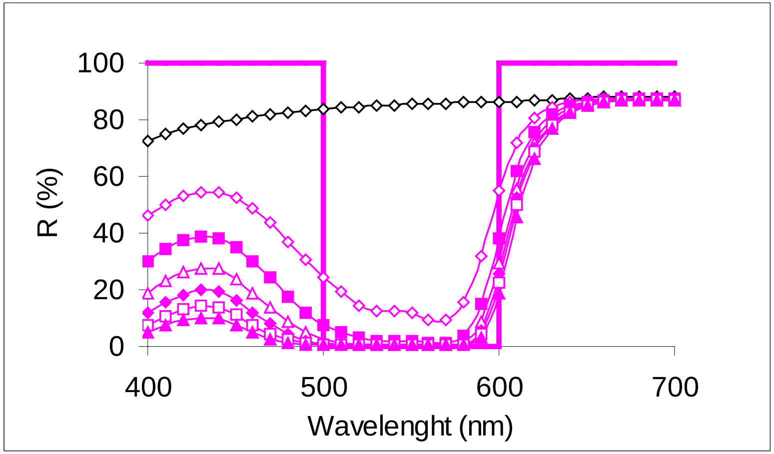
Process inks

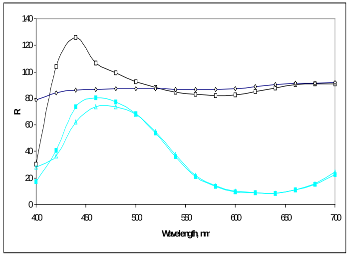
increasing ink weights (Ink jet)

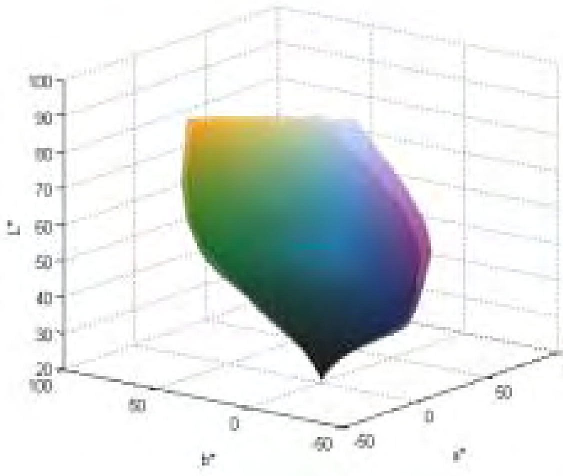
Transmittance   Absorption





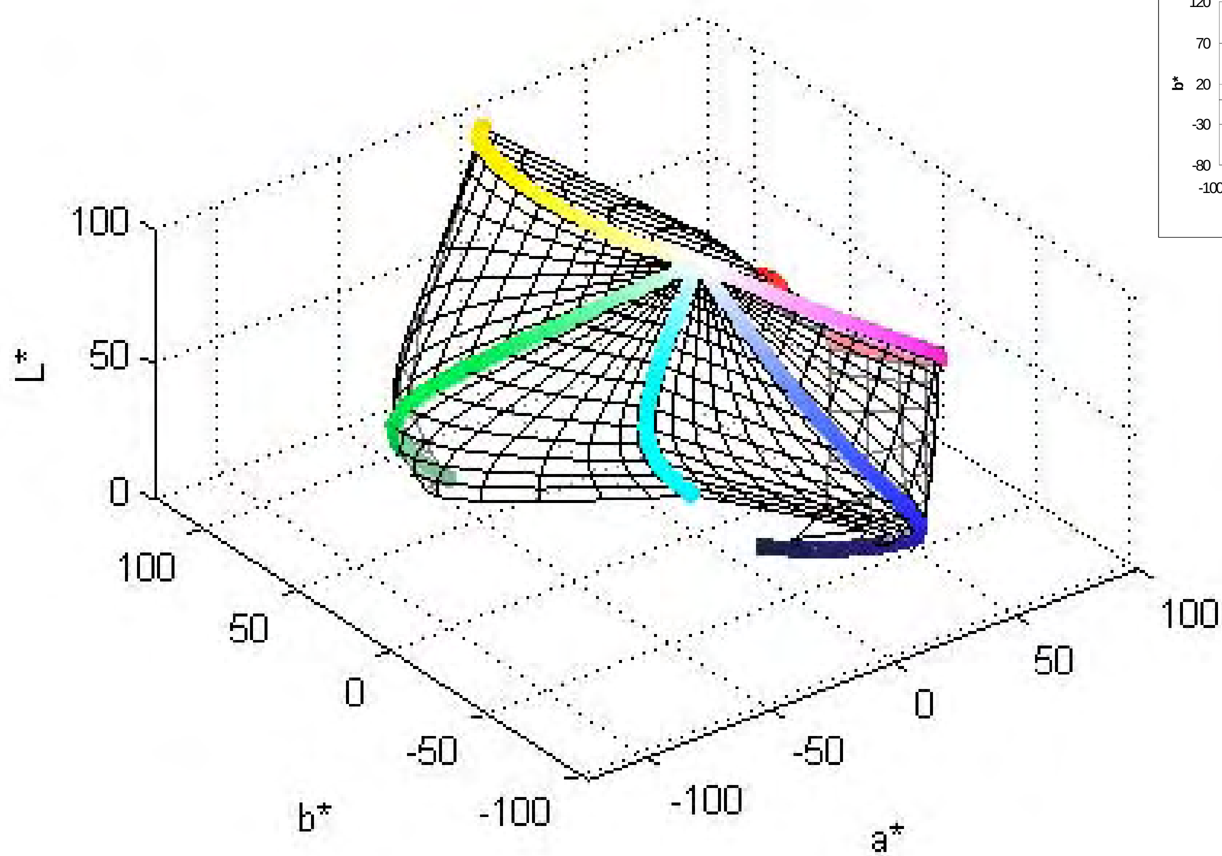


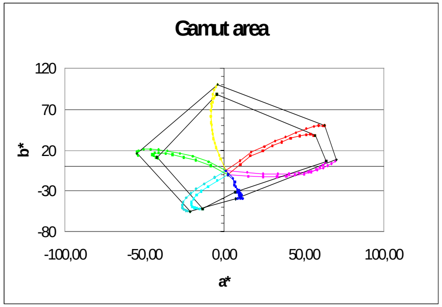




Increasing ink weight

Calculation using Kubelka-Munk theory

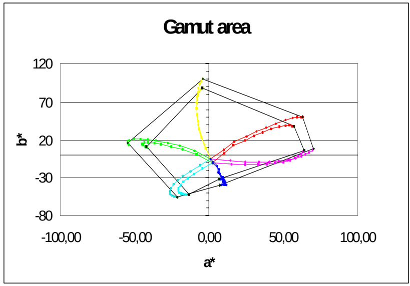




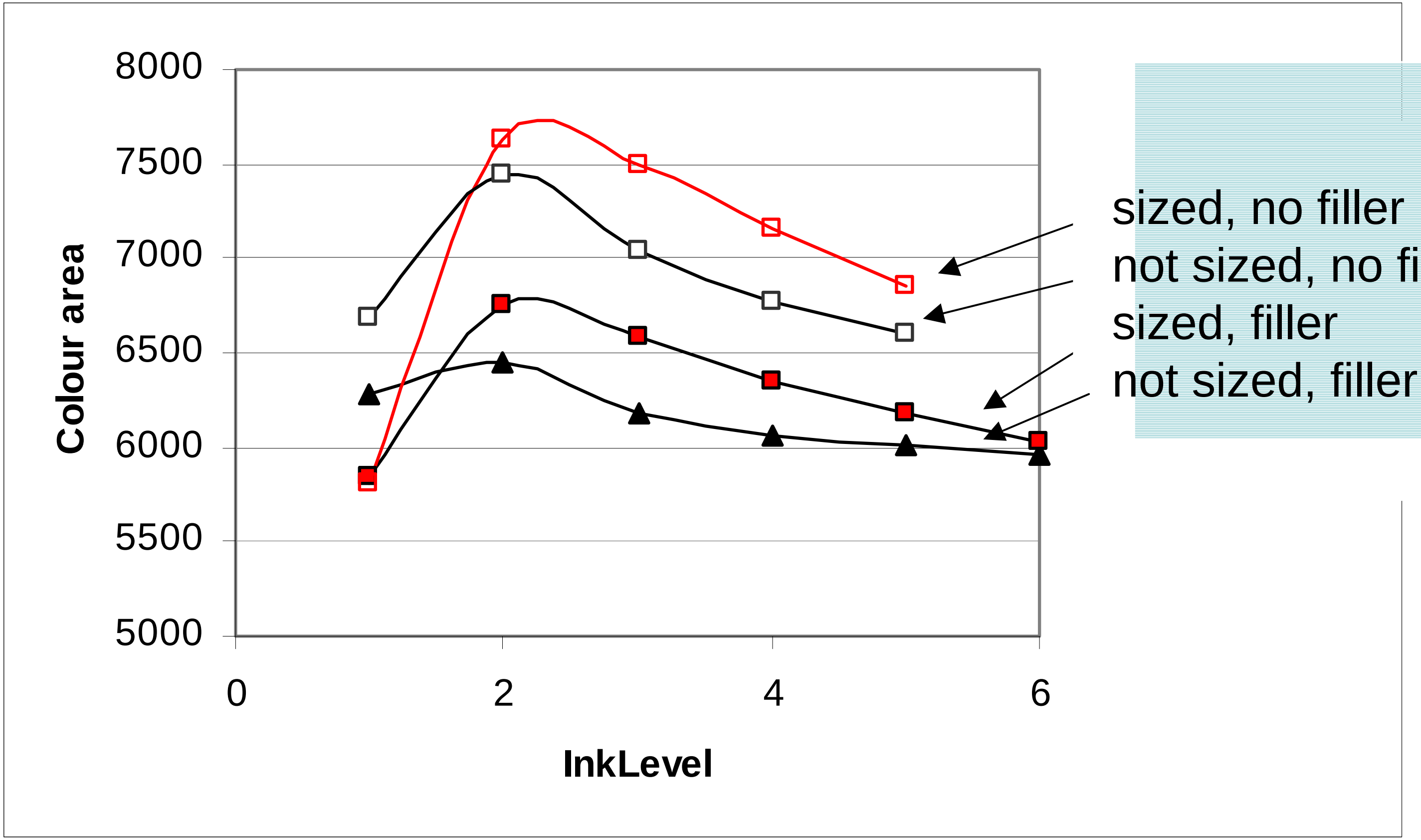
CGYRMB

Colour area

Measurements with spectrophotometer



*/hat is the best
ık level for ink
ıt?*



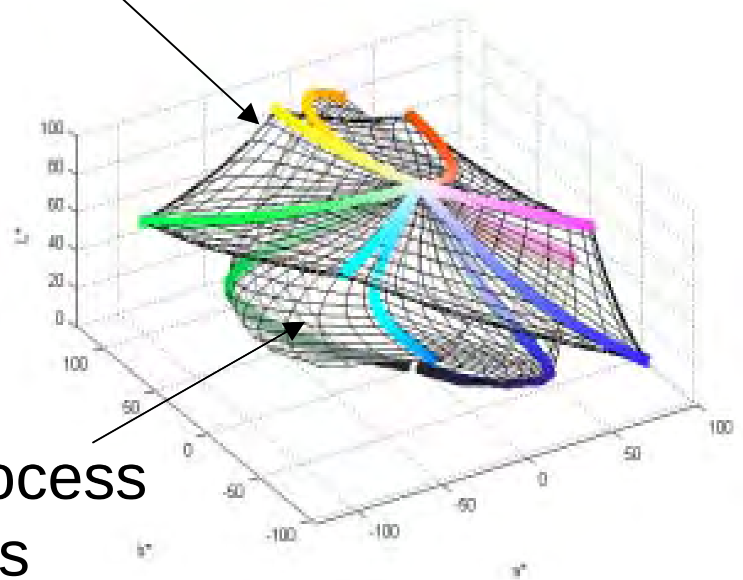
sized, no filler
not sized, no fille
sized, filler
not sized, filler

Comparison ideal inks and process inks

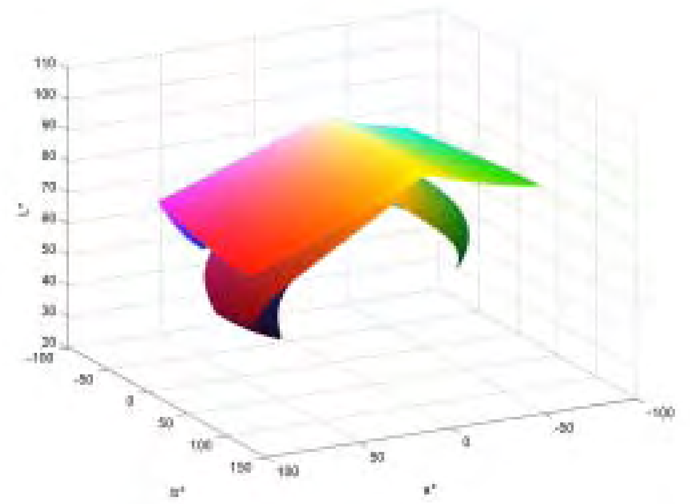
Calculations using Kubelka Munk theory

the upper part of colour gamut

Ideal inks



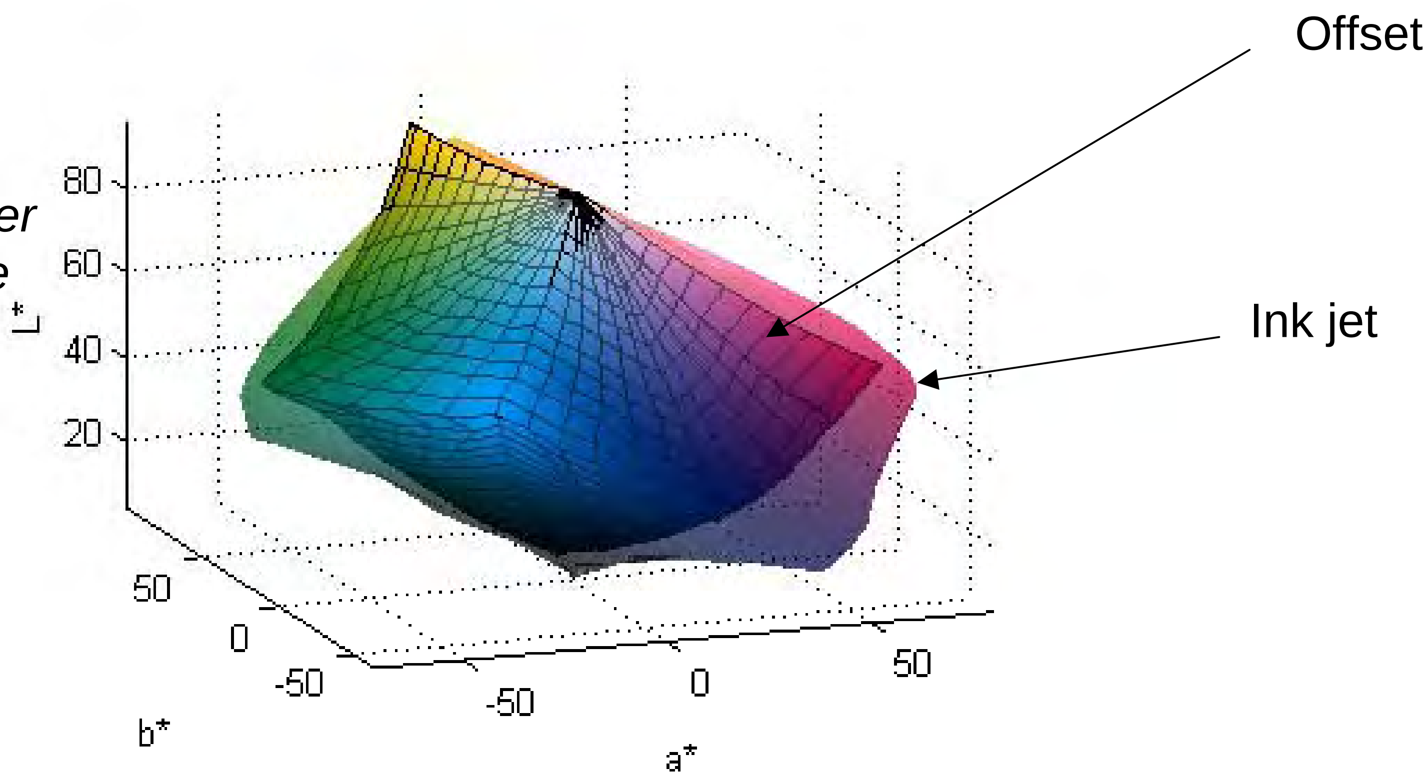
Process inks



The difference between offset and Ink jet

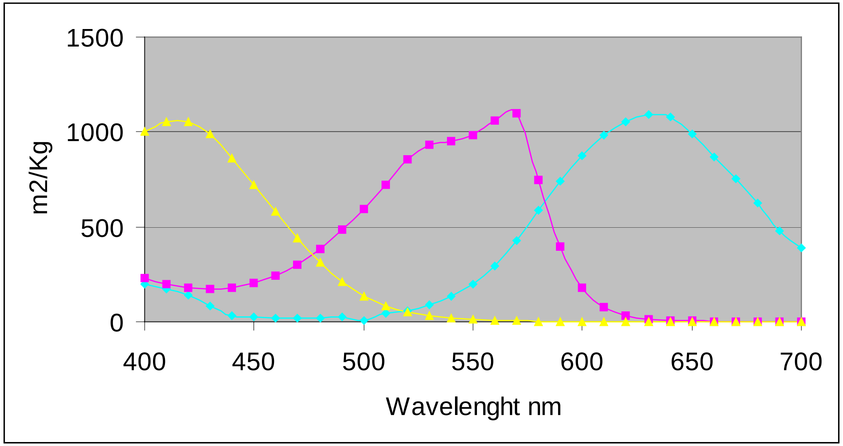
Measurements with spectrophotometer

Offset is smaller with a concave shape

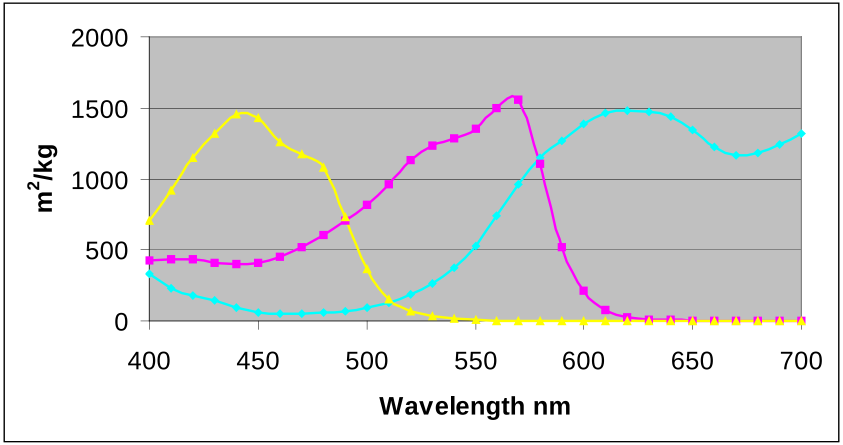


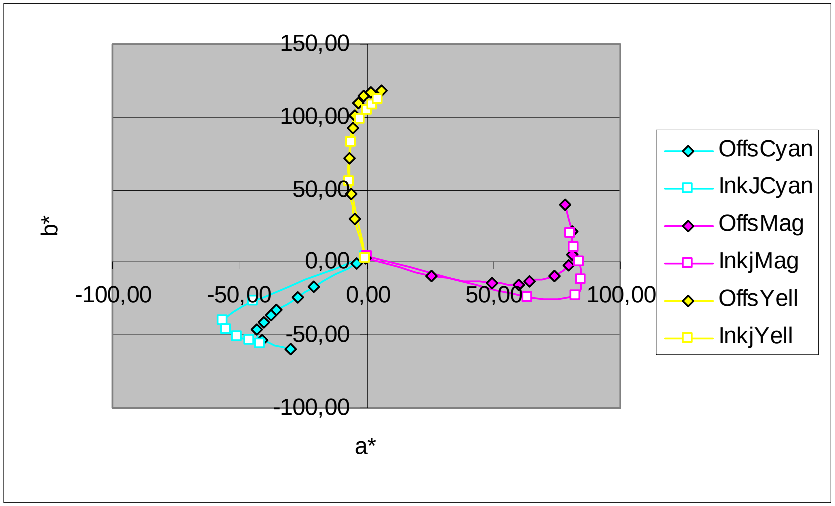
Light absorption of process inks are similar

Ink jet



Offset

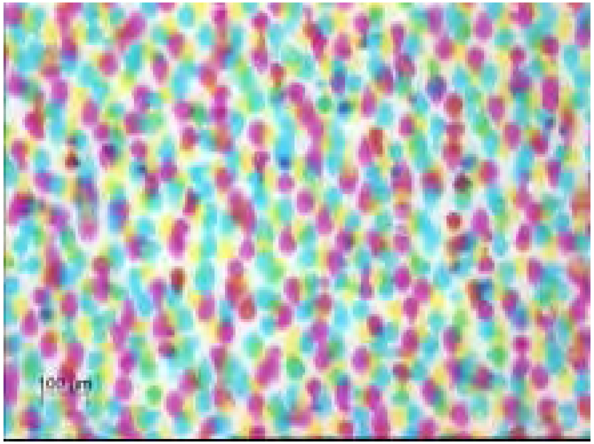




Offset: Prüfbau on Mylar film 0-4 g/m2
Inkjet: Ink jet on transparency 0-5,5 g/m2

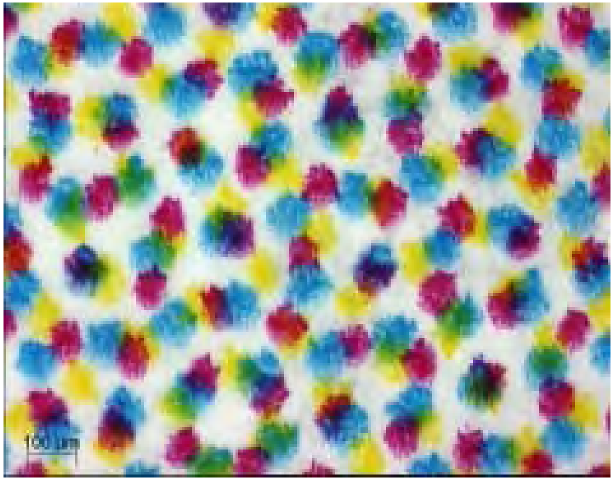
Colour half toning

Ink jet photo gloss



Colour control:
Changing the dot size
Changing the dot frequency
Changing the ink amount

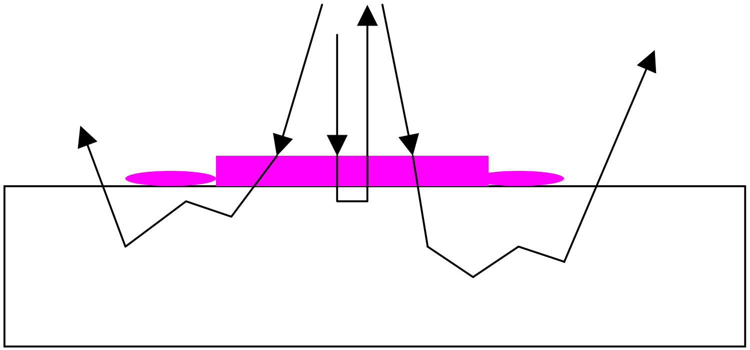
Offset

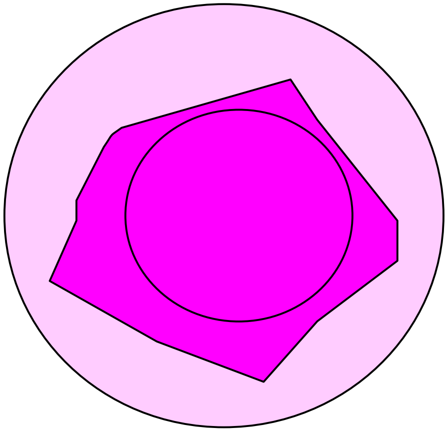


Colour control:
Changing the dot size
(Changing the dot frequenc

Dot gain or tone value increase

Mechanical and optical dot gain



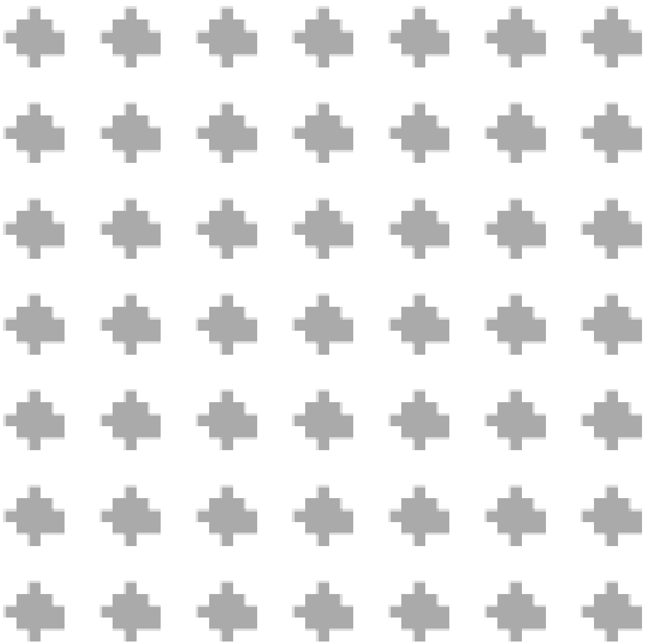


‘Corona’

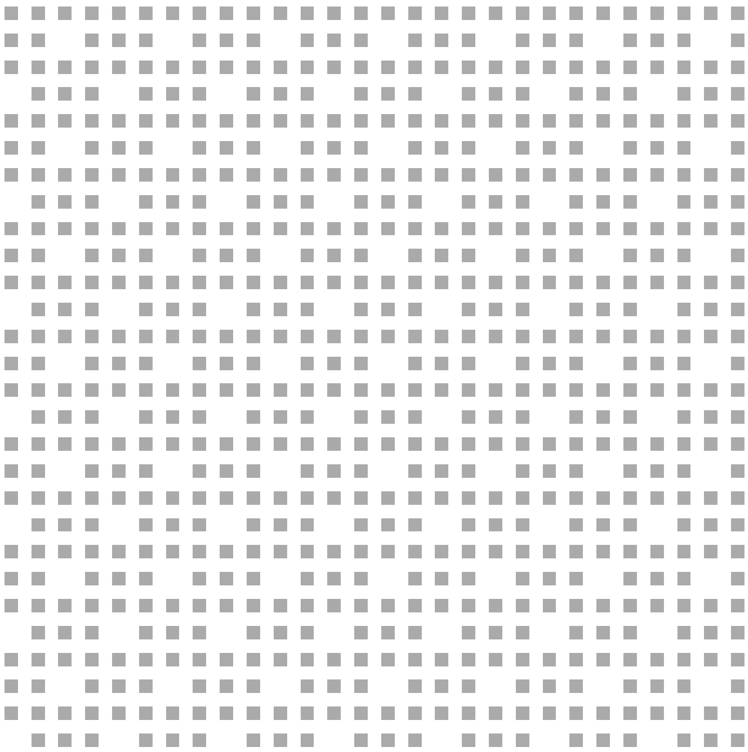
Comparison of large and small dots

Test printing with inkjet with 5 ink levels

Large (condensed) dots



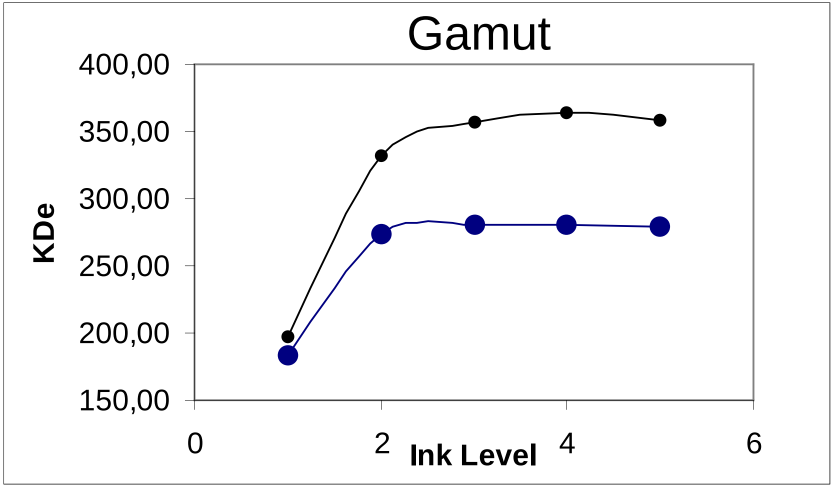
Small (disperse) dots

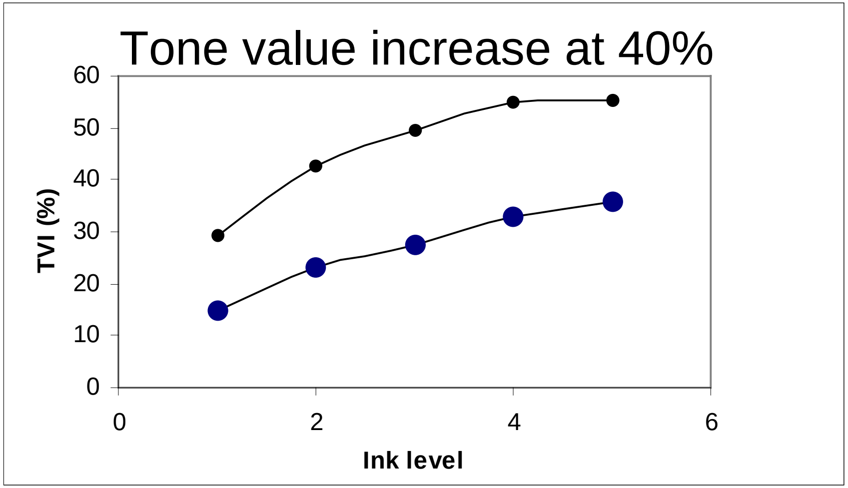


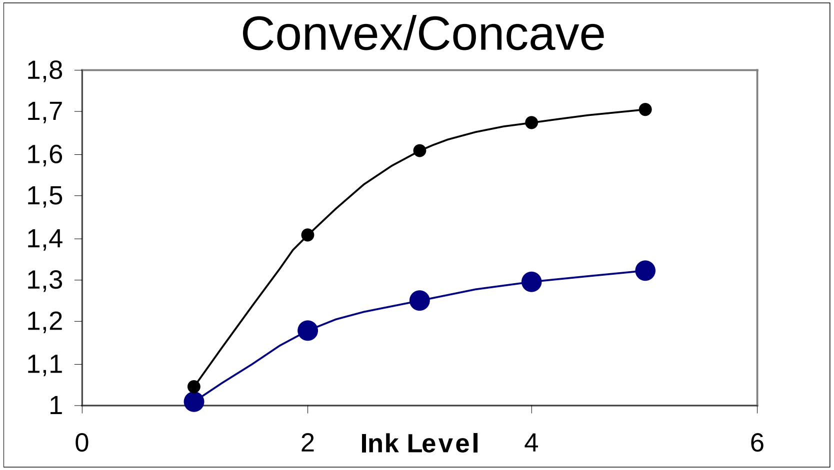
Comparison of large and small dots

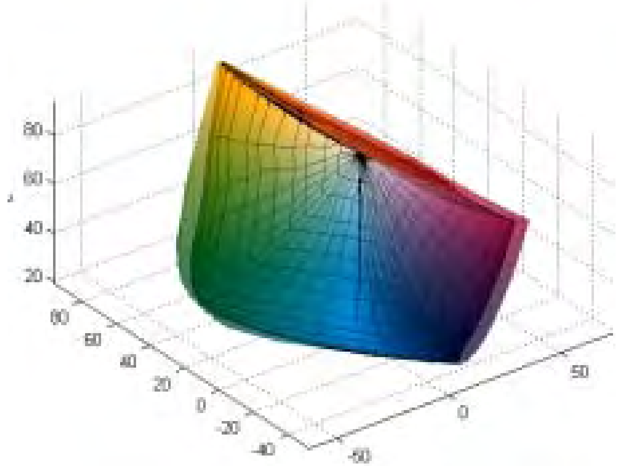
at 5 ink levels

Test printing and measurements with spectrophotometer



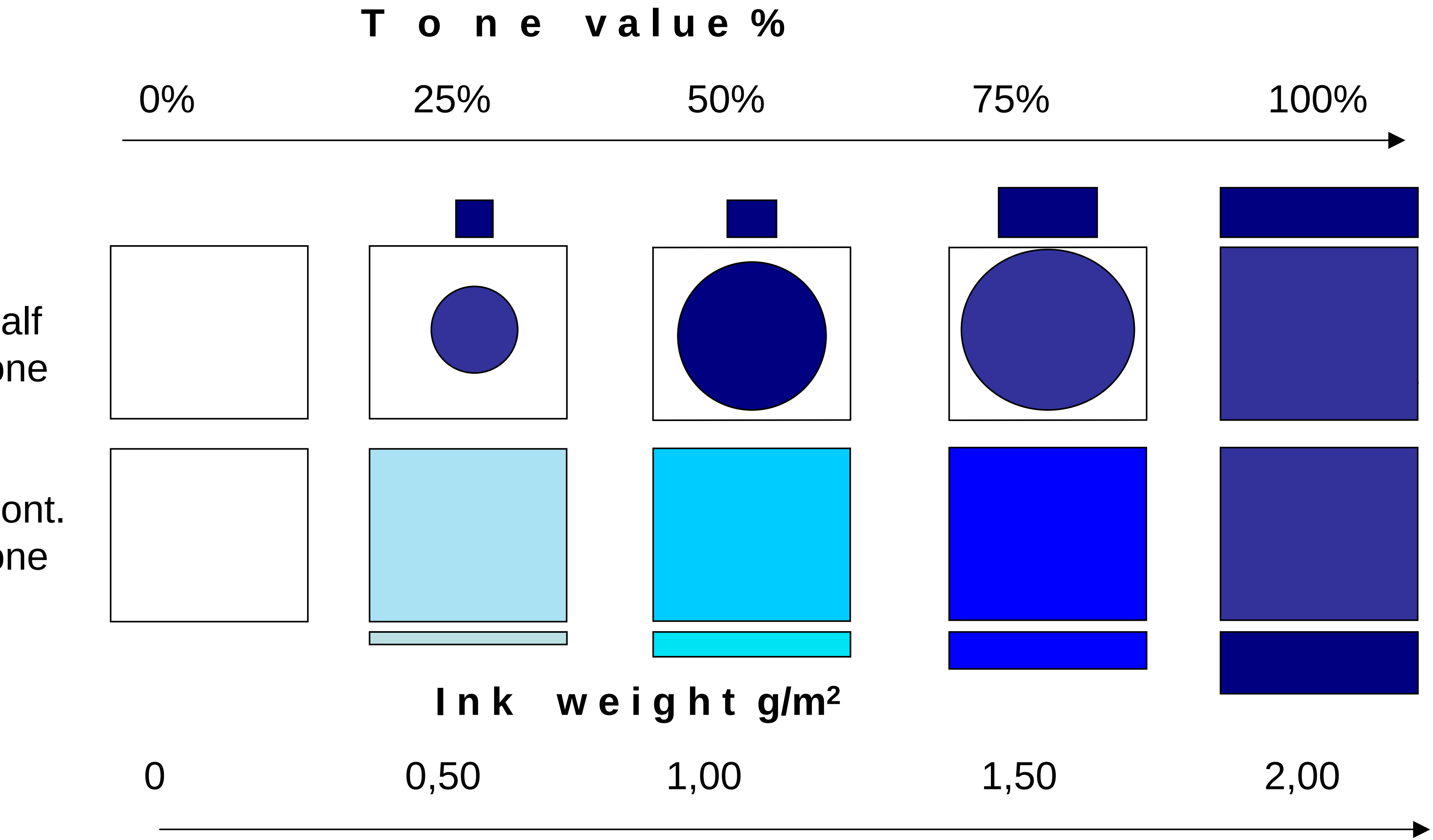






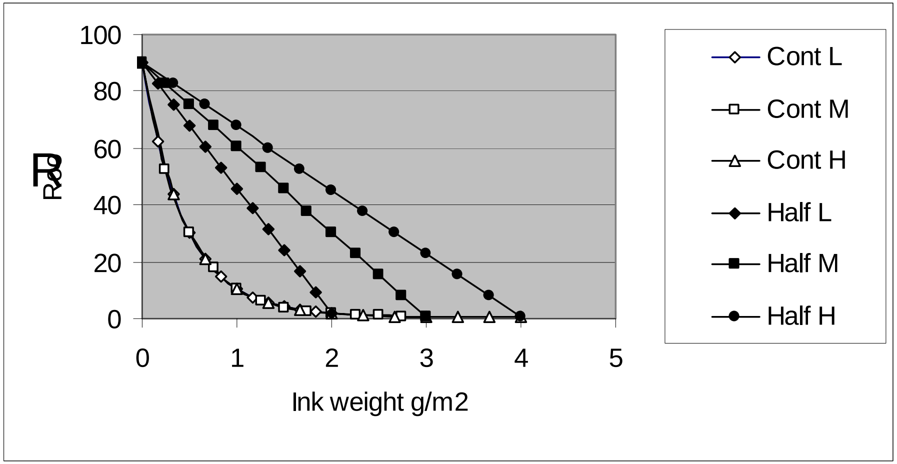
Halftone and continuous tone

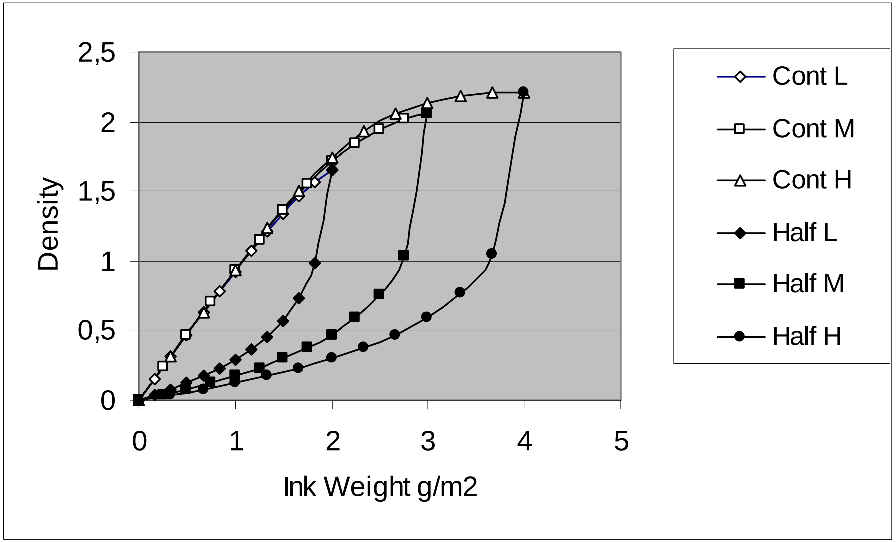
Compared at ink amount per unit area



Simulation

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



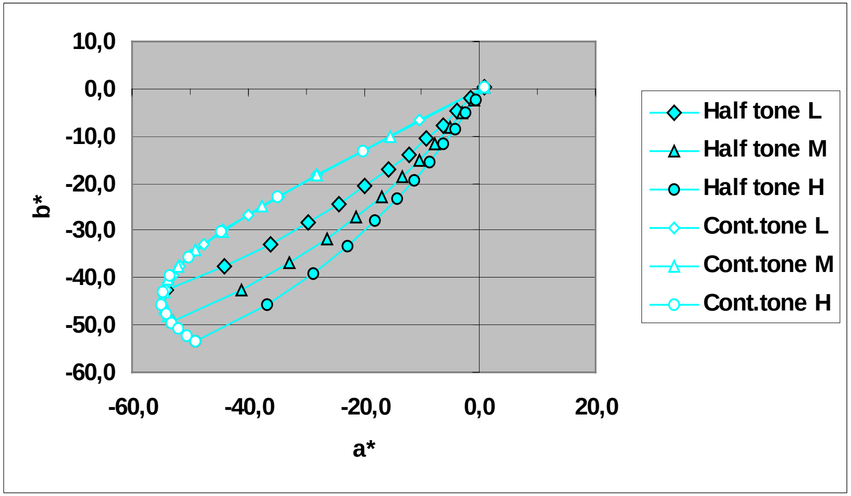


Continuous tone is more effective than half tone

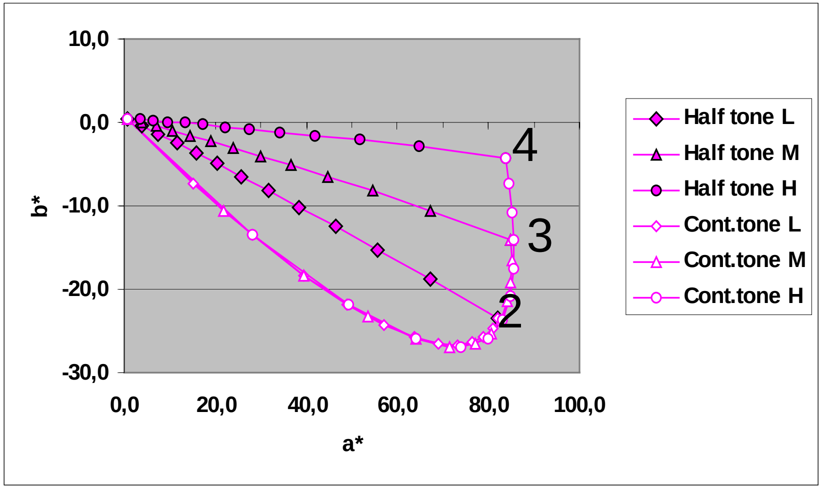
(Compared at ink amount per unit area)

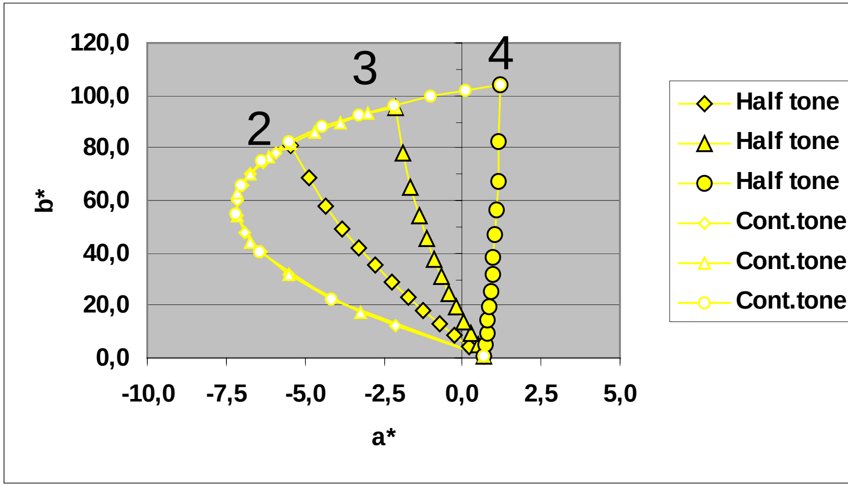
Simulation

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



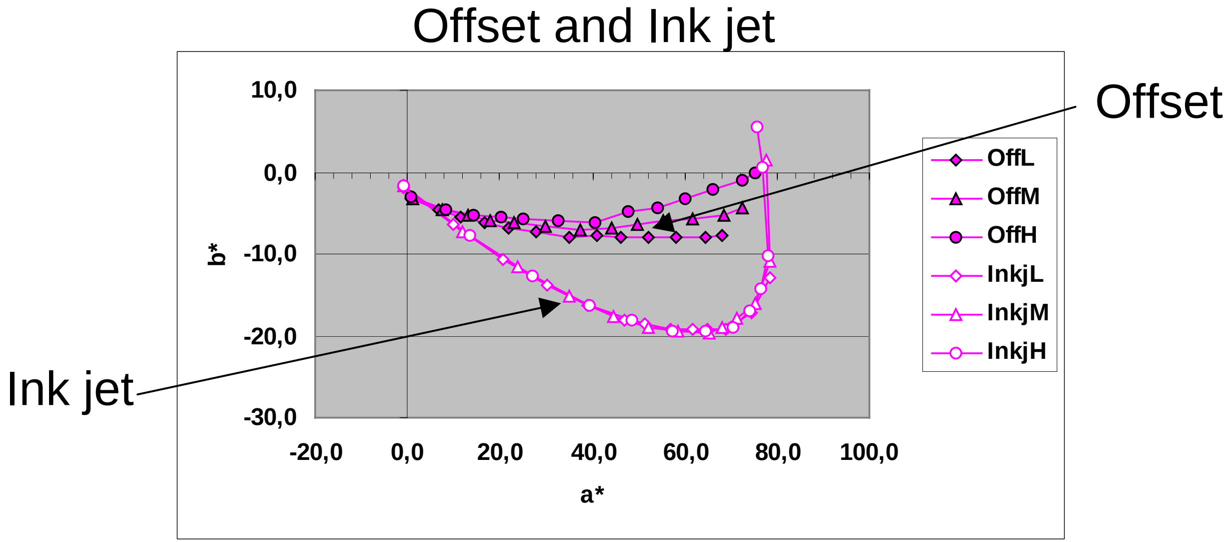
Half tone is more linear than continuous tone in a* vs. b* plots

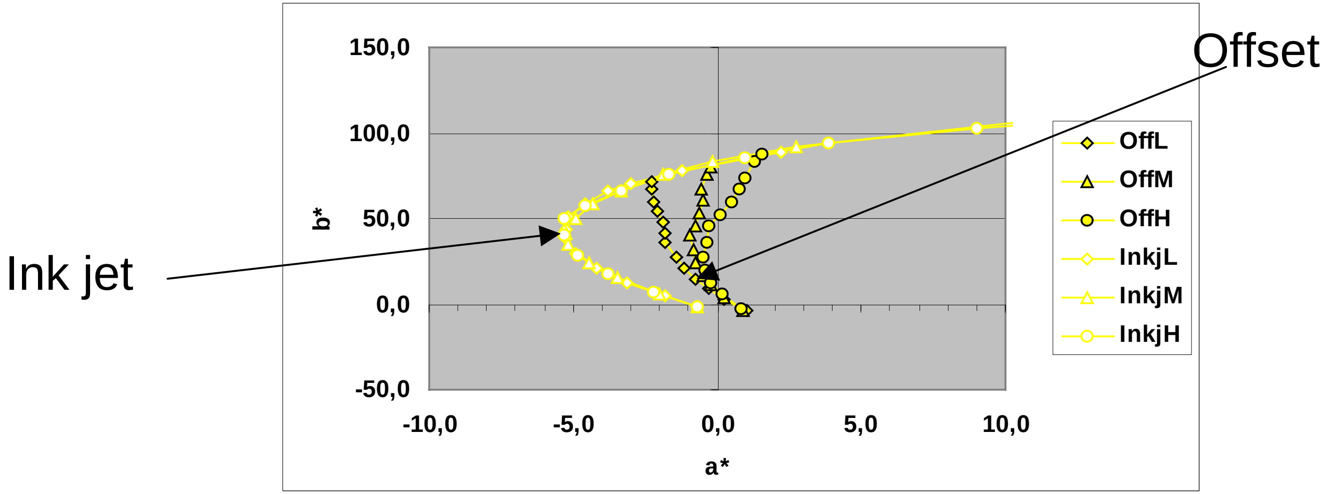




The tone values 0-100 %

measurements on prints with three ink levels

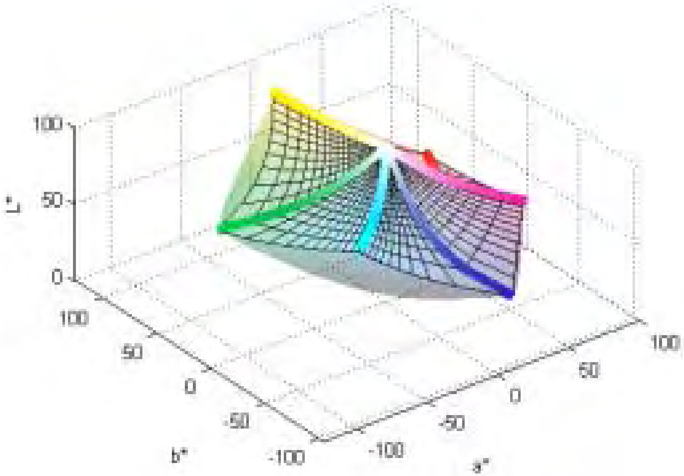




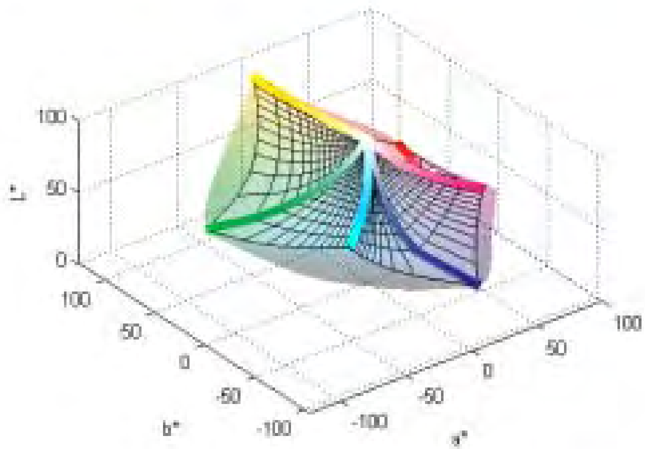
Simulation for increased ink level

for half tone and continuous tone

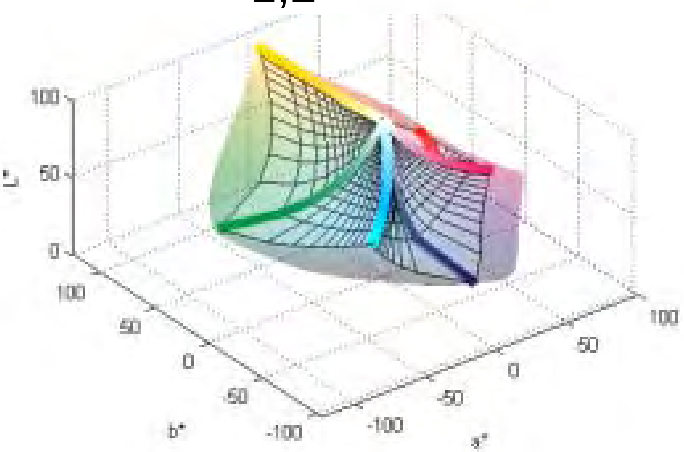
0,6 g/m2



0,9



1,2



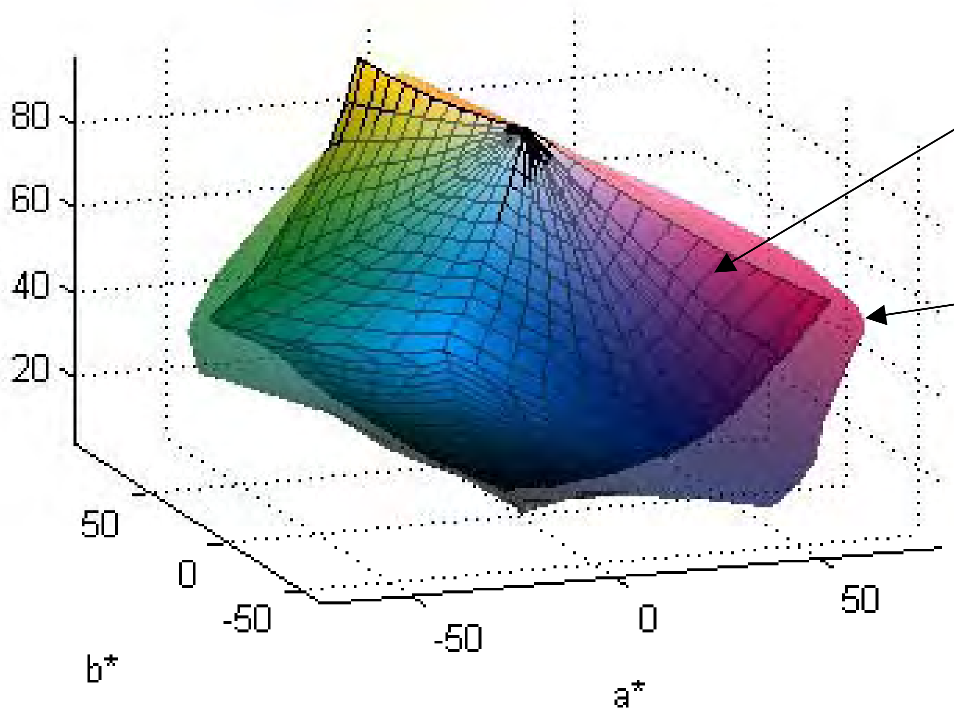
Half tone has concave shape of gamut

continuous tone has convex shape

The difference between offset and Ink jet

Measurements with spectrophotometer

Offset is smaller with a concave shape

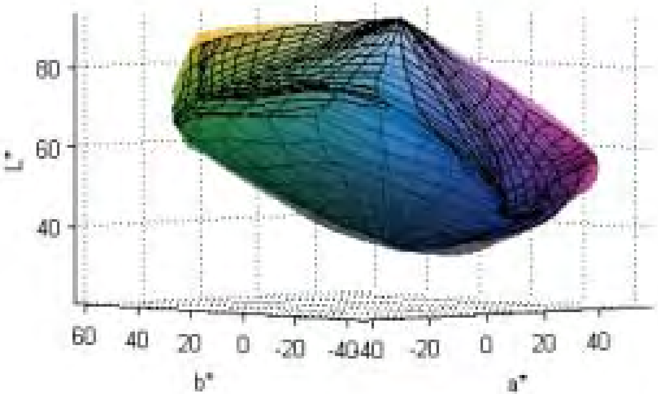


Offset

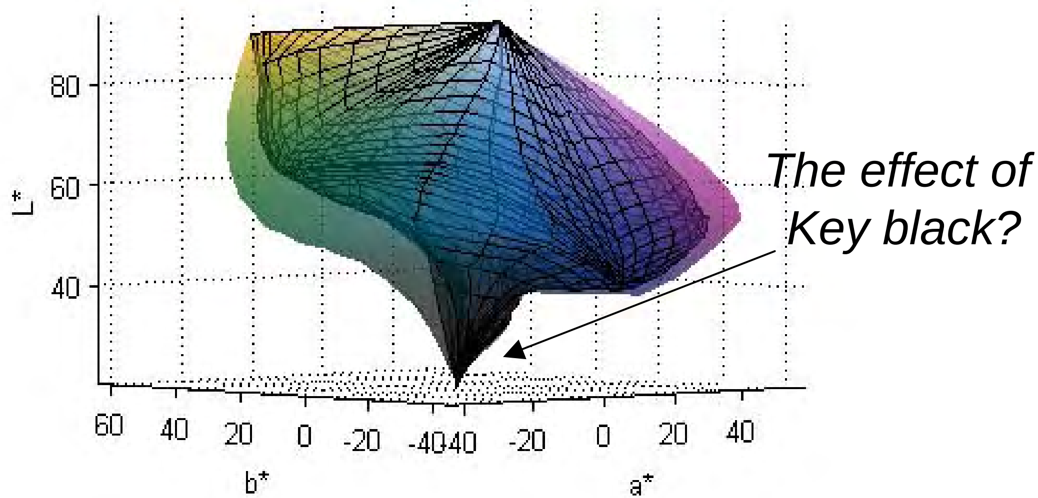
Ink jet

Two different printers
Plain paper

Printer1



Printer2



Grid with ICC profile

Grid with colour correction of the printer

Measurements of Colour gamut

With spectrophotometer

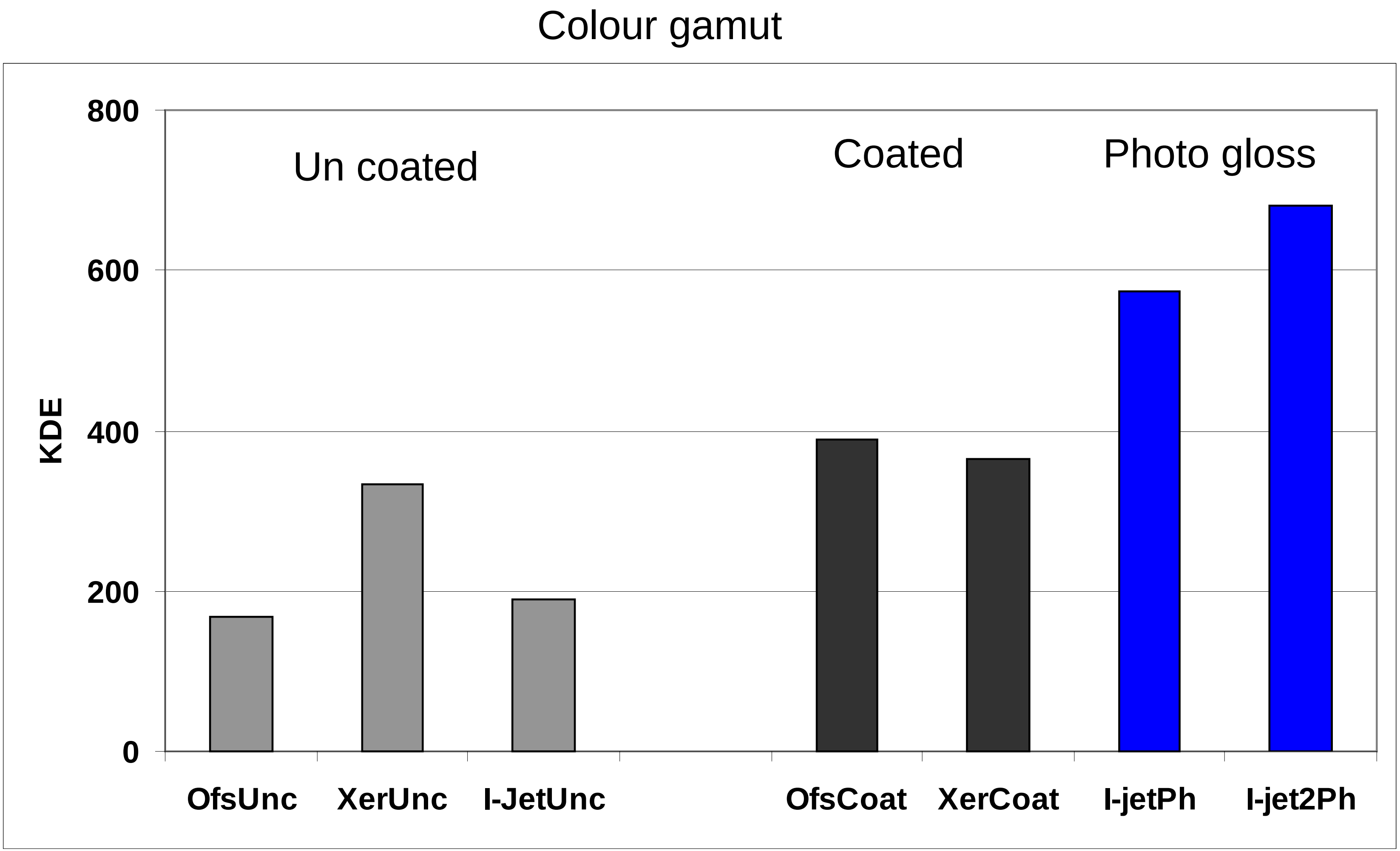
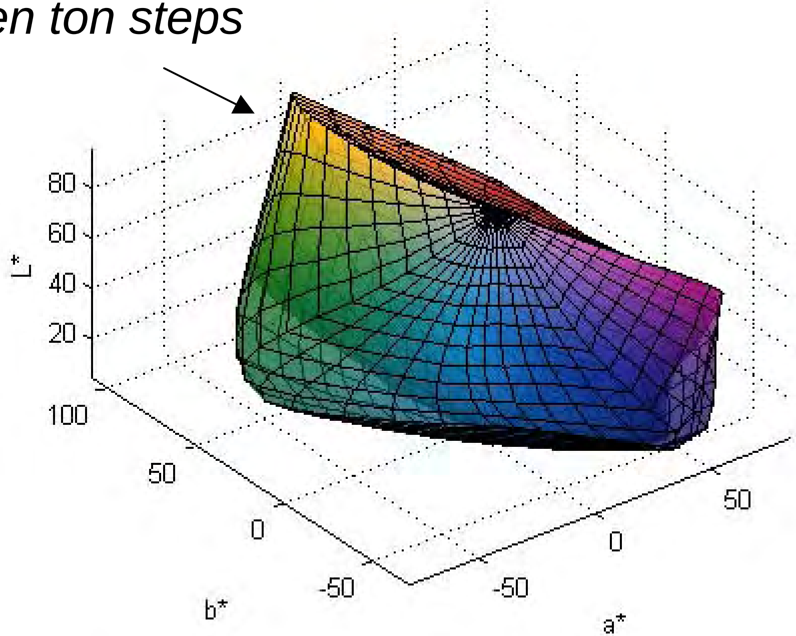


Photo ink jet

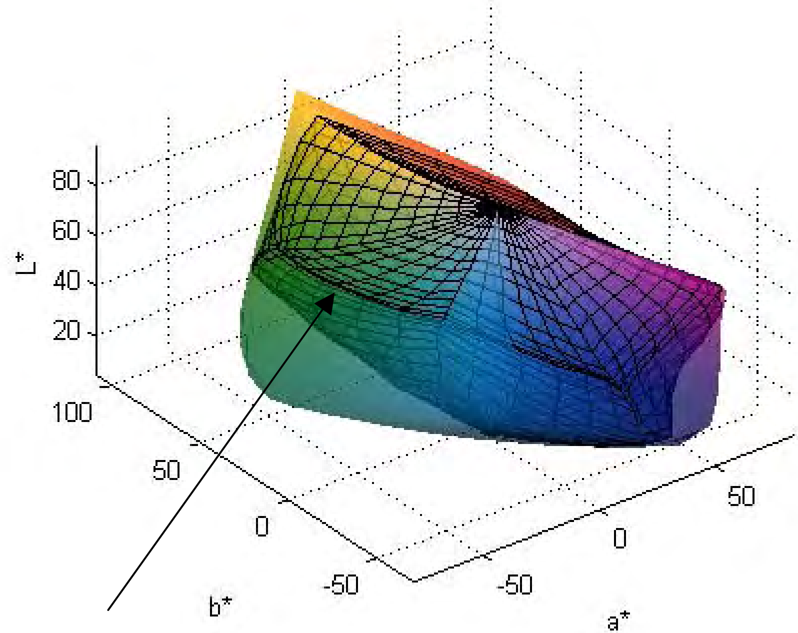
with and without colour correction

Grid: No colour correction

Even ton steps



Grid: Colour corrected with ICC profile



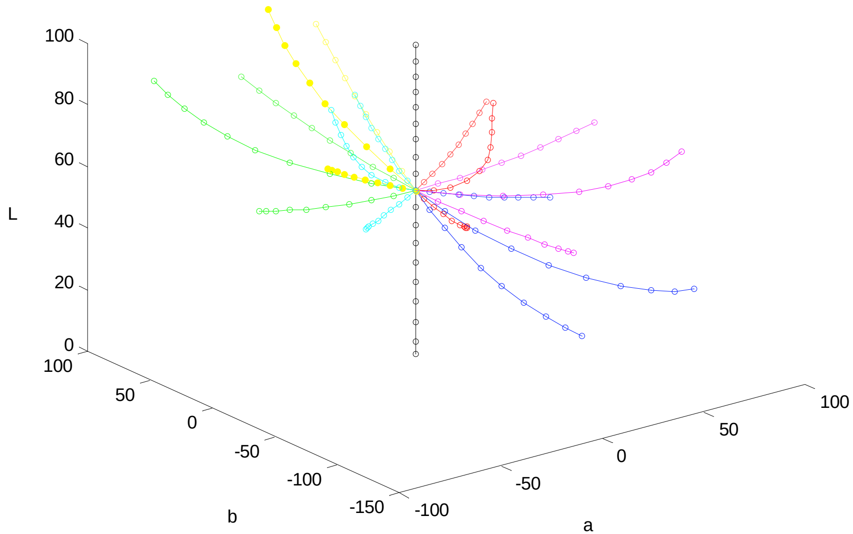
Aggregation due to gamut mapping

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

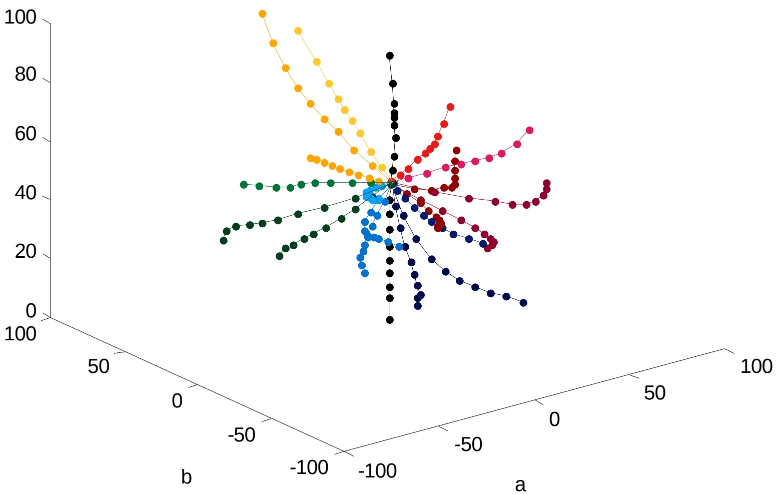
he RGB star

sRGB D50/2



Printer1 with ICC profile

Printer1 no colour correction



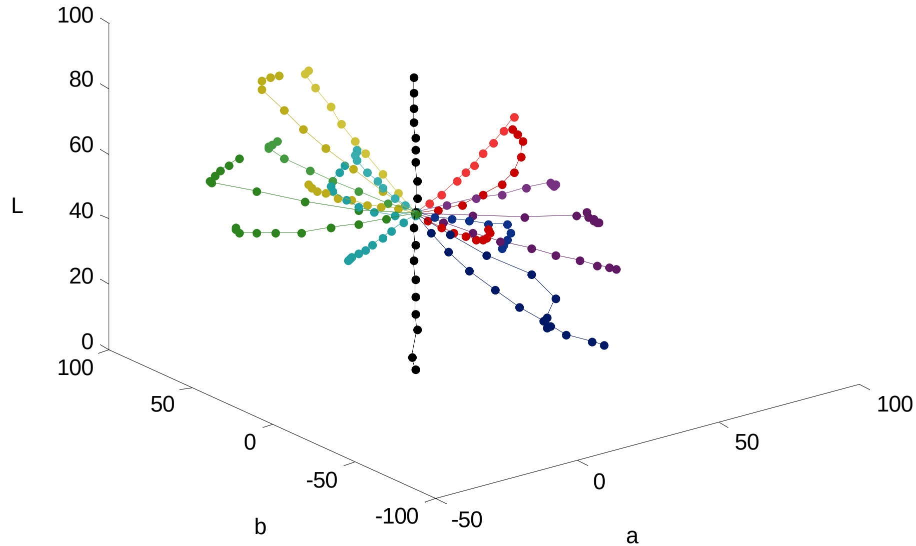
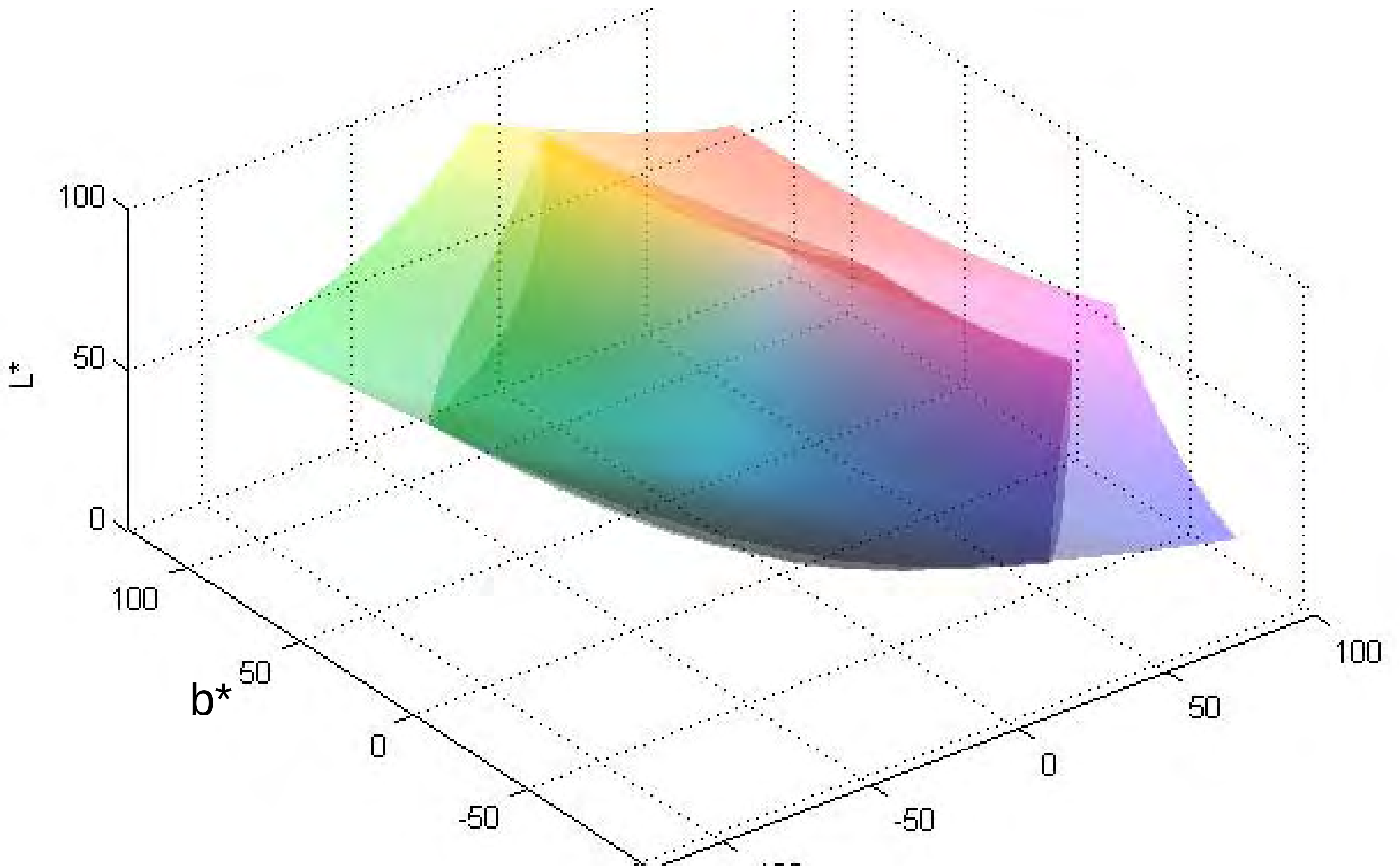


Photo quality

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

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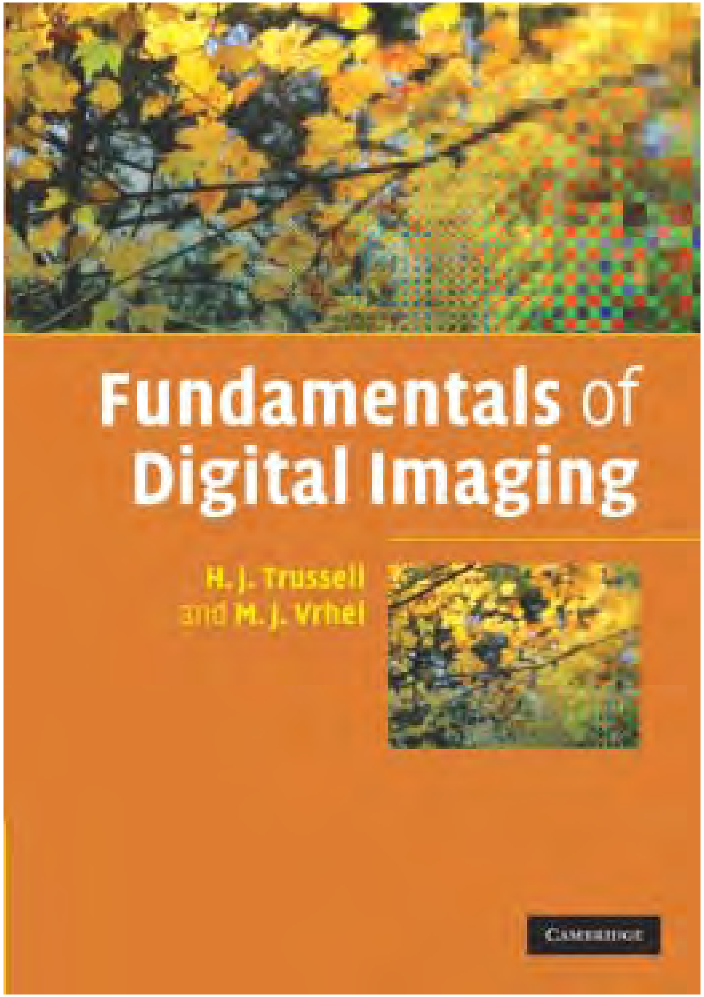


Background and Motivation

- Limited number of spectral reflectance databases available to researchers
  - http://www.it.lut.fi/ip/research/color/database/database.html
  - ftp://ftp.eos.ncsu.edu/pub/eos/pub/spectra/
  - http://www.cs.sfu.ca/~colour/data/
  - ISO/TR 16066:2003 and ISO 17321-1:2006

- 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

$\mathbf{m}_i = \mathbf{H}^T \mathbf{L} \mathbf{r}_i + \mathbf{n}_i$	Example color measuring system model
$\mathbf{m}_i^T = [m_1, \ldots, m_K]$	Measurement vector for reflectance i
$\mathbf{H} = [\mathbf{h}_1, \ldots, \mathbf{h}_K]$	Transmittances of color filters
$\mathbf{L}$	Illumination spectral distribution (diagonal matrix)
$\mathbf{r}_i$	Spectral reflectance i
$\mathbf{n}_i^T = [n_1, \ldots, n_K]$	Noise vector

Example: Color measurement models cont.

$$\mathbf{t}_i = \mathbf{A}^T \mathbf{L}_v \mathbf{r}_i$$ CIEXYZ value for illuminant $\mathbf{L}_v$

$$e = E\left\{M\left[L(\mathbf{t}) - L(F(\mathbf{m}))\right]\right\}$$ 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

- 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.

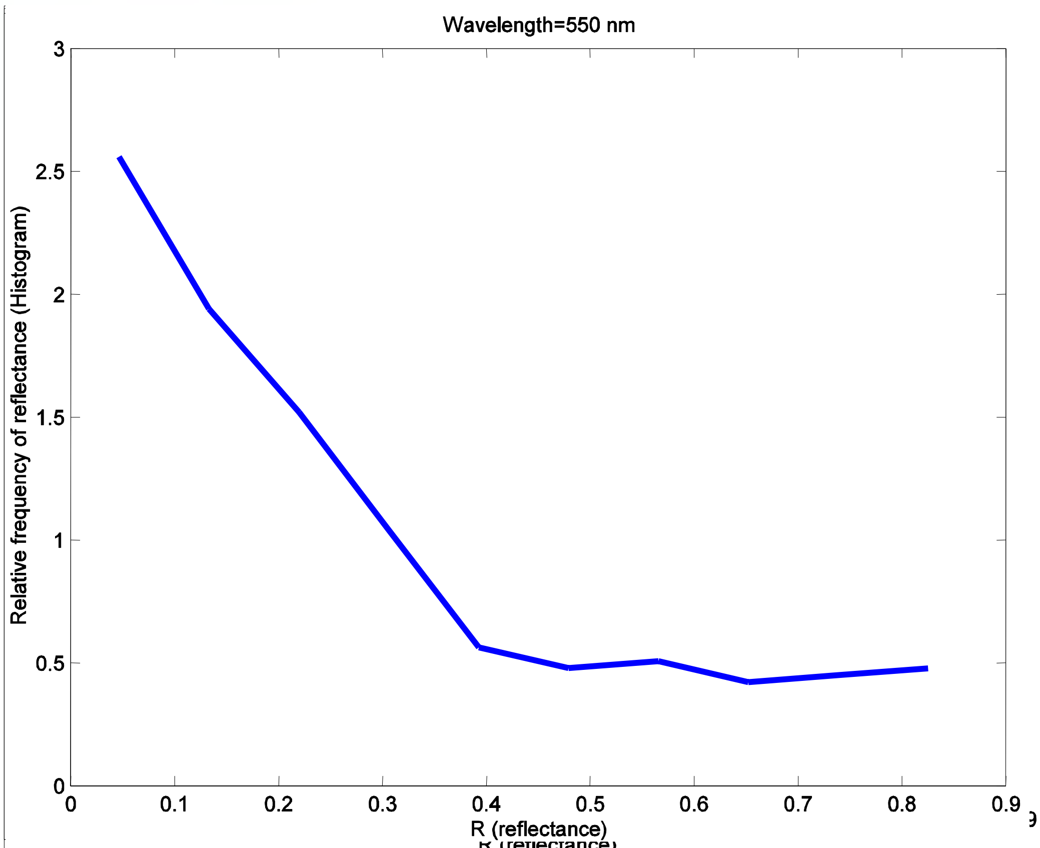
- If data were multivariate Gaussian, this would be sufficient. However data is not Gaussian distributed and these two quantities do not completely characterize the data.

- Data is bounded between 0 and 1.

- Probability distribution of data varies across wavelengths.

Example data set
ftp://ftp.eos.ncsu.edu/pub/eos/pub/spectra

Data collected of 170 natural objects from 390nm to 730nm at 2nm intervals.



Ten bin histogram at wavelength

450nm

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?

Method 1: The Copula cont.

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.

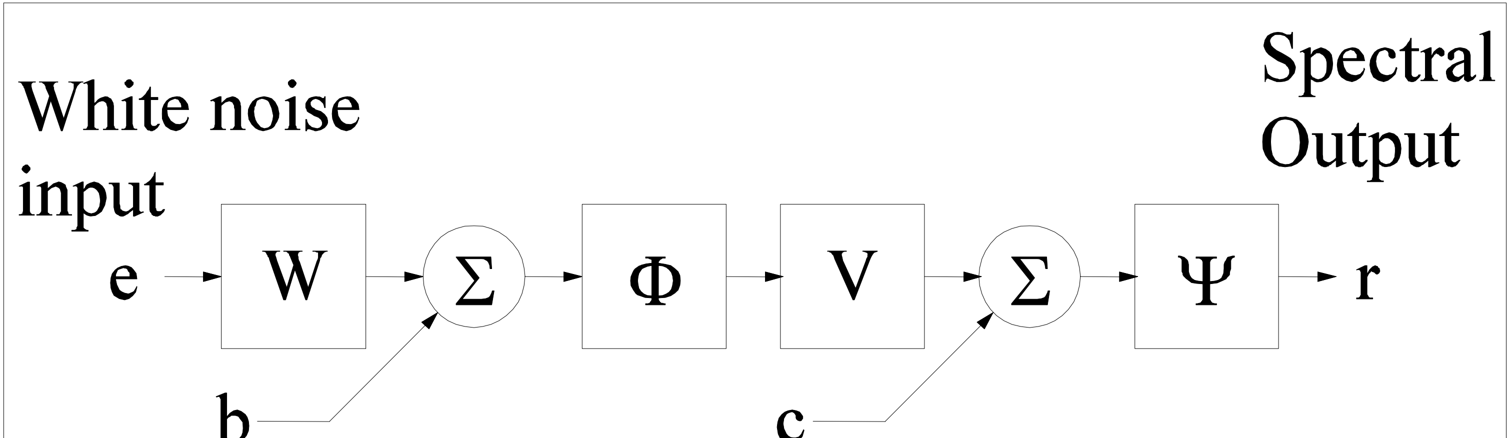
$$[\mathbf{r}]_i = F_i^{-1}\left(\left[\frac{1}{2}\operatorname{erf}\left(\frac{[\mathbf{v}]_i}{\sqrt{2}}\right)\right]\right)$$

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 $\phi(x) = \frac{2}{1+\exp(-2*x)} - 1$
- 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 **e**?

Use distributions of whitened spectral data.

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

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.

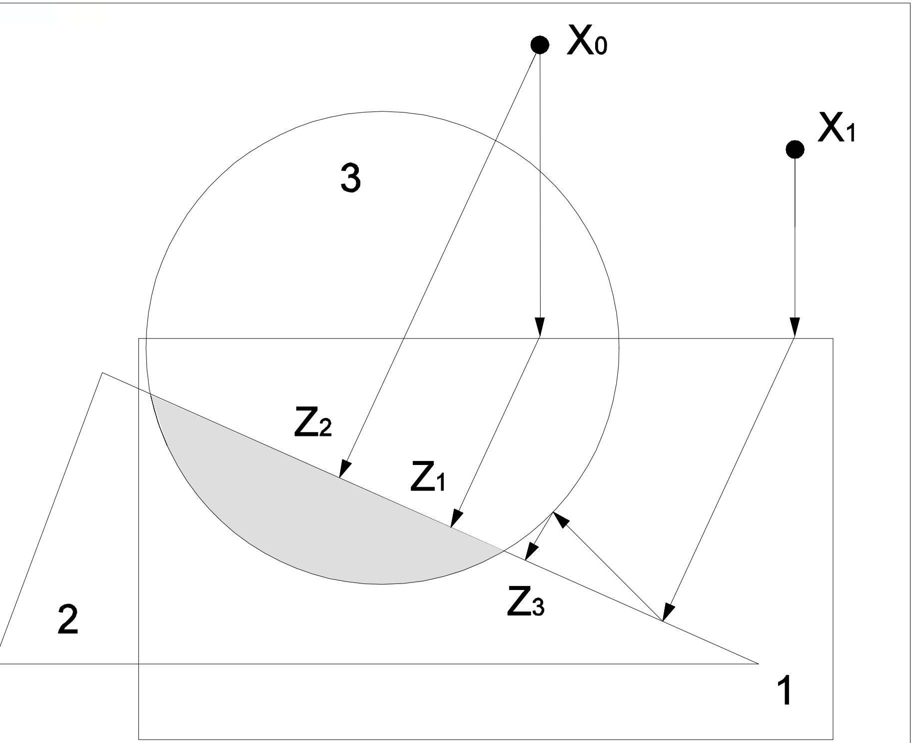
Step 2: Use Network

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 **R**, which has M columns of simulated spectra.

Force constraints upon **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.

$$\mathrm{C}_{\mathrm{bound}} = \left\{ \ \mathbf{R} \mid \ r_{min_i} \le r_{i,j} \le r_{max_i} \ \right\} \ \ i = 0,\ldots,(N-1) \quad j = 0,\ldots,(M-1)$$

$$\mathrm{C}_{\mathrm{mean}} = \left\{ \ \mathbf{R} \ \mid \ \| \mathbf{R1} - M\,\mathbf{r}_{mean} \|_2 \le \ \delta_{\mathrm{mean}} \ \right\} \qquad \mathbf{1} \ \text{vector of all ones}$$

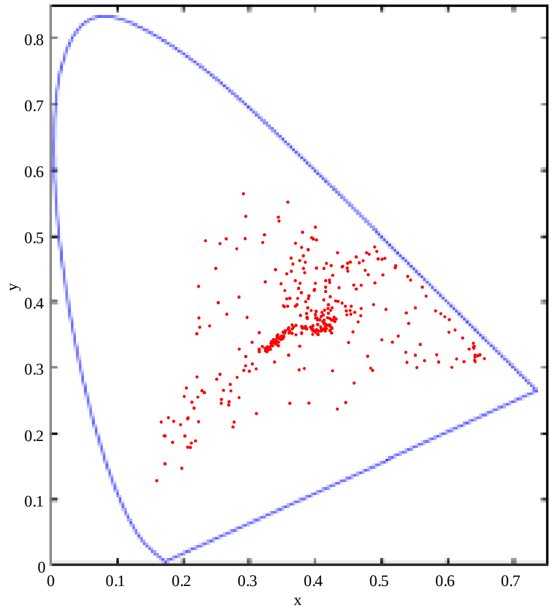
$$\mathrm{C}_{\mathrm{cov}} = \left\{ \ \mathbf{R} \mid \ \| \, \mathbf{RR}^T - M\,(\mathbf{K}_r + \mathbf{r}_{mean}\mathbf{r}^T_{mean}) \, \|_F \ \le \ \delta_{\mathrm{cov}} \ \right\}$$

Step 1: Generate random NxM matrix.

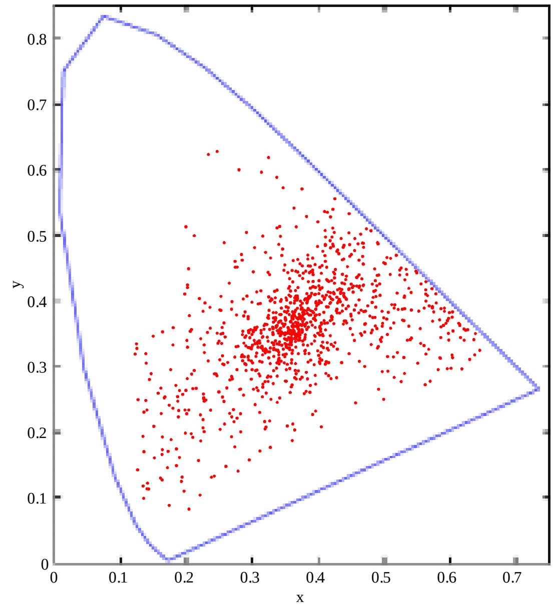
Step 2: Perform alternating POCS on above constraint sets, stop upon convergence.

Results Chromaticity

Generated 1000 spectra using each of the three methods



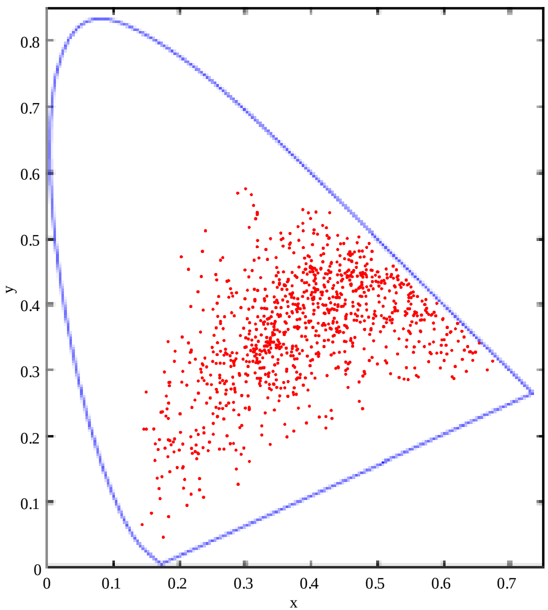
Real chromaticity



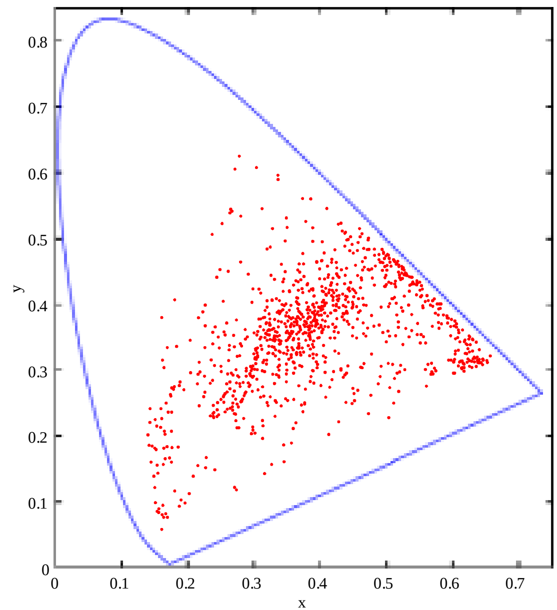
ANN chromaticity

Results Chromaticity

Generated 1000 spectra using each of the three methods



Copula chromaticity

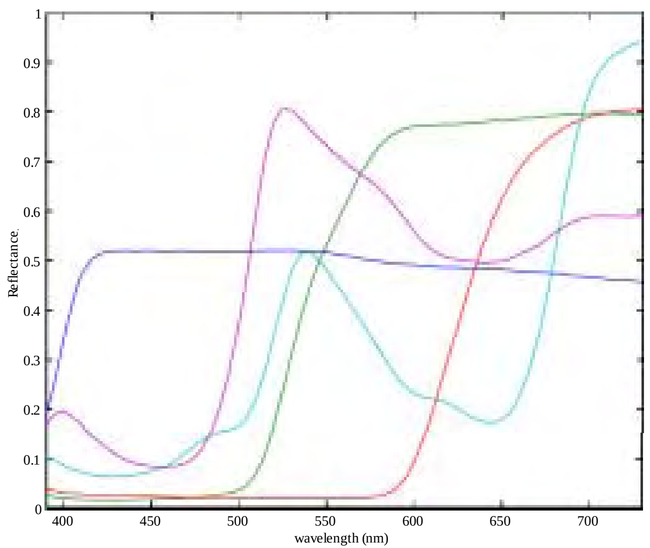


POCS chromaticity

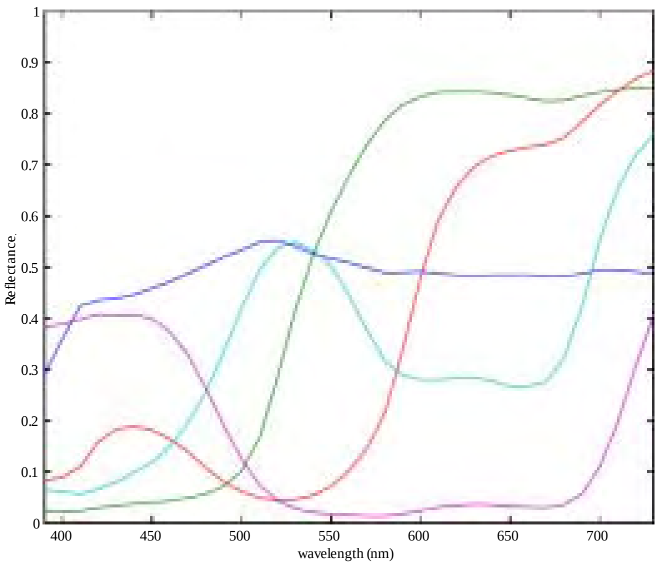
Results Spectra

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

Results Spectra

Difficult to show all the spectra.

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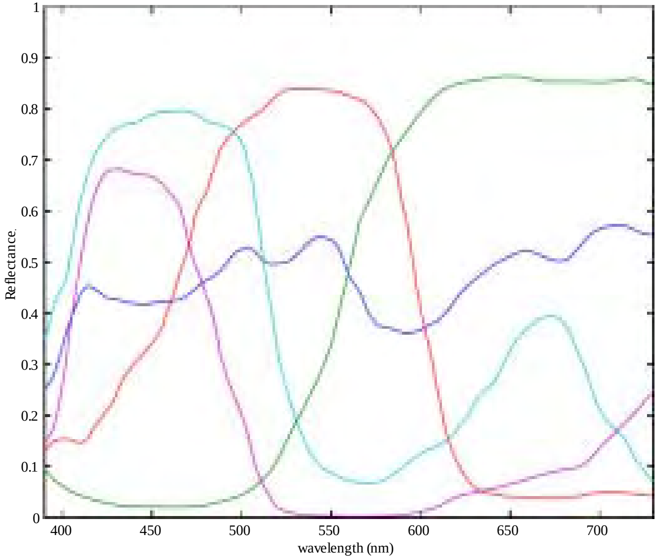
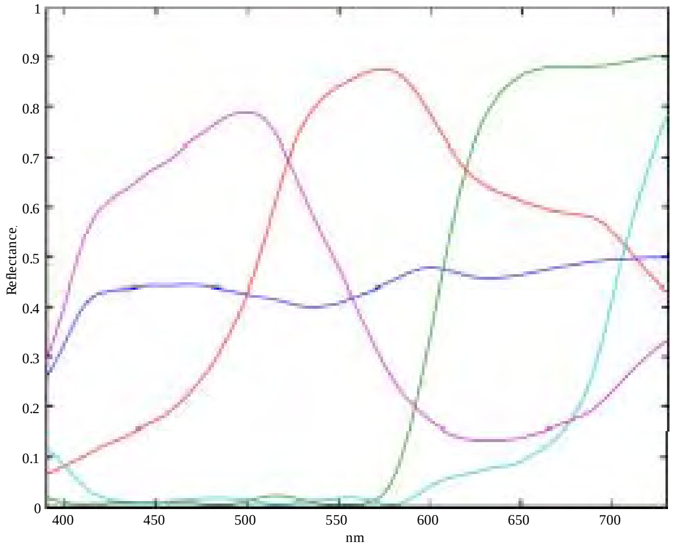


Copula spectra



POCS spectra

ARTIFEX Software Inc.

Relative Quantitative Comparisons

Method	ε_{cov}	$\varepsilon_{\text{mean}}$	$\varepsilon_{\text{rank}}$
Copula	0.68	0.18	0.42
ANN	0.45	0.17	1.00
POCS	0.10	<0.0001	1.74

$$\grave{o}_{\text{mean}} = \left\| \mathbf{S1} - M\mathbf{r}_{\text{mean}} \right\|$$

$$\grave{o}_{\text{cov}} = \left\| (\mathbf{SS}^T - \mathbf{s}_{\text{mean}} \mathbf{s}_{\text{mean}}^T) - \mathbf{K}_r \right\|_F$$

$$\grave{o}_{\text{rank}} = \left\| T(\mathbf{S}) - T(\mathbf{R}) \right\|_F$$

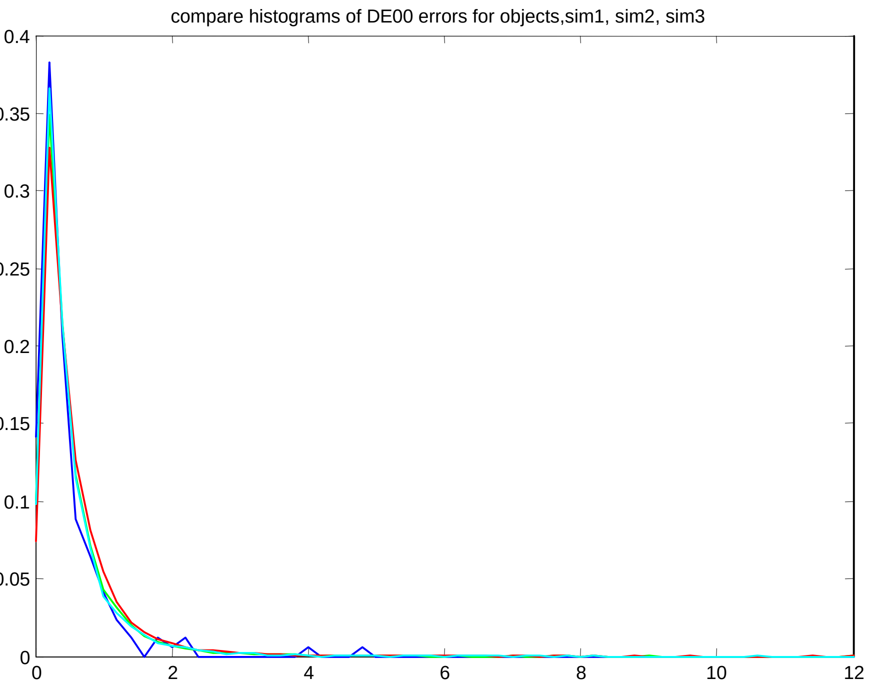
T computes Kendall rank correlation matrix.

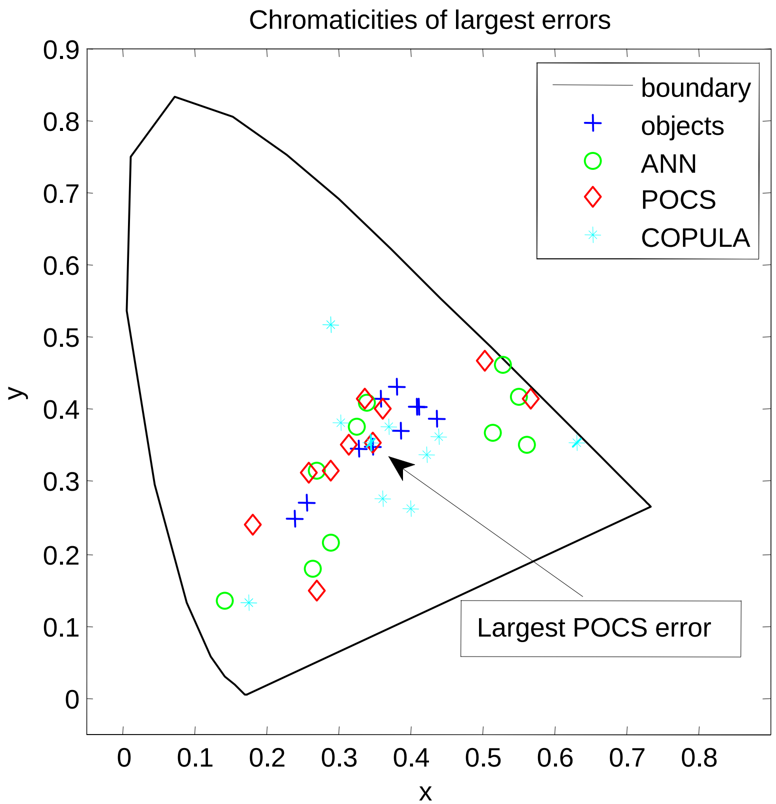
Application – Finding worst performance

Consider simulation of color measuring instrument with red green blue Gaussian shaped transmittances and MLSE estimator for CIEXYZ tristimulus values.

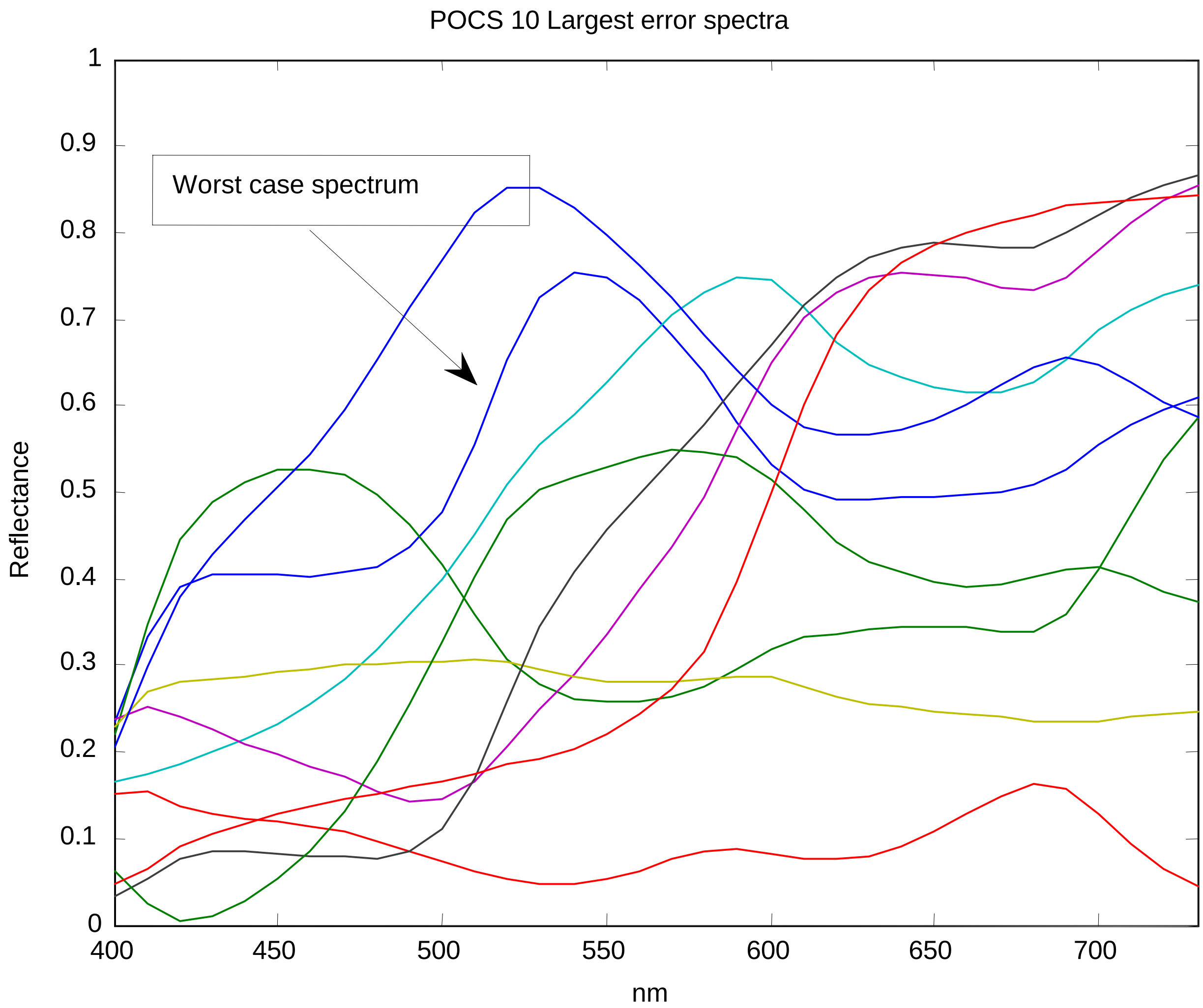
Data Set	Average ΔE 2000	Max ΔE 2000
Real Data 170 samples	0.46	4.80
Copula 10000 samples	0.50	10.68
ANN 10000 samples	0.52	12.85
POCS 10000 samples	0.51	20.38

Application – Finding worst performance





Application – Finding worst performance



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

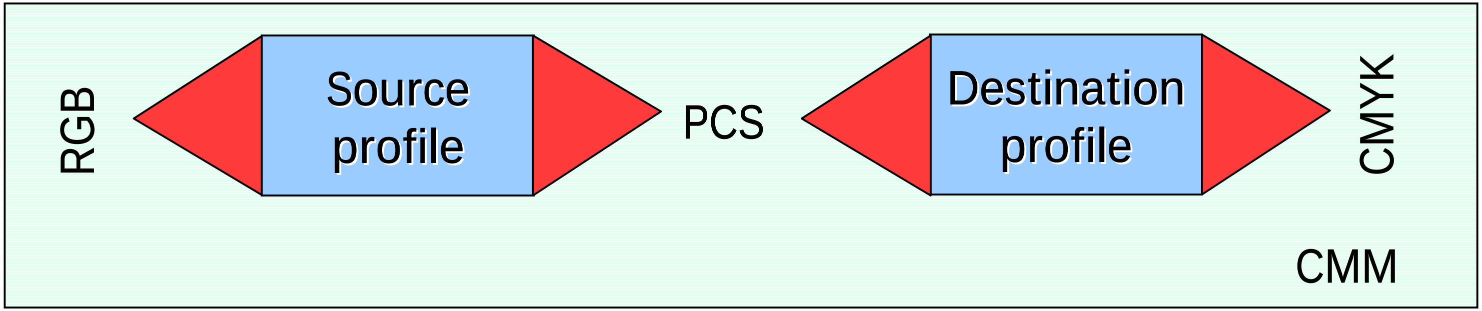
- *Colorimetric CMS Framework*
- *Spectral CMS Framework*
- *Spectral estimation*
- *Spectral CMS Workflow*
- *Conclusions*

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



Proofing Workflow

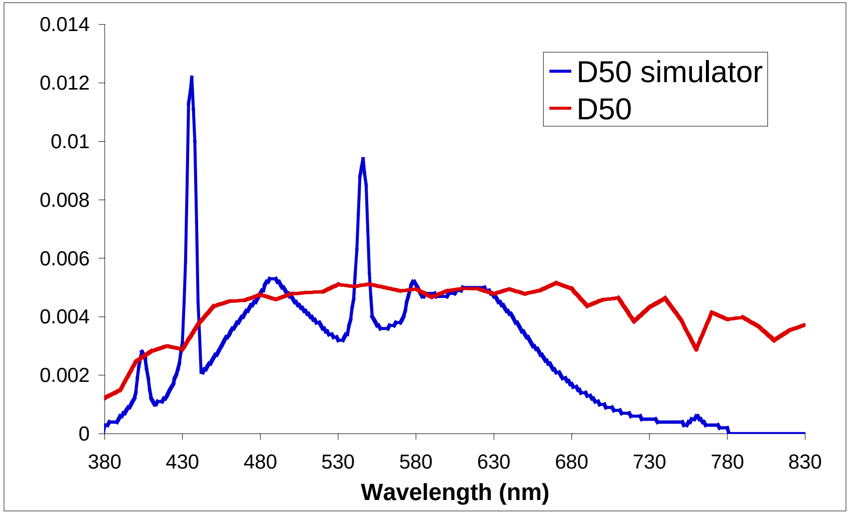
- *D50 as match, viewed under D50 simulator*

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

but viewing conditions are often D50 simulator

=> visual mismatch possible

=> how large?



Proofing Workflow

- *D50 to D65 simulator*

Viewing conditions
- D50
- CIE 1931 Observer

PCS viewing cond.
- D50
- CIE 1931 Observer

Viewing conditions
- D65 simulator
- CIE 1931 Observer

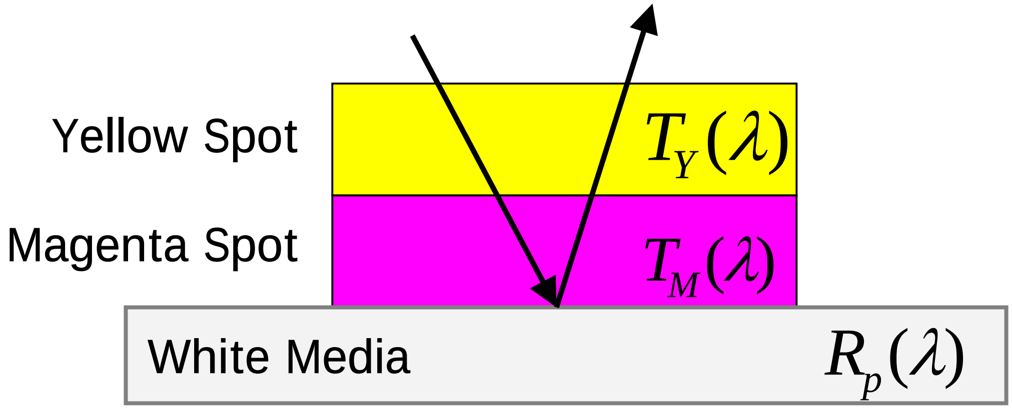
- *No match!!*
- *For most characterization data : no spectral data is available (e.g. FOGRA39)*

** This is where spectral estimations are needed

Duotone Rendering

- *Color mixing model for 2 Spot Colors*

$$R(\lambda) = T_M^2(\lambda) T_Y^2(\lambda) R_p(\lambda)$$



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***

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

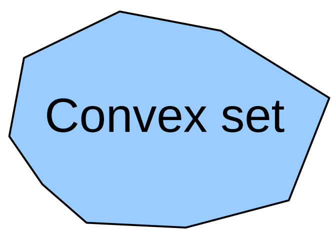
  – with R_i the reflectance spectrum of the object, I_i the spectral power distribution of the illuminant, $\bar{x}_i \bar{y}_i \bar{z}_i$ the Color Matching Function (CMF) , & *N* the dimension of the spectral space

Finding the Convex Set

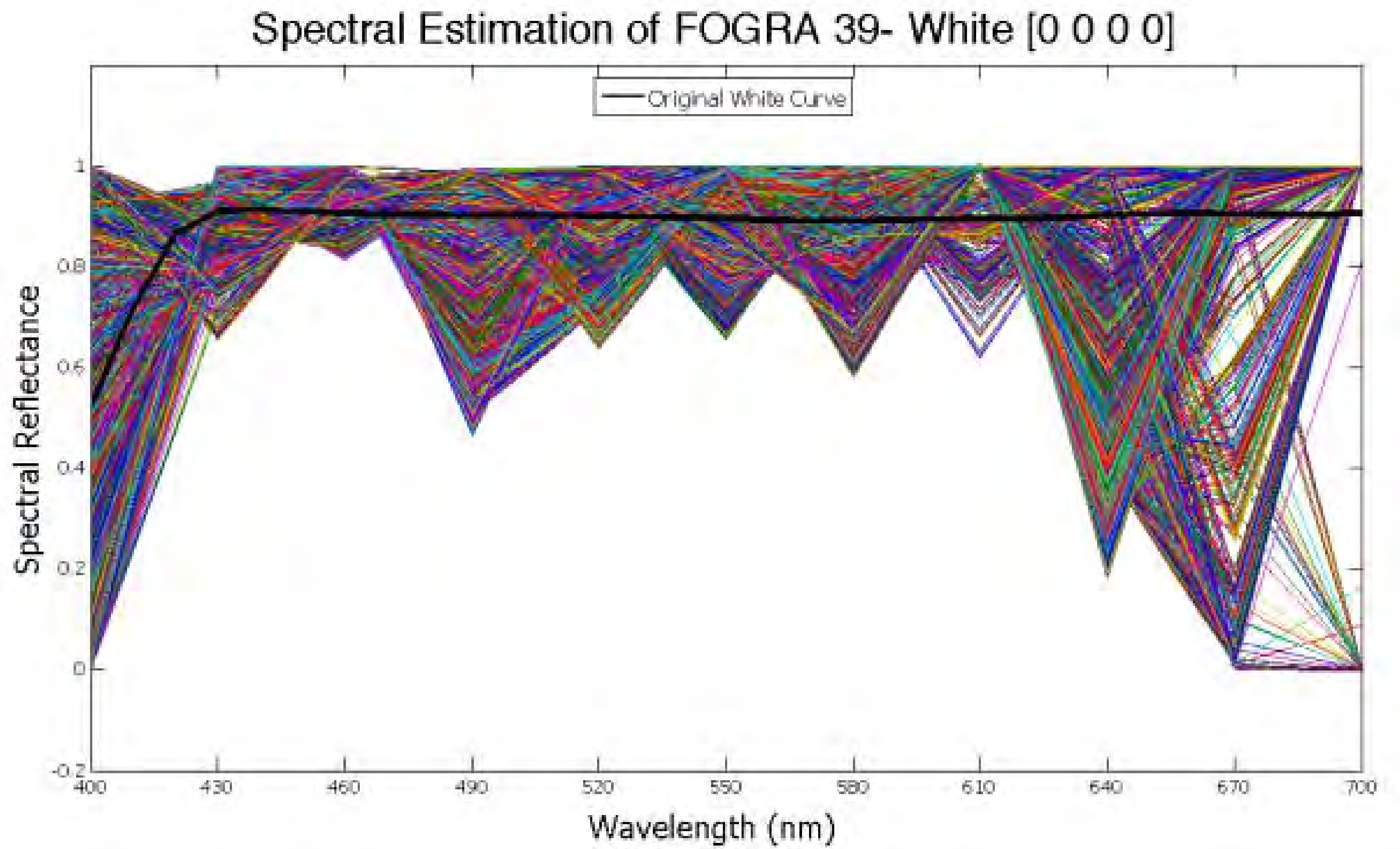
- *Spectral reflectance estimation*
  - Definition
    - Invert the tristimulus values & solve for $\overline{R}$ with $0 \le R_i \le 1$ for all $i : 1 \to N$

$$A' = \begin{pmatrix} \overline{x}_1 I_1 & \overline{x}_2 I_2, & \cdots, & \overline{x}_N I_N - X \\ \overline{y}_1 I_1 & \overline{y}_2 I_2, & \cdots, & \overline{y}_N I_N - Y \\ \overline{z}_1 I_1 & \overline{z}_2 I_2, & \cdots, & \overline{z}_N I_N - Z \end{pmatrix} \longrightarrow A' \begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_N \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

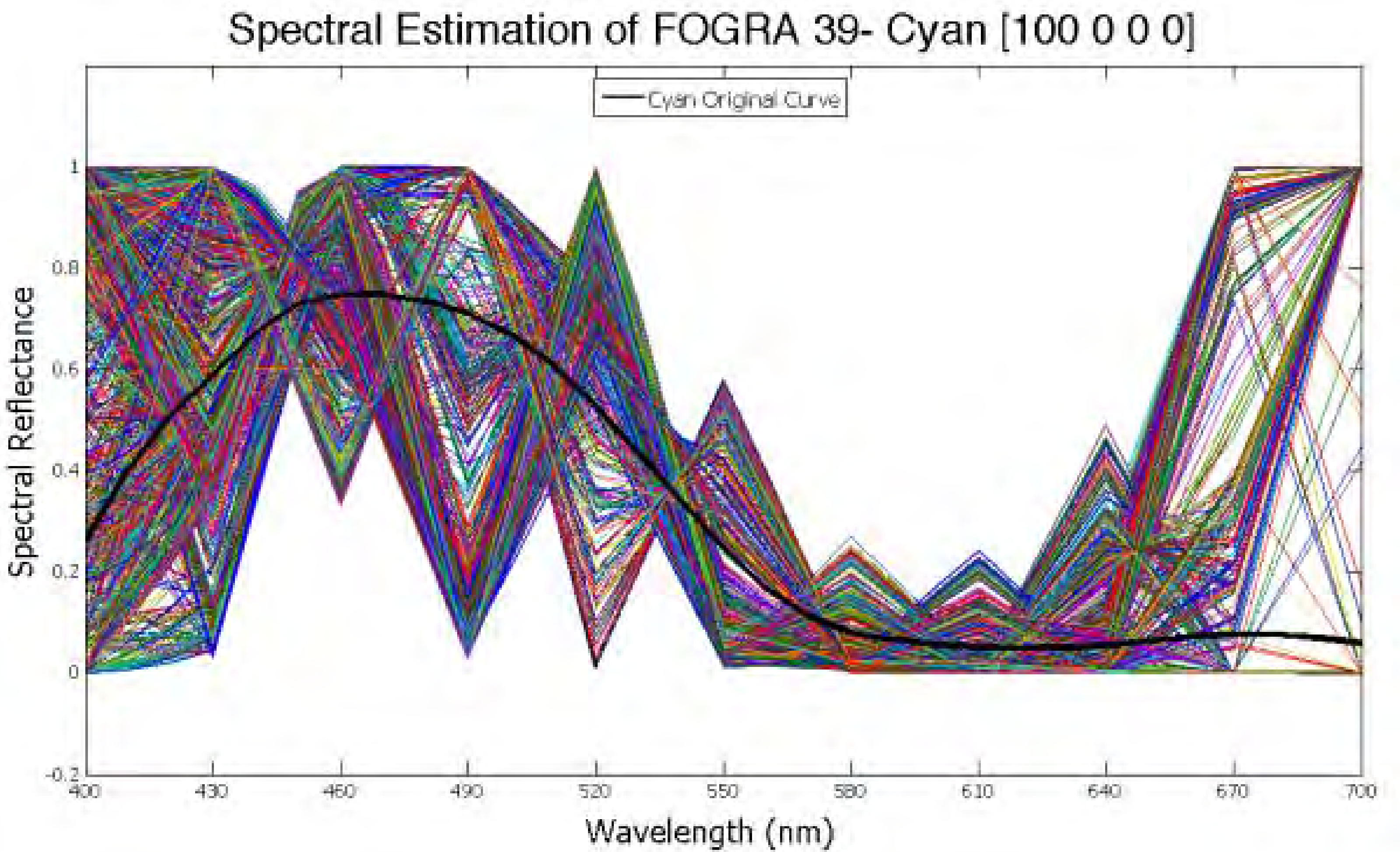
  - Solution space
    - Convex set in spectral space



Reflectance Estimations



Reflectance Estimations



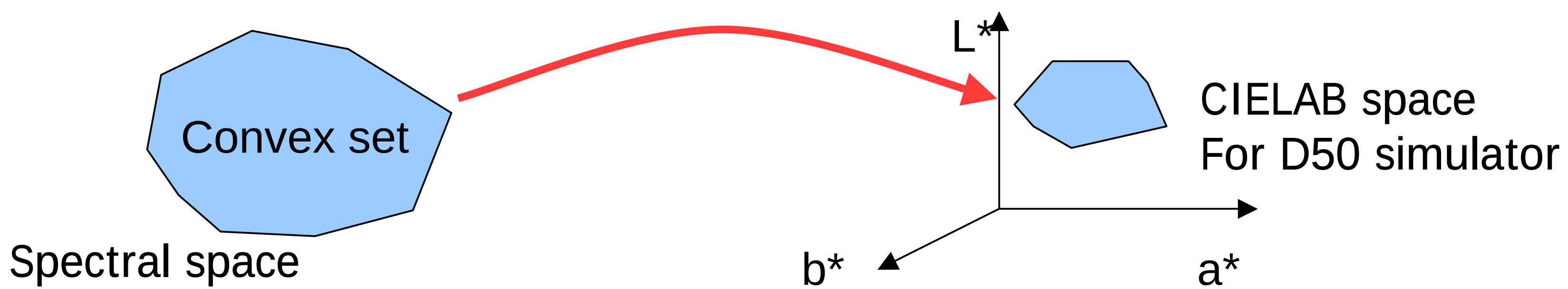
Convex Set in CIELAB

D50 simulator

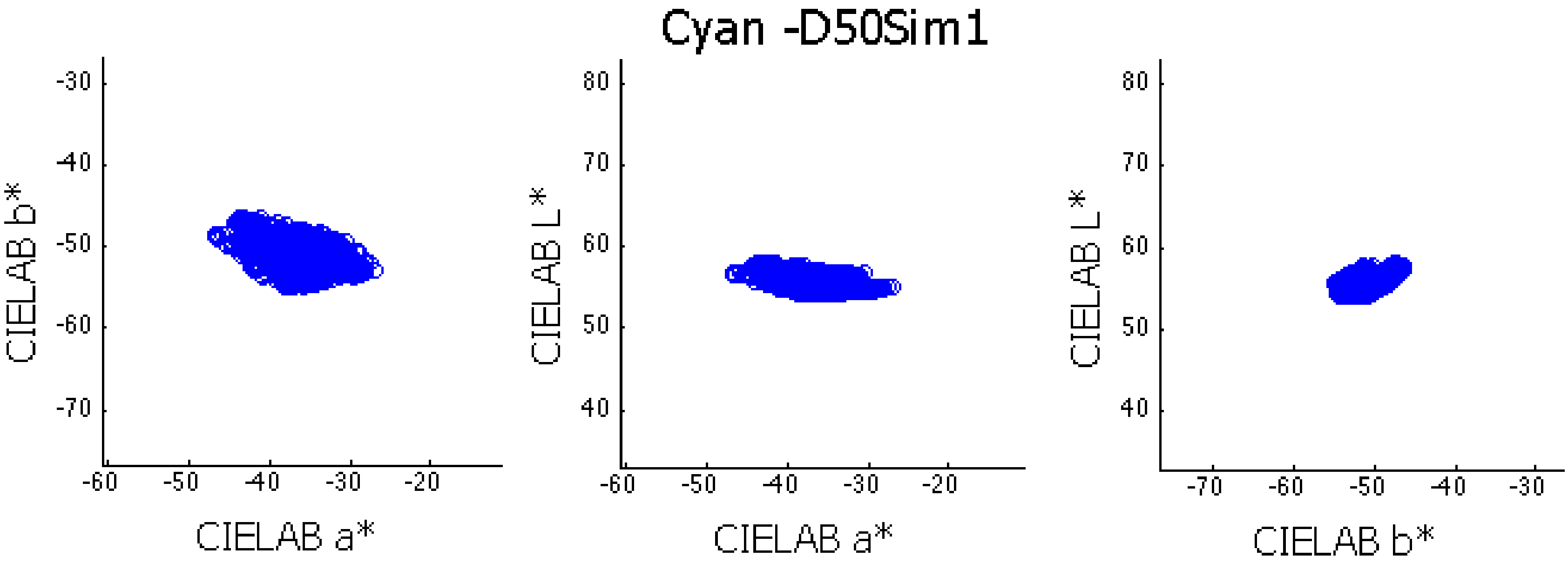
=> visual mismatch possible

=> how large? Compare D50 and D50 simulator

- *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



Projection Results



– FOGRA39 Estimates for Solid Cyan under D50 Simulator

Results Reviewed

- *Results*
  - FOGRA39: Within the convex set for D50 simulator

Color	*Max. Spectra*	*Max ΔE^*_{ab}*
White	*8.15*	*3.85*
Solid Black	*4.24*	*13.65*
Solid Cyan	*12.41*	*19.04*
Solid Magenta	*10.80*	*13.71*
Solid Yellow	*9.32*	*7.33*

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 ΔE^*_{ab}: ~ 2

Optimal Reflectance Curve

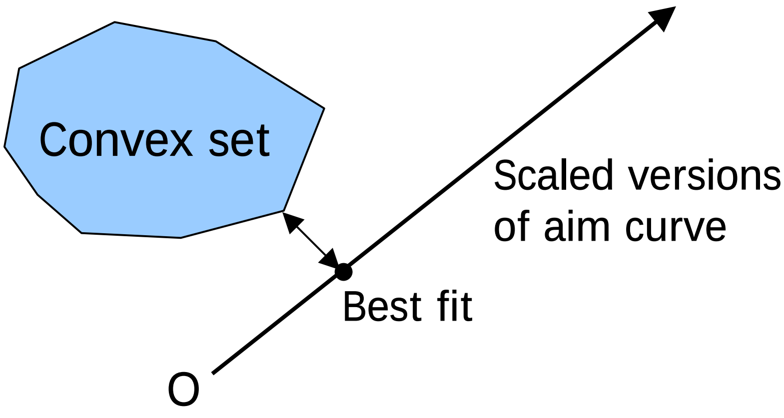
- *Selecting a spectrum out of the convex set*
  - Quadratic programming
    - Equation:

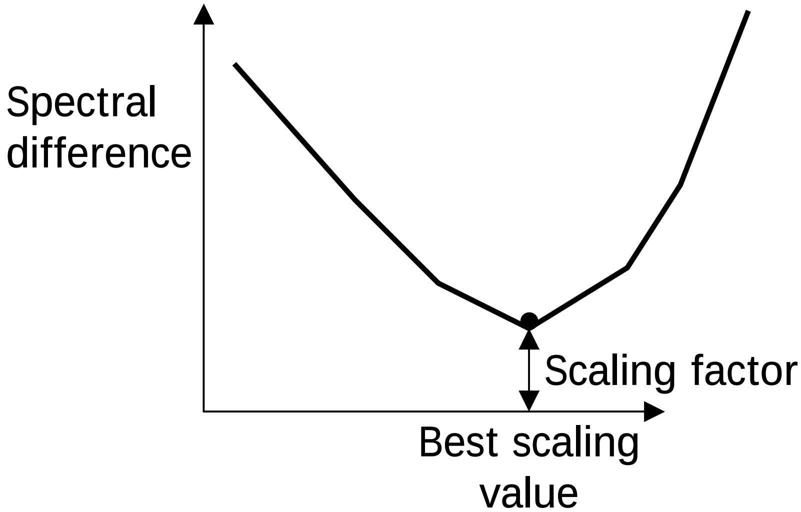
$$\begin{pmatrix} \bar{x}_1 I_1 & \bar{x}_2 I_2 & \cdots & \bar{x}_N I_N \\ \bar{y}_1 I_1 & \bar{y}_2 I_2 & \cdots & \bar{y}_N I_N \\ \bar{z}_1 I_1 & \bar{z}_2 I_2 & \cdots & \bar{z}_N I_N \end{pmatrix} \begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_N \end{pmatrix} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

      with $0 \le R_i \le 1$ 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





Finding the optimal curve

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

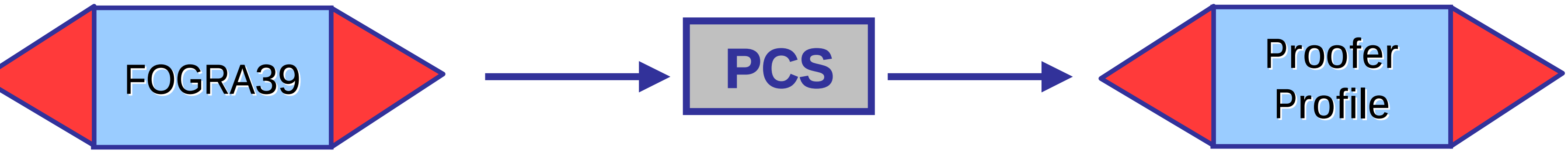
Illuminant D50 Simulated											
	Original CIELAB			Orig. Est CIELAB			Norm Est. CIELAB			Not	Norm
	L*	a*	b*	L*	a*	b*	L*	a*	b*	$\Delta E_{ab}*$	$\Delta E_{ab}*$
Solid White	88.66	4.37	-0.86	88.60	4.20	-1.32	88.65	4.37	-0.88	0.50	0.03
Solid Black	18.64	1.83	-0.49	18.63	2.02	-0.45	18.65	2.08	-0.35	0.19	0.28
Solid Cyan	55.30	-35.43	-45.47	55.35	-35.20	-45.53	55.32	-35.41	-45.29	0.24	0.17
Solid Magenta	47.84	68.03	-5.22	47.52	68.16	-5.87	47.78	68.00	-5.21	0.74	0.07
Solid Yellow	84.12	0.33	81.37	84.00	0.12	81.61	84.09	0.29	81.77	0.34	0.41

Spectral CMS Workflow Examples

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

Proofing Example

- *Matching for the proper viewing conditions*



Viewing conditions	**PCS viewing cond.**	**Viewing conditions**
- D50	- D50	- D65 simulator
- CIE 1931 Observer	- CIE 1931 Observer	- CIE 1931 Observer

- 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

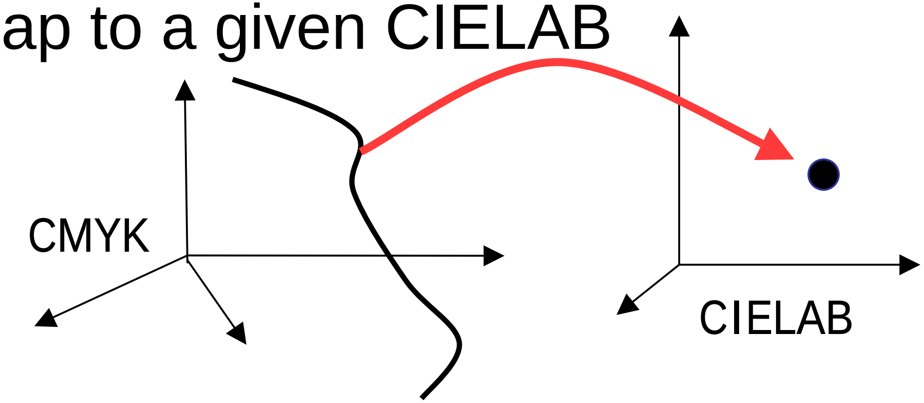
Multi-tone Example

- *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 ΔE^*_{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 :
    - ΔE^*_{ab} up to 20 theoretically
    - ΔE^*_{ab} up to 2 for CMYK ink jet printer
- Selection of a spectral curve
  - Quadratic programming with normalized aim curve

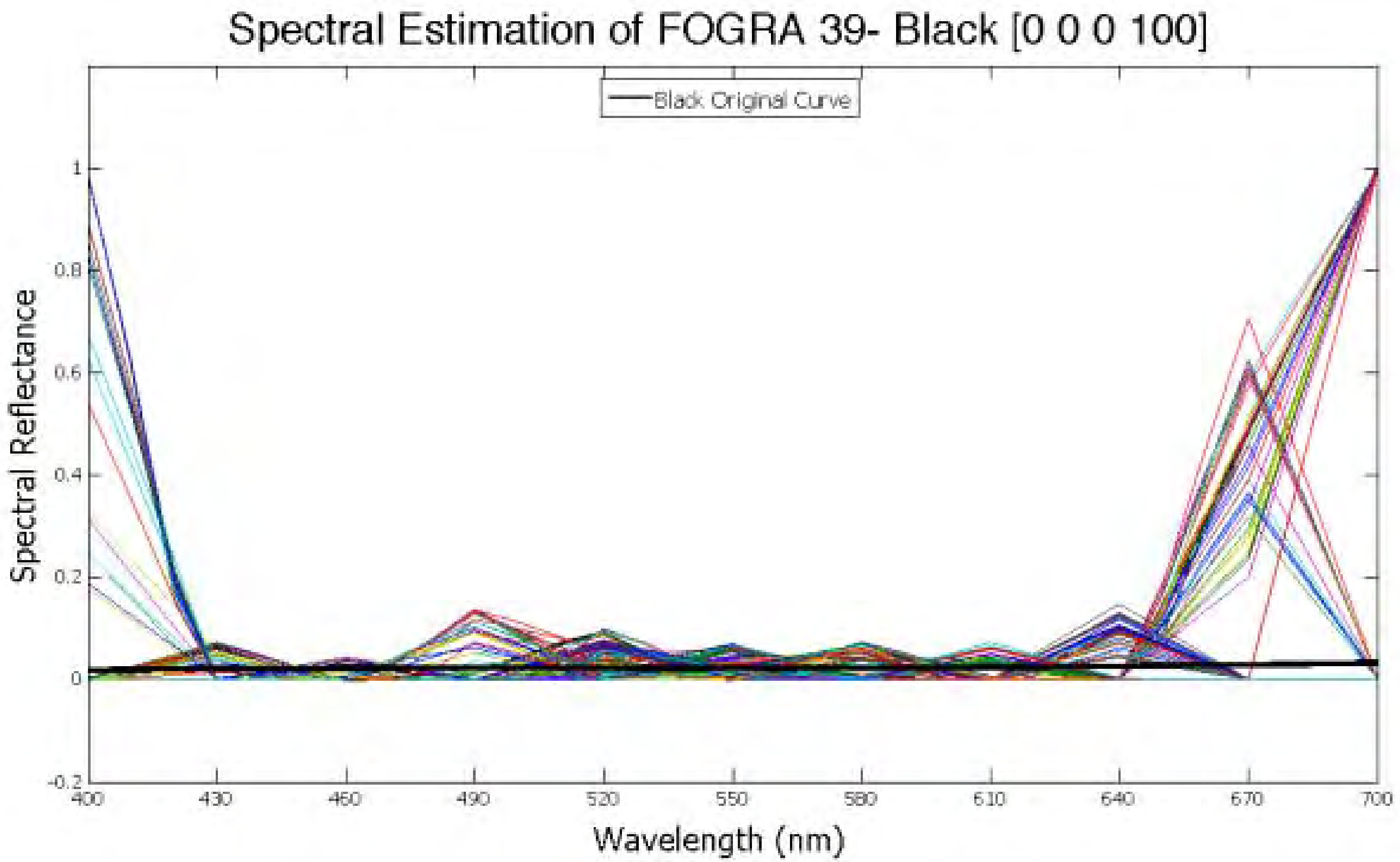
Applications

- Proofing, spot color rendering, metameric matches, …

Thank you for your time

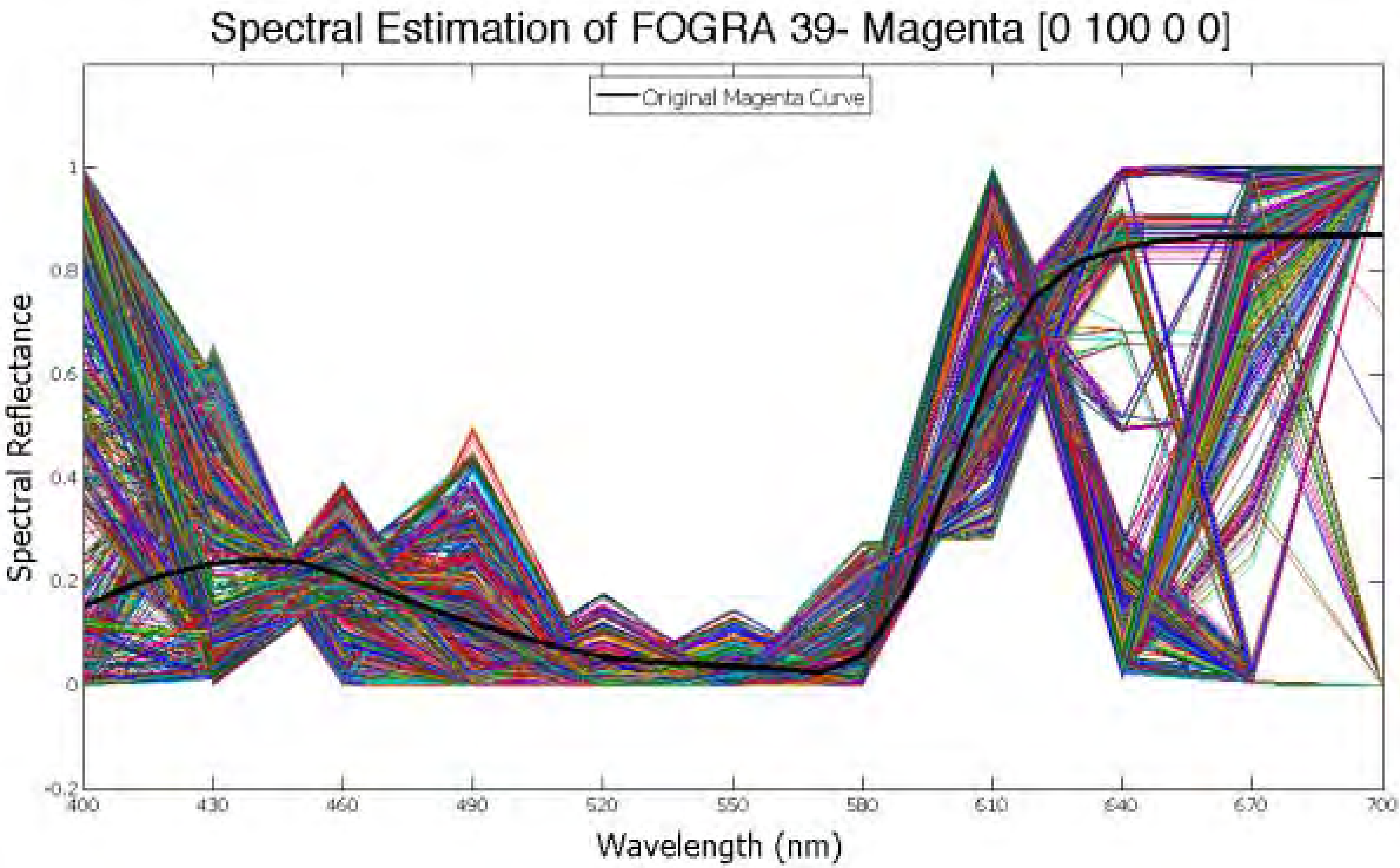
? ? ? ?

Reflectance Estimations

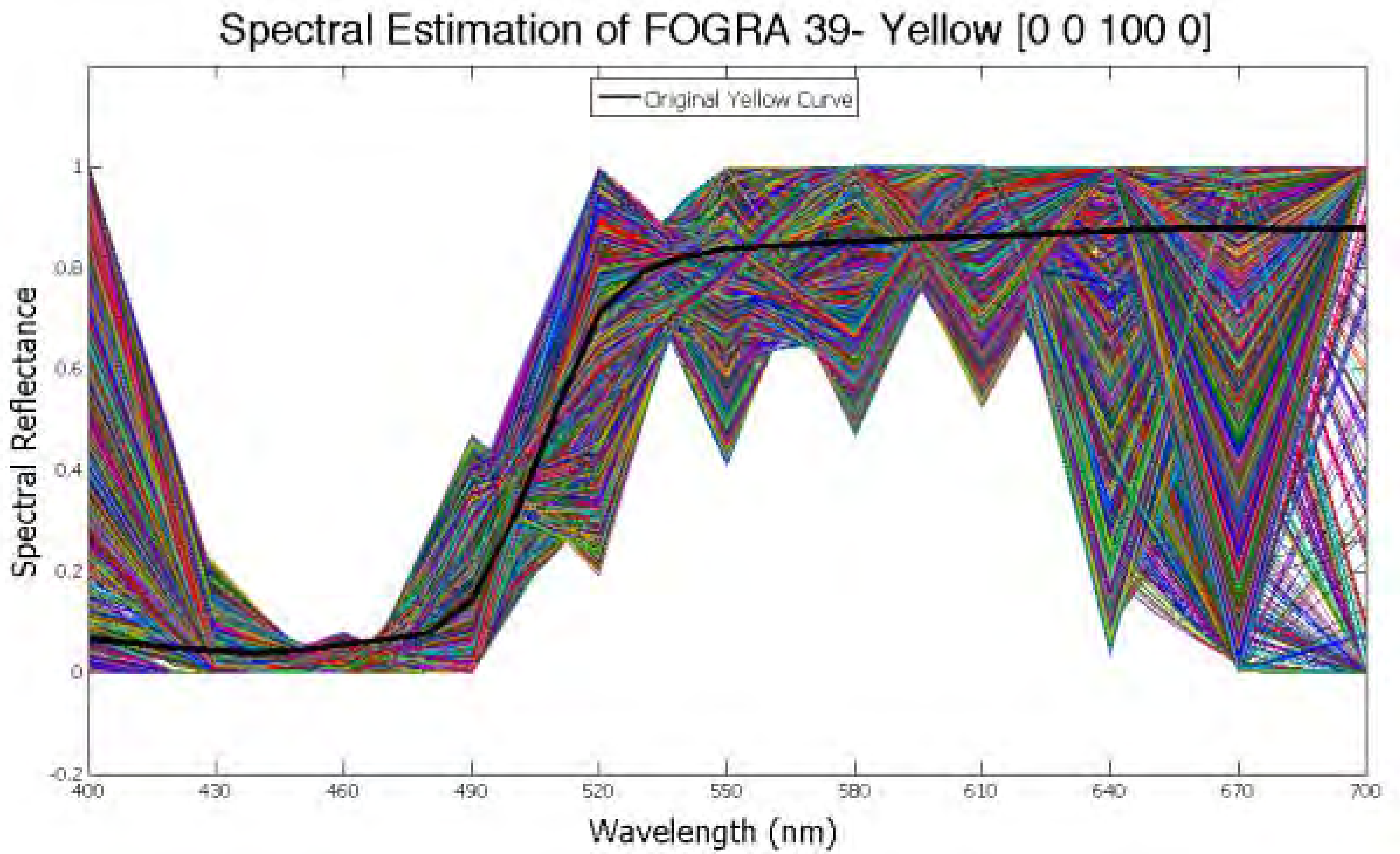


AGFA

Reflectance Estimations



Reflectance Estimations



Spectral Color Reproduction: Model Based and Vector Error Diffusion Approaches

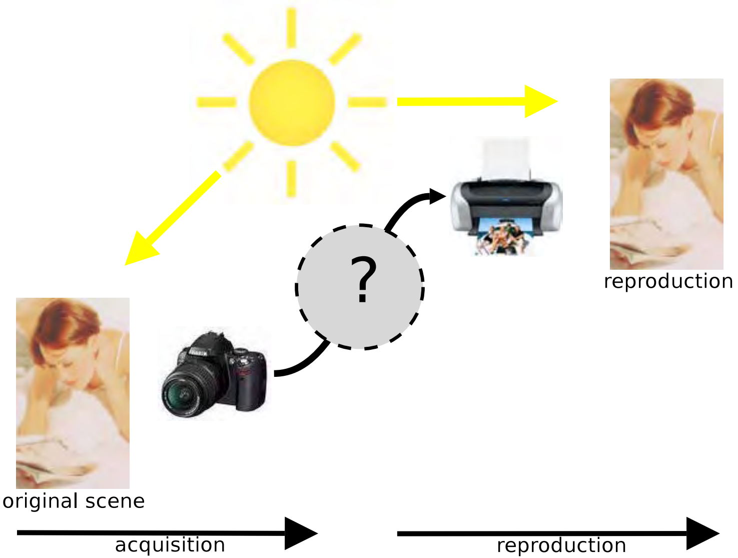
Jérémie Gerhardt

ICC Digital Print Day
Paris 4 March 2009

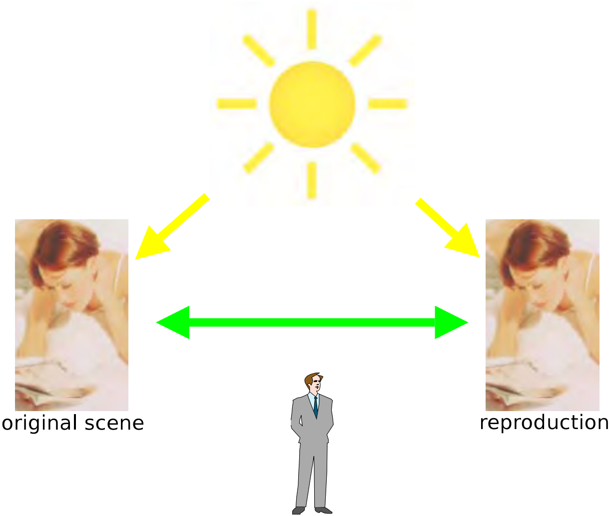
FIRST
Fraunhofer Institut
Rechnerarchitektur
und Softwaretechnik

Outline

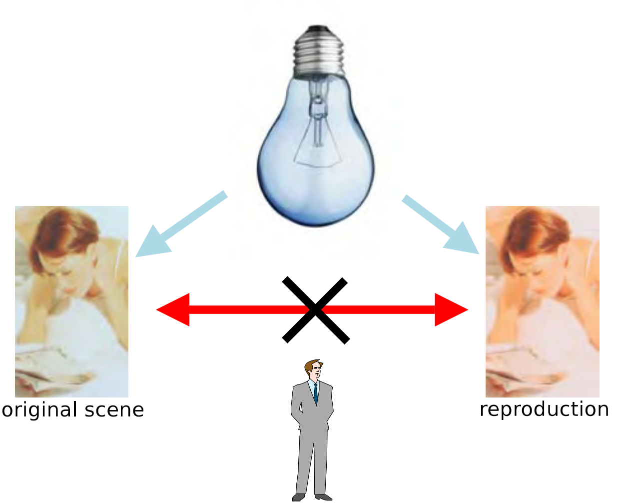
Conventional color reproduction workflow



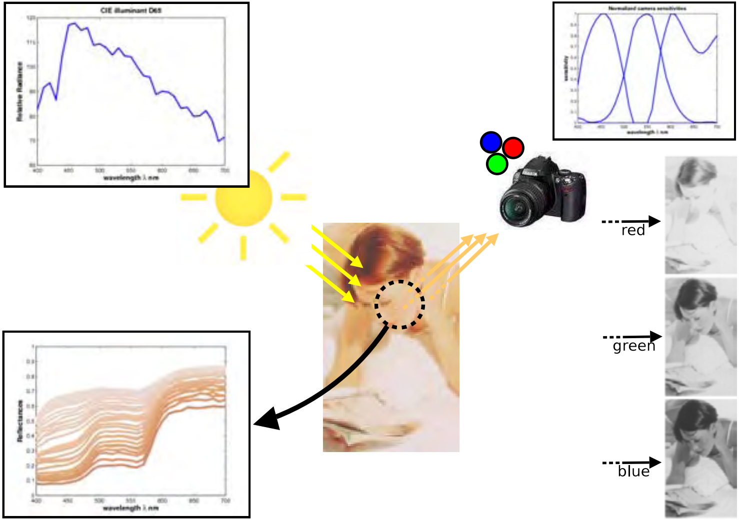
Metameric match



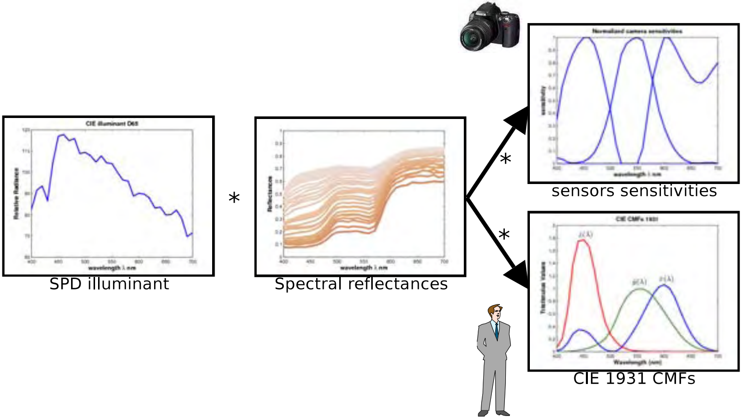
Metamerism mismatch



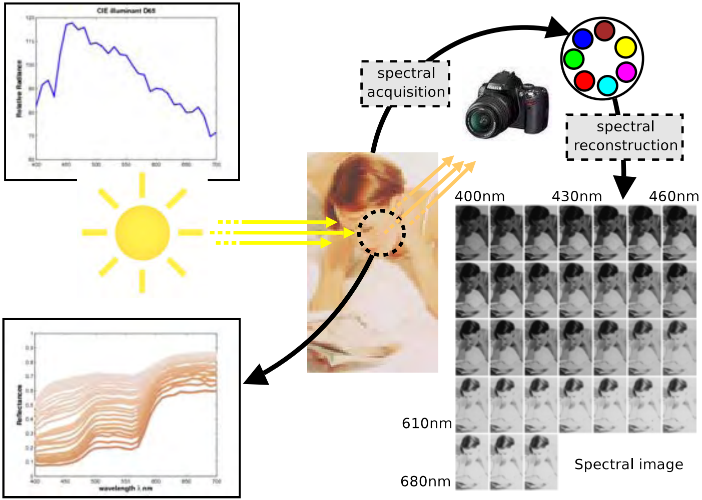
Color acquisition system I



Color acquisition system II



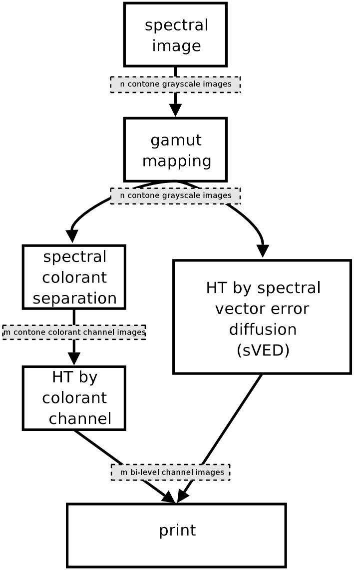
Spectral color imaging I



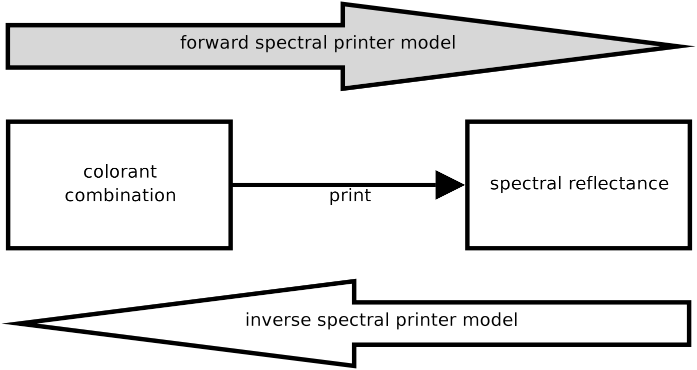
Spectral color imaging II

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

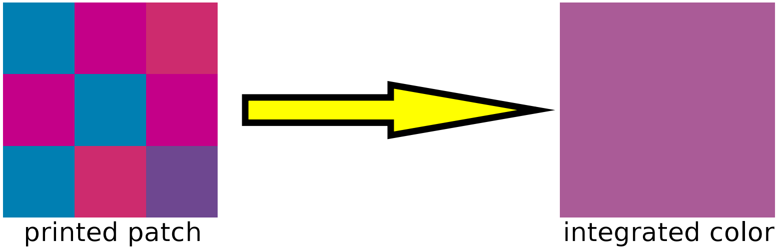
Spectral color reproduction pipeline



Model based approach



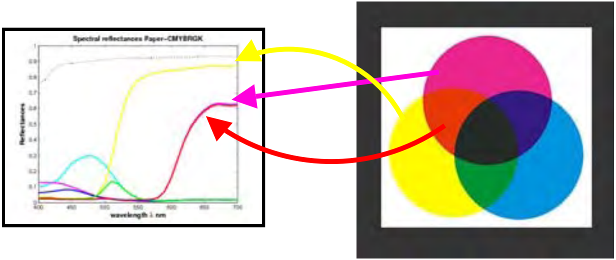
Multi-colorant print - Spectral Neugebauer printer model



- **Spectral Neugebauer model**:
  $\Rightarrow$ 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:

$$\hat{R}(\lambda) = \sum_{i=0}^{2^m-1} w_i P_{i,\max}(\lambda) \Rightarrow \hat{\mathbf{r}} = \mathbf{w}_{(\mathbf{m})}^{\mathbf{T}} \mathbf{P}_{(\mathbf{m})}$$

Color reproduction



- subtractive color mixing
  $\Rightarrow$ light filtered by the ink layers
- colorants with **fixed densities**
  $\Rightarrow$ **halftoning**
- m-colorant printer $\longrightarrow$ 2^m solid colors

w_i's estimation by Demichel model I

- The Demichel model estimates the weights w_i of the NPs for a given colorant combination
- Statistical model:

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

- For a 2 colorants combination:

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

- For 20% of cyan and 60% of magenta:

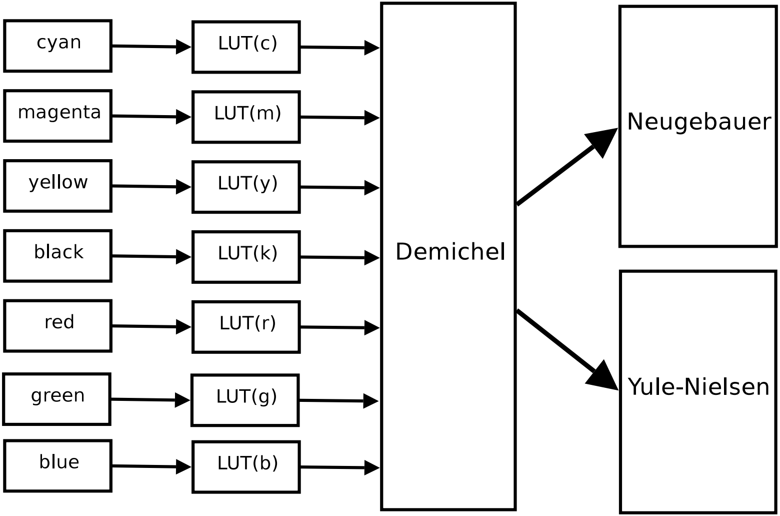
$$\begin{aligned} w_{paper} &= (1-02)\times(1-0.6) = 0.32 \\ w_c &= 0.2\times(1-0.6) = 0.08 \\ w_m &= (1-0.2)\times 0.6 = 0.48 \\ w_{cm} &= 0.2\times 0.6 = 0.12 \end{aligned}$$

Spectral Yule-Nielsen modified Neugebauer model (YNSN)

- Optical dot gain taken into account by the n factor:

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

Spectral printer model (summary)



Comments on model based approach

Lack of accuracy in the dot gain modeling:

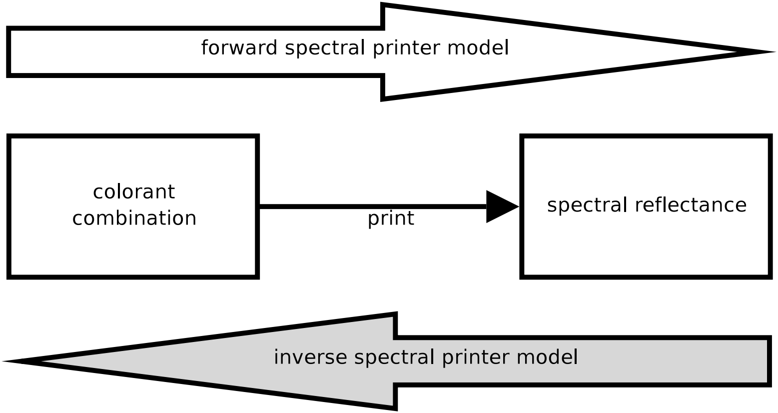
- Each colorant: same optical dot gain
- Colorant overlapping: same mechanical/optical dot gains
- Each dot: uniform spectral color/spectral reflectance

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 $\Leftrightarrow$ **ability to be inverted**
  (we are interested in the inverse spectral printer model!)

Spectral colorant separation



Spectral colorant separation I

- Inversion of the forward printer model
  = **optimization problem**

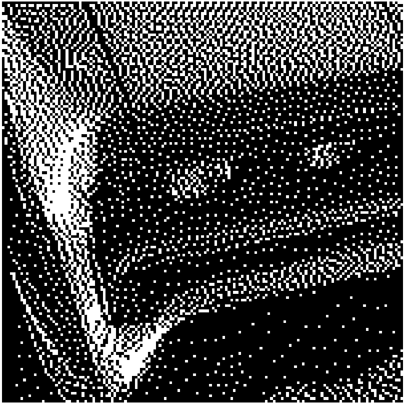
$$\min_{\mathbf{c}} F(\mathbf{c})$$

$$F(\mathbf{c}) = ||R_\lambda(\mathbf{c}) - r_\lambda||^2$$

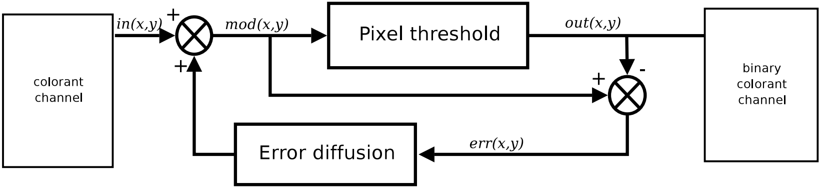
r_λ: spectral reflectance target
$R_\lambda(\mathbf{c})$: estimated spectral reflectance
(spectral NG equations and Demichel equation)
$\mathbf{c}$: colorant combination for m colorants:

$$\mathbf{c} = [c_1 \ \ldots \ c_m]^T, c_i \in [0,1] \text{ for } i = 1, \ldots, m,$$

Example of halfoning by error diffusion I



Example of halfoning by error diffusion II



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

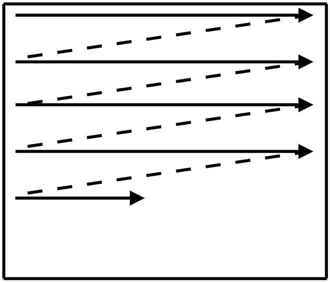
- *in(x,y)*: pixel at position *(x,y)*
- *mod(x,y)*: modified pixel
- *out(x,y)*: binary colorant output value
- *err(x,y)*: error to diffuse after the thresholding

Example of halfoning by error diffusion III

- Jarvis, Judice and Ninke's filter:

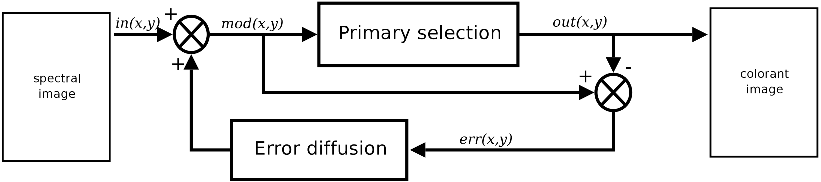
$$\begin{bmatrix} & & \bullet & w_{1,4} & w_{1,5} \\ w_{2,1} & w_{2,2} & w_{2,3} & w_{2,4} & w_{2,5} \\ w_{3,1} & w_{3,2} & w_{3,3} & w_{3,4} & w_{3,5} \end{bmatrix} = (\frac{1}{48}) \times \begin{bmatrix} & & \bullet & 7 & 5 \\ 3 & 5 & 7 & 5 & 3 \\ 1 & 3 & 5 & 3 & 1 \end{bmatrix}$$

$$mod(x+i, y+j) = mod(x+i, y+j) + w(i,j) * err(x,y)$$



Spectral vector error diffusion I

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



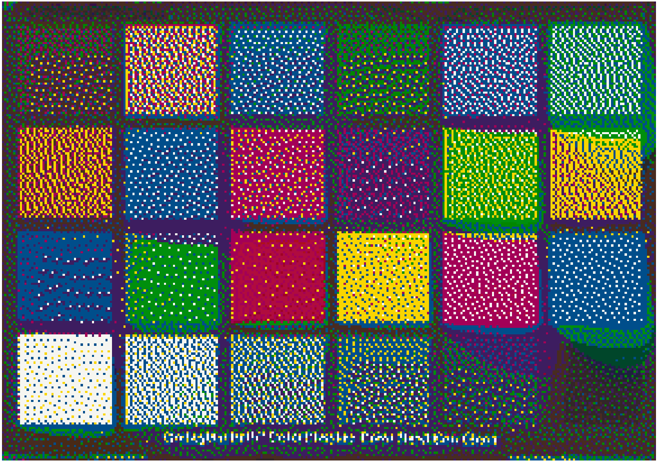
$$out(x, y) = \arg\min_{\mathbf{p}_k} \|mod(x, y) - \mathbf{p}_k\|$$

- *in(x,y)*: spectral reflectance at the pixel position *(x,y)*
- *mod(x,y)*: modified spectral reflectance
- *out(x,y)*: binary colorant combination (selected NP)
- *err(x,y)*: error to diffuse after NP selection *out(x,y)*

Spectral vector error diffusion II

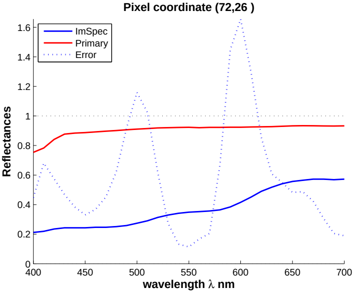
▶ D50 color rendering of the MacBeth ColorChecker (CC) spectral image

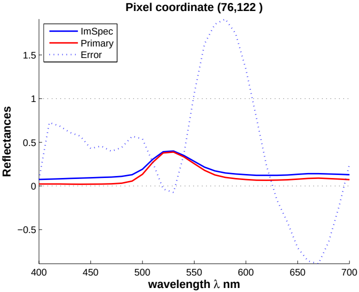
Spectral vector error diffusion III



- Halftoning by sVED of the CC spectral image

Spectral vector error diffusion IV

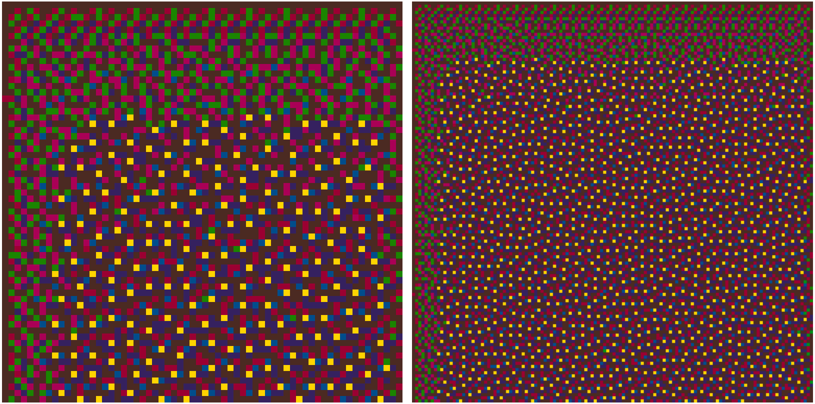




Spectral vector error diffusion V

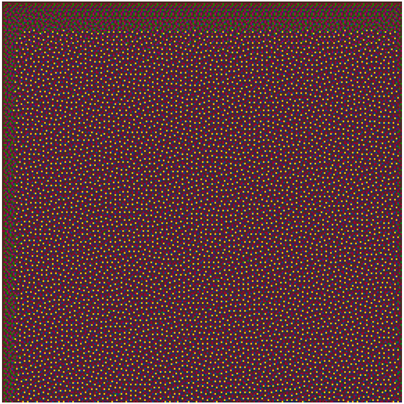
- 'Slowness' of vector error diffusion:
  $\Rightarrow$ visibility of the error accumulation
- Improvement of vector error diffusion:
  $\Rightarrow$ increasing resolution
  $\Rightarrow$ pre-processing by gamut mapping
  $\Rightarrow$ new filter design

Effect of resolution on sVED I



- left patch: 64×64 pixels, right patch: 128×128 pixels

Effect of resolution on sVED II



- left patch: 256×256 pixels, right patch: 512×512 pixels

sVED with pre-processing I

- Spectral gamut mapping is performed before halftoning
  $\Rightarrow$ inversion of the printer model for the weights only

sVED with pre-processing II

- Original *CC* spectral image

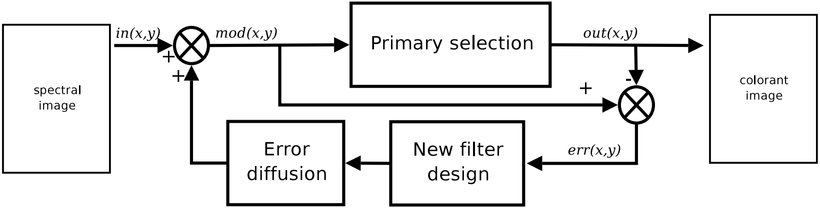
sVED with pre-processing III

- gamut mapped *CC* spectral image

sVED with pre-processing IV

- Halftoning by sVED of the spectrally gamut mapped (sGM) *CC* spectral image

sVED with new filters design



- We design new filters such that:

$$\sum_{k=1}^{k=n} w_k = 1$$

sVED with new filters - New filters by distances I

- Weights related to the distance from selected NP to pixel's neighbors:

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

- To have weights values $\in [0, 1]$:

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

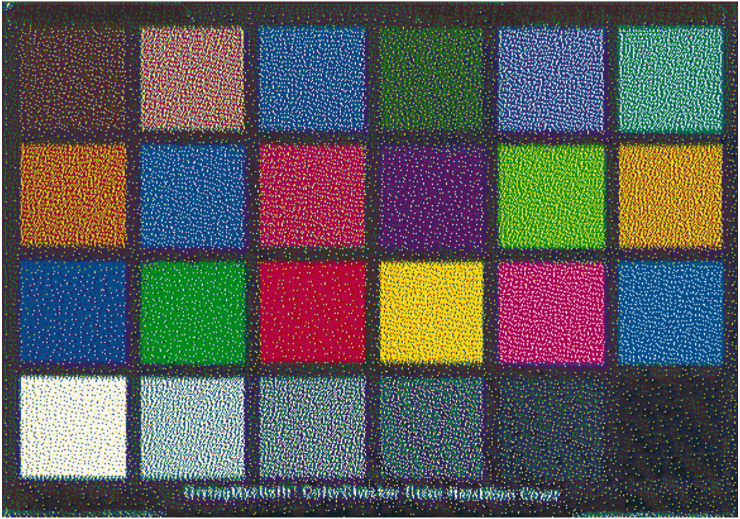
- Maximum $= 1$ on the farthest neighbor
  $\Rightarrow$ we want the **inverse relation**
  $\Rightarrow$ remove the pixel contribution: $d''_k = 1 - d'_k$
- To normalize the weights:

$$w_k = \frac{d''_k}{\sum_k d''_k}$$

sVED with new filters - New filters by distances II

- Halftoning by sVED of the sGM *CC* spectral image

sVED with new filters - New filterS by distances III



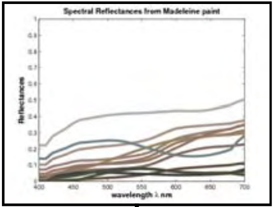
- Halftoning by sVED and new filters by distance of sGM *CC* spectral image

Comment on the vector error diffusion approach

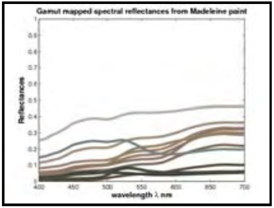
- Spectral color reproduction by sVED works
- Slowness of error diffusion still present
- **Reduction of error visibility**
  $\Rightarrow$ spectral gamut mapping before sVED
  $\Rightarrow$ new filters design keep details in the image but bring noise

Comparison of the two approaches

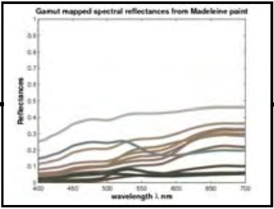
Experimental setups I



Spectral gamut mapping

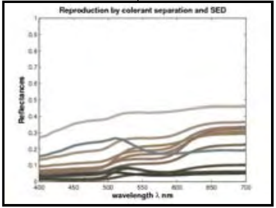


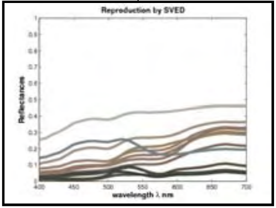
Experimental setups II



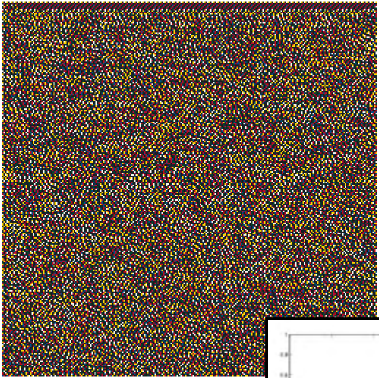
-colorant separation (CS)
-halftoning by error diffusion (ED) by colorant channel

-halftoning by sVED

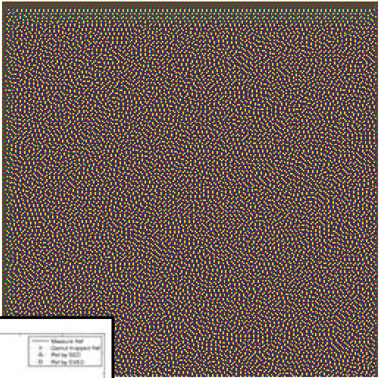




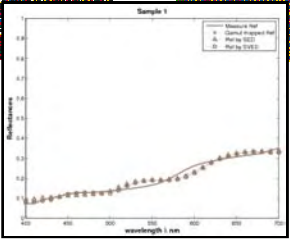
Result sample I



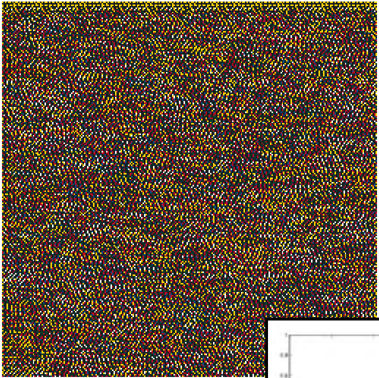
CS + ED



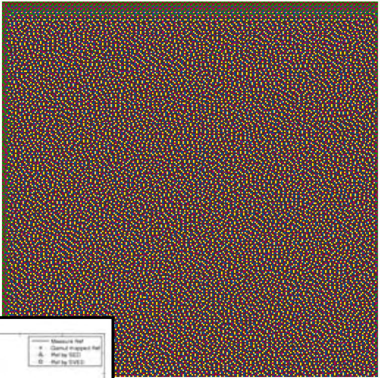
sVED



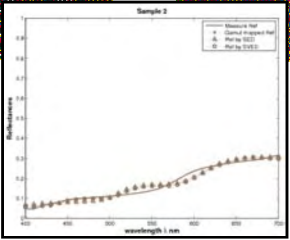
Result sample II



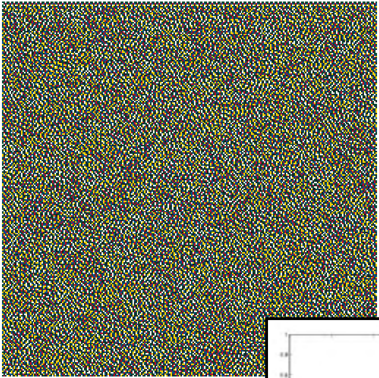
CS + ED



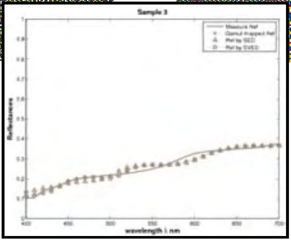
sVED

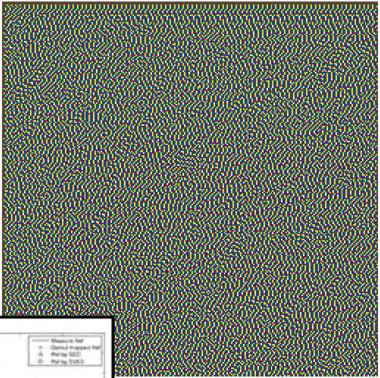


Result sample III



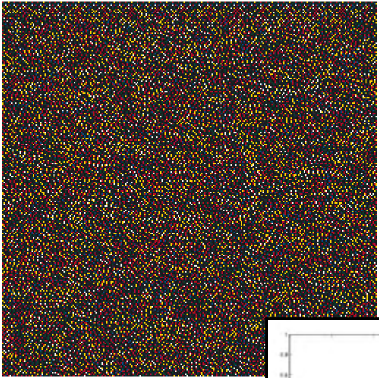
CS + ED



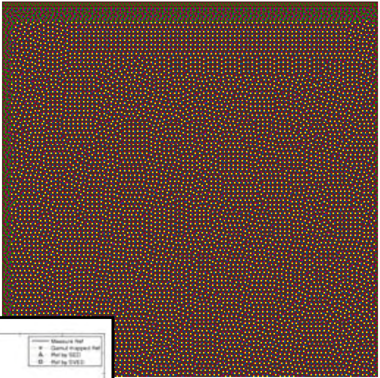


sVED

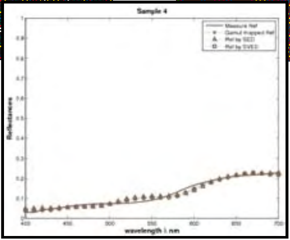
Result sample IV



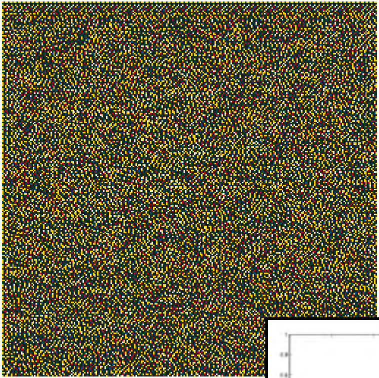
CS + ED



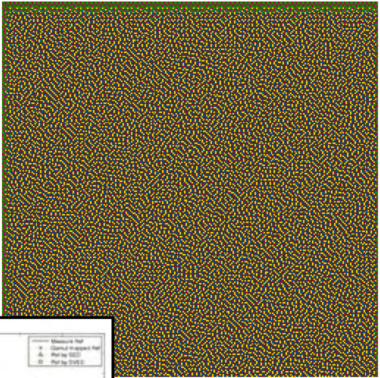
sVED



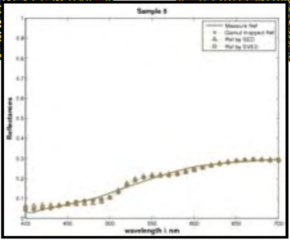
Result sample V



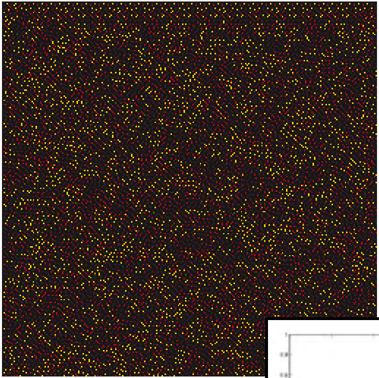
CS + ED



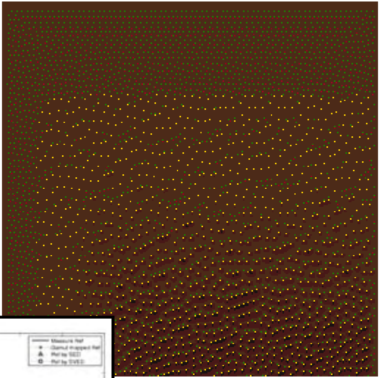
sVED



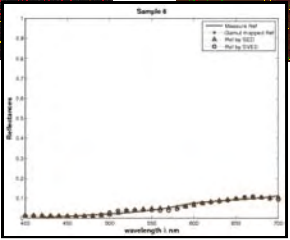
Result sample VI



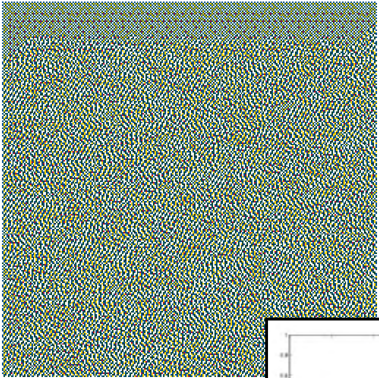
CS + ED



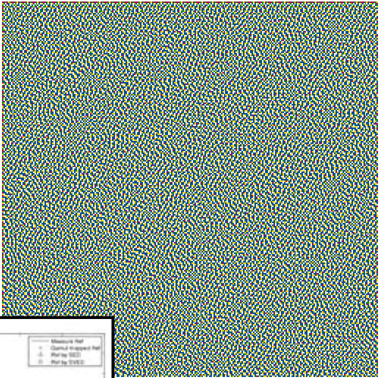
sVED



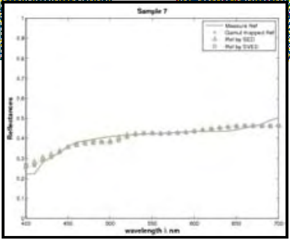
Result sample VII



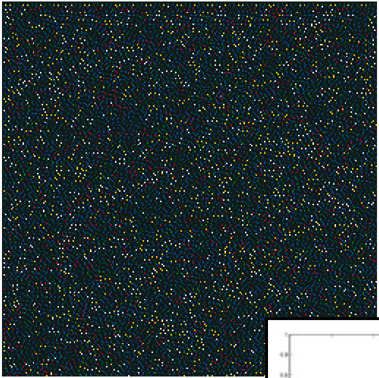
CS + ED



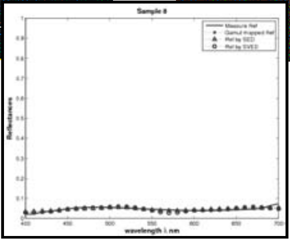
sVED

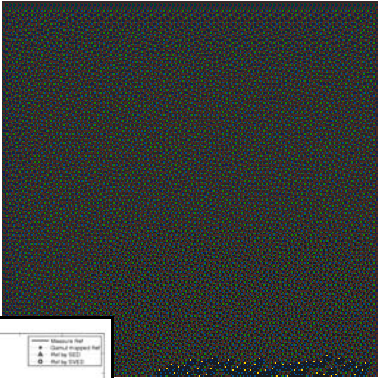


Result sample VIII



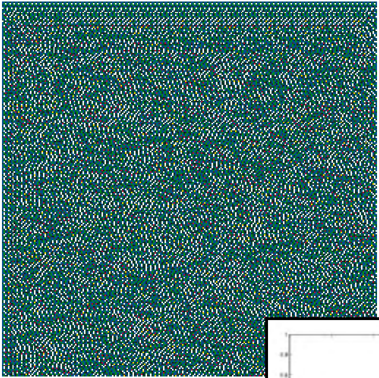
CS + ED



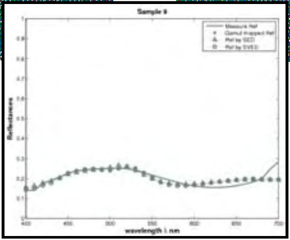


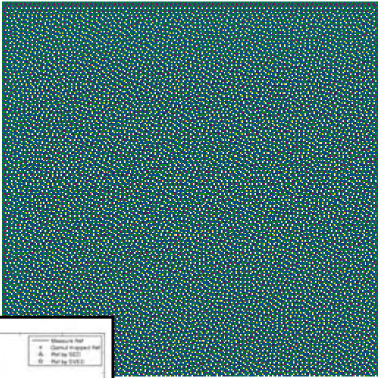
sVED

Result sample IX



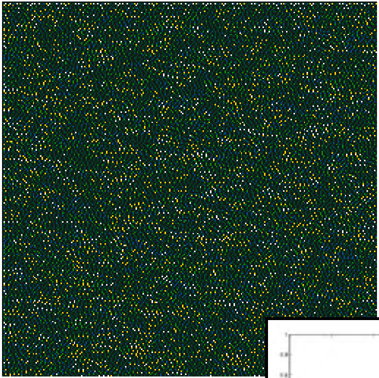
CS + ED



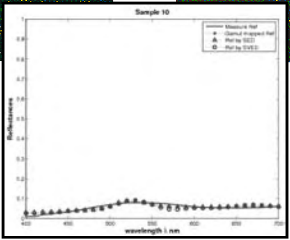


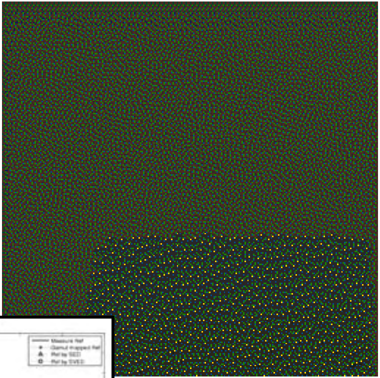
sVED

Result sample X



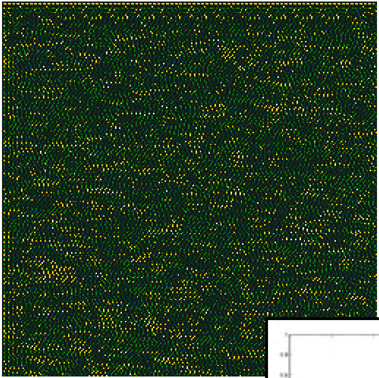
CS + ED



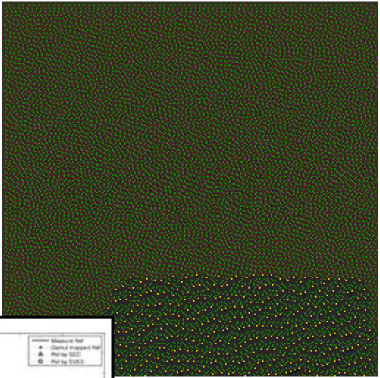


sVED

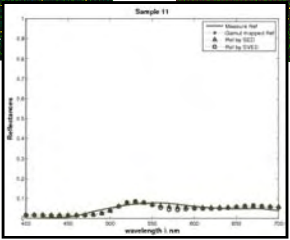
Result sample XI



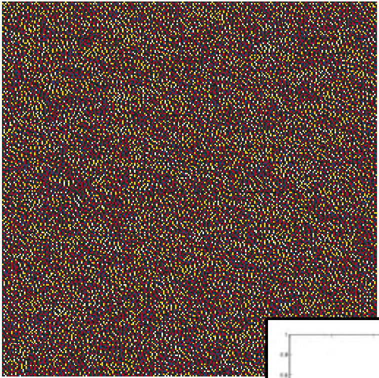
CS + ED



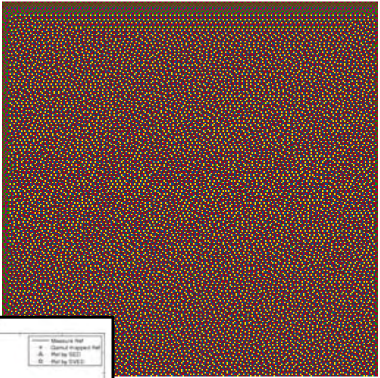
sVED



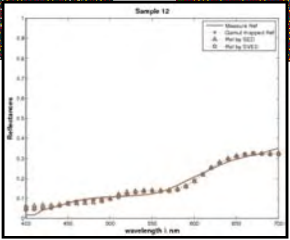
Result sample XII



CS + ED



sVED



Results analysis

- Similar performance for both approaches in term of spectral differences
- Main difference in the final dot distribution

Conclusion and perspectives

- **Model based approach**
  $\Rightarrow$ difficulties to model the dot gain
  $\Rightarrow$ use cellular YNSN model/physical model
- **Vector error diffusion approach**
  $\Rightarrow$ sVED works and gives more pleasant dot distribution
  $\Rightarrow$ promising results with new filter design/spectral gamut mapping
- **Challenges remain**:
  $\Rightarrow$ practical use in real applications
  $\Rightarrow$ spectral gamut mapping
- 'ICC' approach using LABPQR

FIRST

Fraunhofer Institut Rechnerarchitektur und Softwaretechnik

- merci pour votre attention

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Towards a new image quality model for color prints

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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

Subjective quality

- 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)

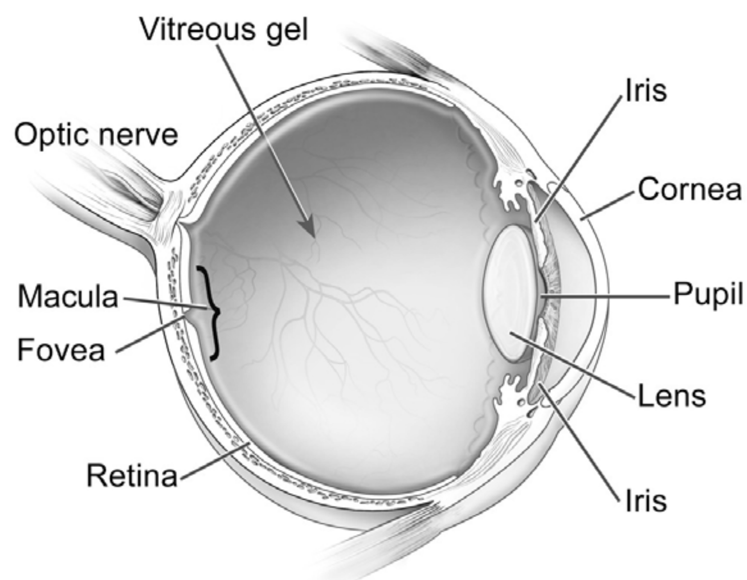
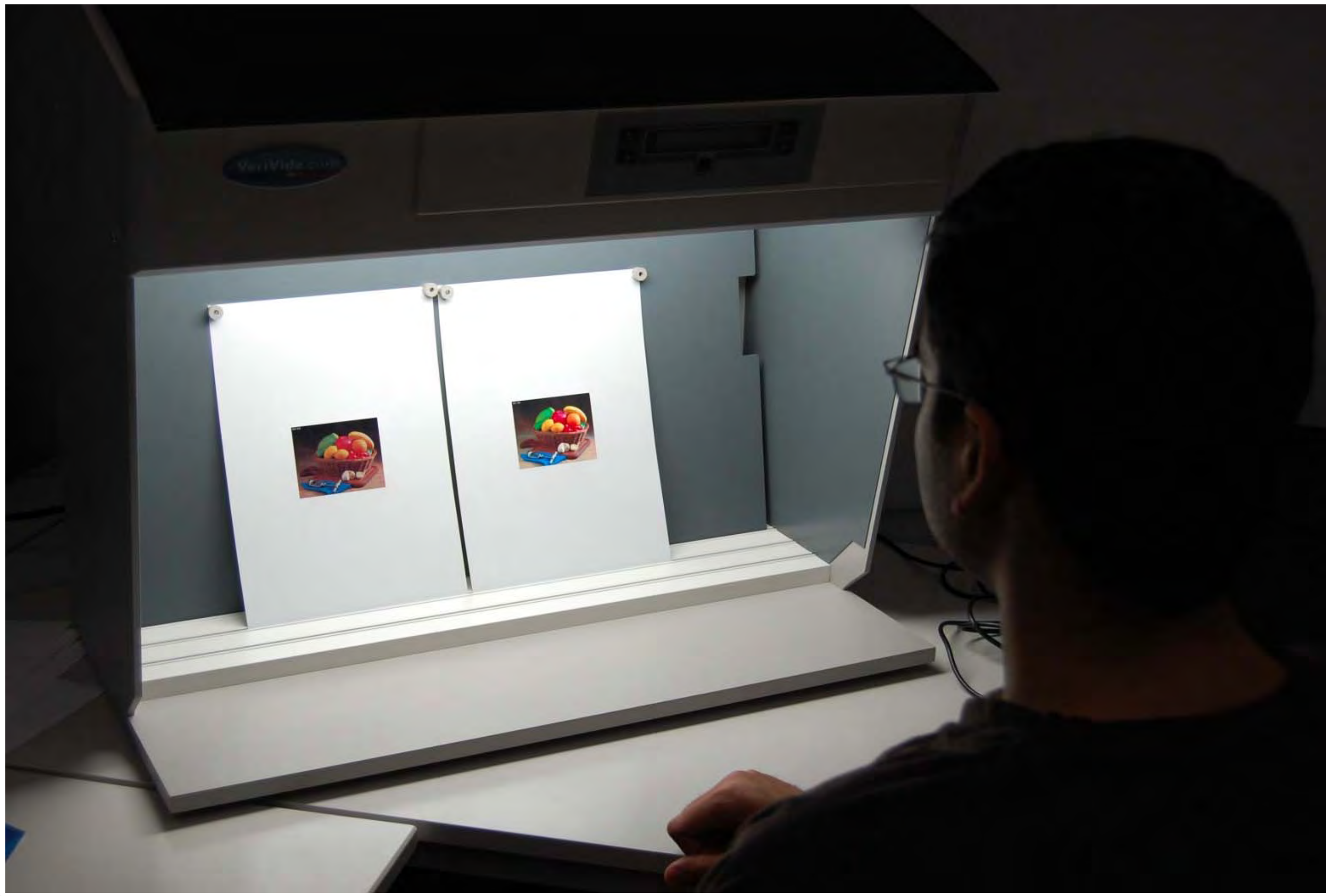


Image from www.northtexasretina.com

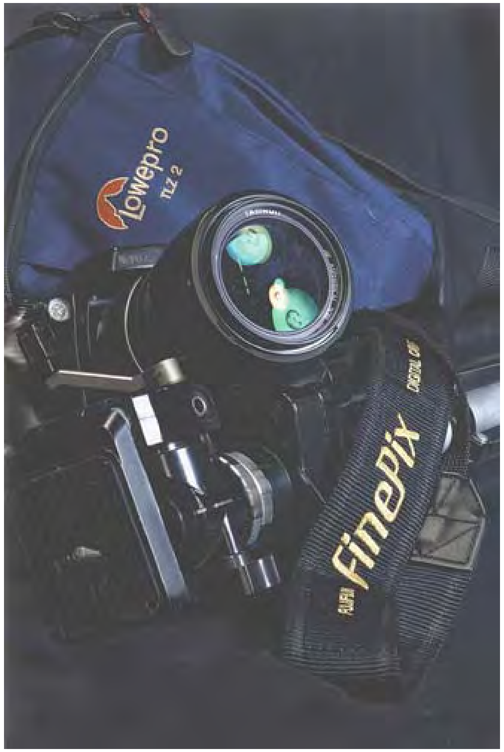
Subjective evaluation

- Carried out by observers



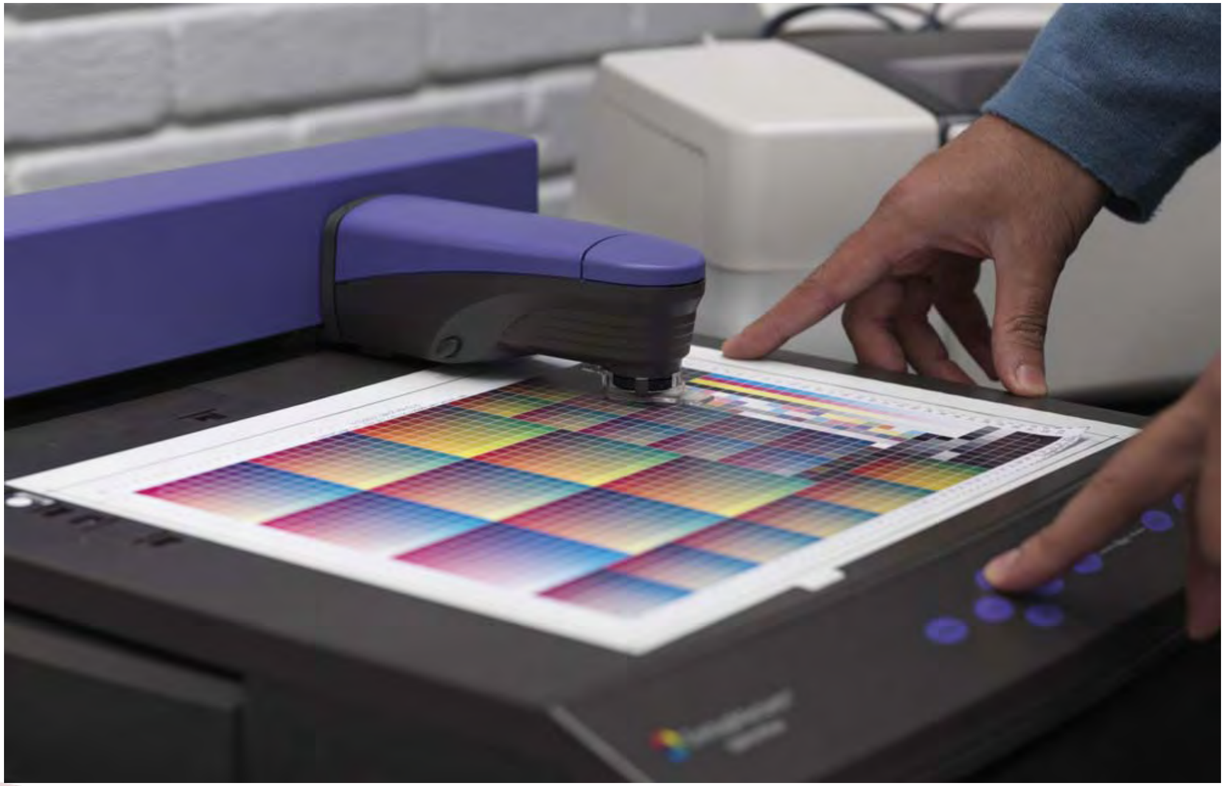
Complexity of image quality

- Image quality depends on
  - The observer
    - HVS
    - Cultural differences
    - Preference
  - Viewing conditions
    - Distance
    - Illuminant
  - Intent
  - Instructions



Objective quality 1/2

- Is the degree of compliance of a process or its outcome with a predetermined set of criteria



Objective quality 2/2

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

Image quality attributes

- Terms of perception[1], such as:
  - Contrast
  - Sharpness
  - Color
  - Artifacts
  - Details
  - Uniformity
  - Saturation
  - Etc.
- Image quality is composed of ‘n’ attributes
  - ‘n’ dimensions of quality

[1]. Wyszecki and Styles (2000). *Color Science, Concepts and Methods, Quantitative Data and Formulae, Second Edition. Derby, UK: Wiley Interscience*

Image quality model

- 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.

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 new image quality model

- 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 [1]

[1]. Jorge Caviedes & Franco Oberti. A new sharpness metric based on local kurtosis, edge and energy information *Signal Processing: Image Communication,* **2004**, *19*, 147-161

Contrast

- There is not a clear and shared definition
- The difference, globally and locally, in both lightness[1] and chromaticity of an image

[1]. E. Peli.Contrast in Complex Images. *Journal of the Optical Society of America A,* 1990*, 7*, 2032-2040

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

[1]. J.S. Friedman. History of Color Photography
Boston : American Photographic Publishing, 1947

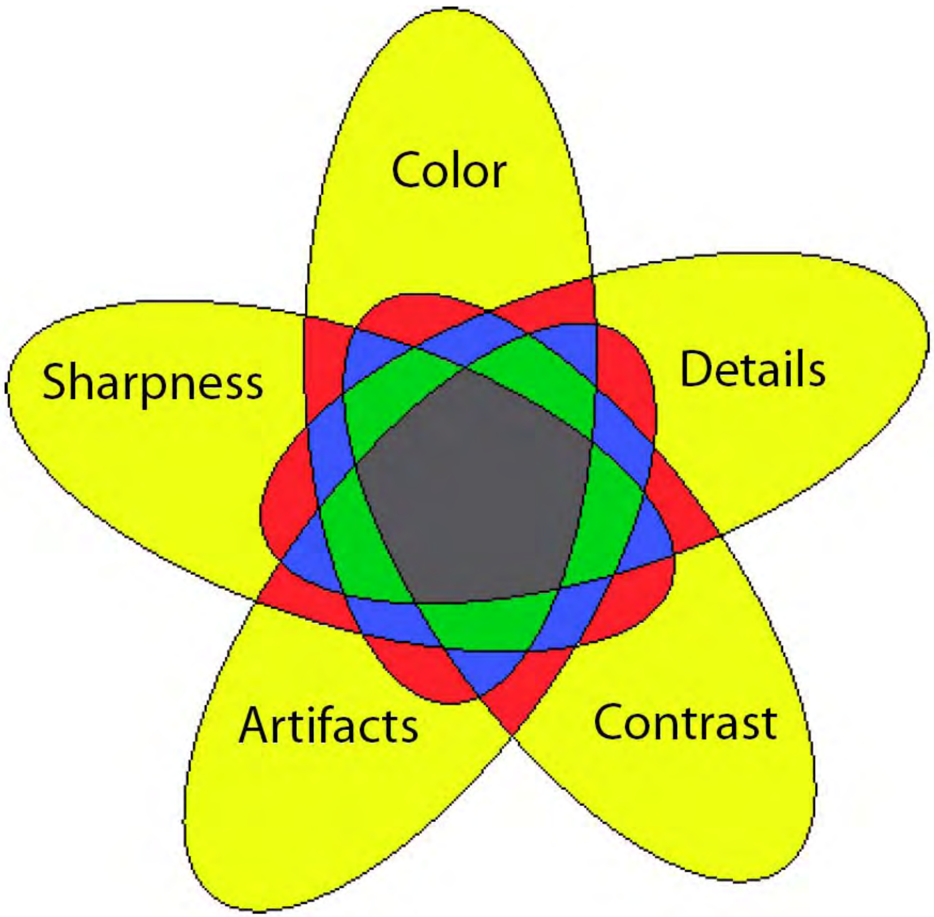
Artifacts

- Error or misrepresentation introduced in the image[1]
  - Noise introduced by the halftoning algorithm
  - Banding caused print head defects

[1]. K. Topfer, B. Keelan, S. O'Dell, and R. Cookingham. Preference in image quality modelling. In *IS&T's 2002 PICS Conference, 2002.*

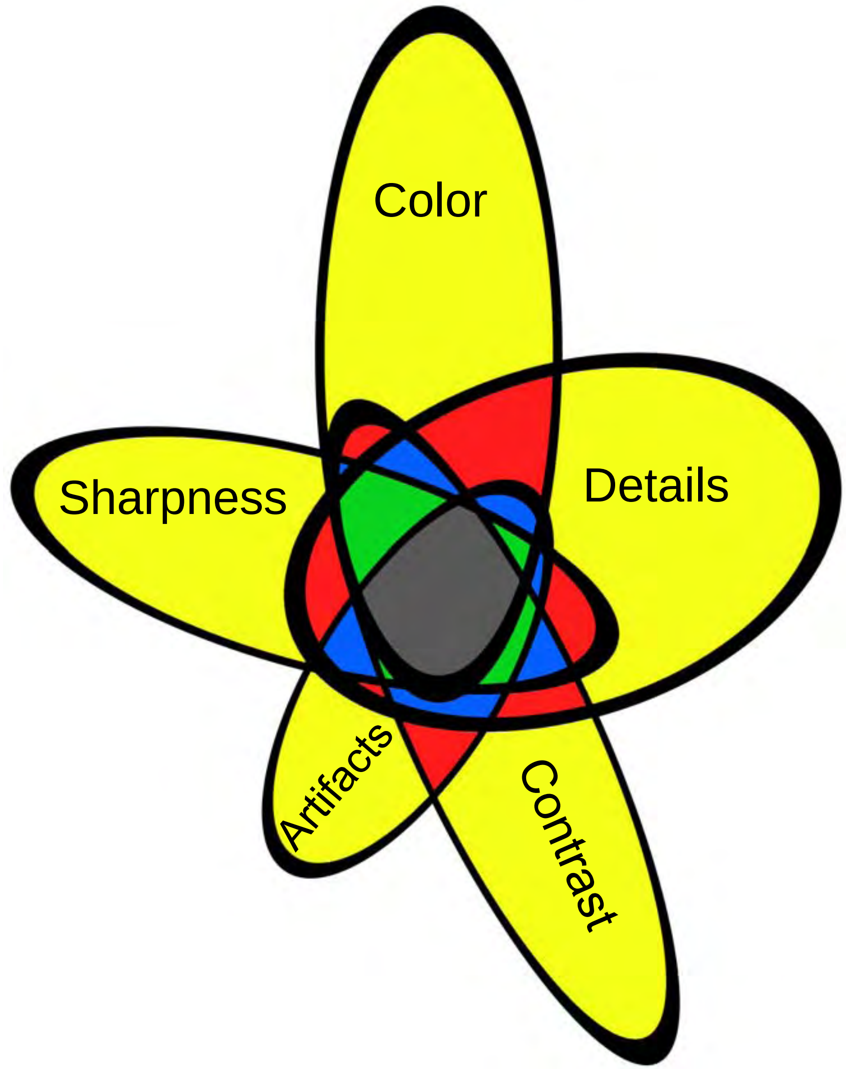
Abstract Illustration of the model

- 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



Influence on image quality

- Attributes might influence quality differently
- Shape and position for the attributes can vary
- Attributes can also be divided for adaptation to specific issues



Conclusion

- 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

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

colorlab.no

The Norwegian Color Research Laboratory

Gjøvik University College

Color Rendering For Pantone Colors

PANTONE®

x·rite

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

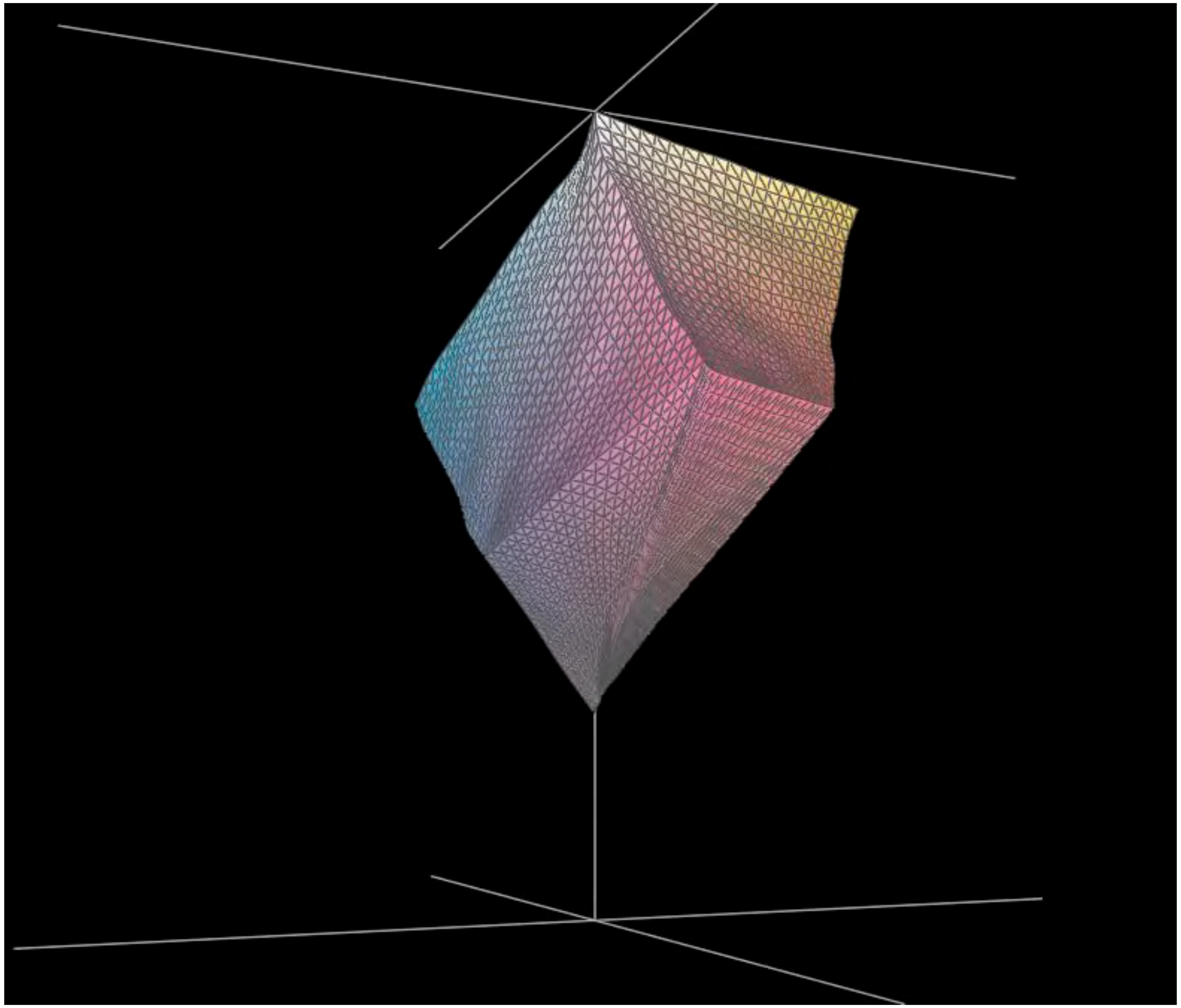
Goals for Rendering Colors for Images

- 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

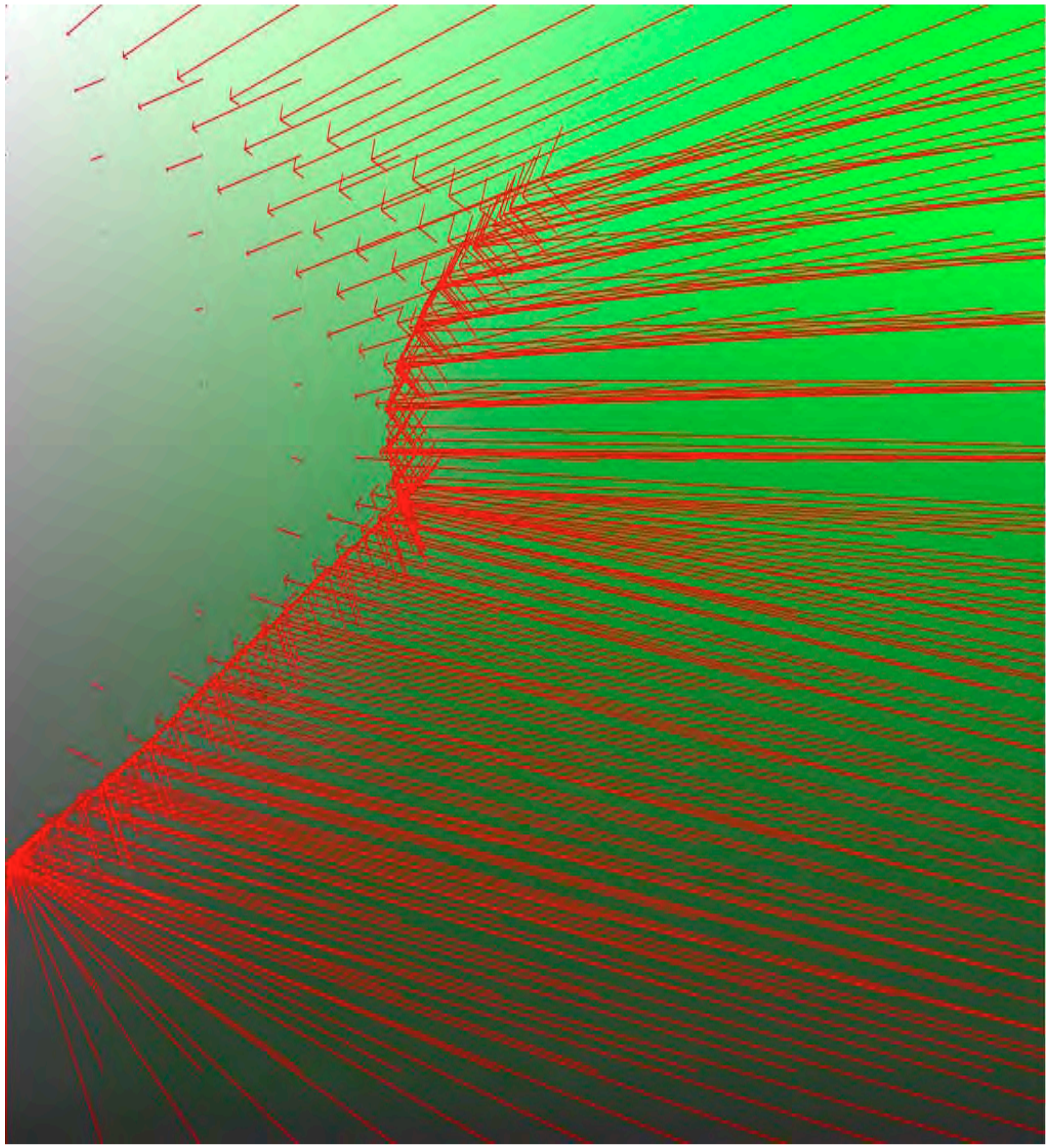
Original

Images converted to CMYK

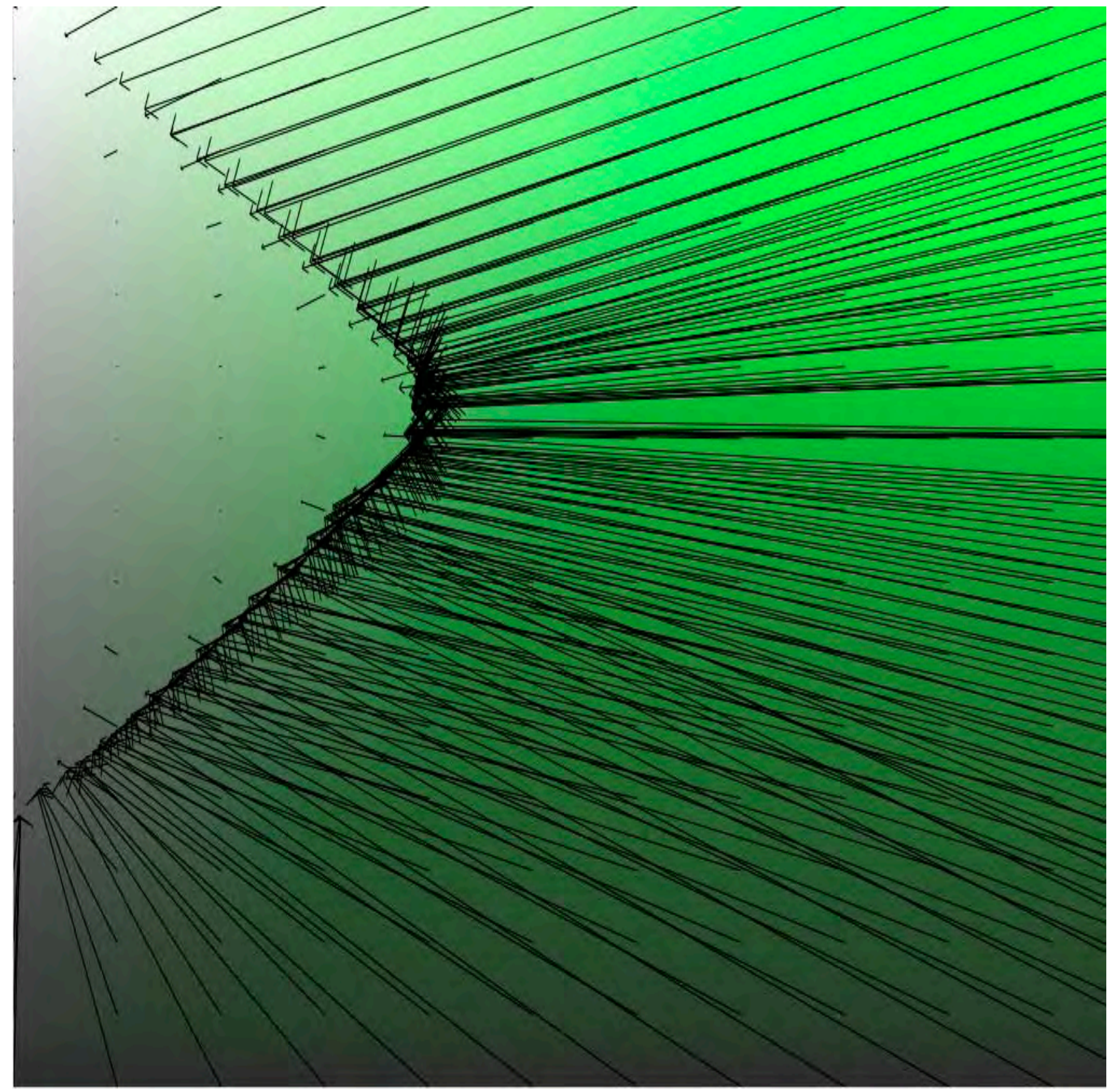
Simple Min DeltaE

Complex Gamut Compression

Gamut Compression

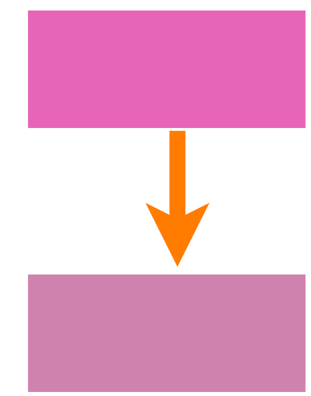


Simple Min DeltaE

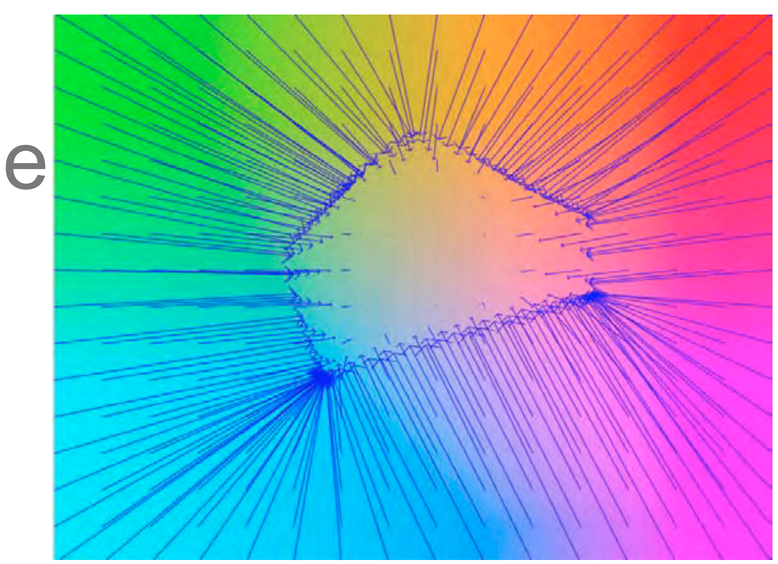


Complex Gamut Compression

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

232

225

0,100,0,0
CMYK
Best Visual Match

Well distributed colors

5,100,0,0
CMYK

0,100,5,0
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

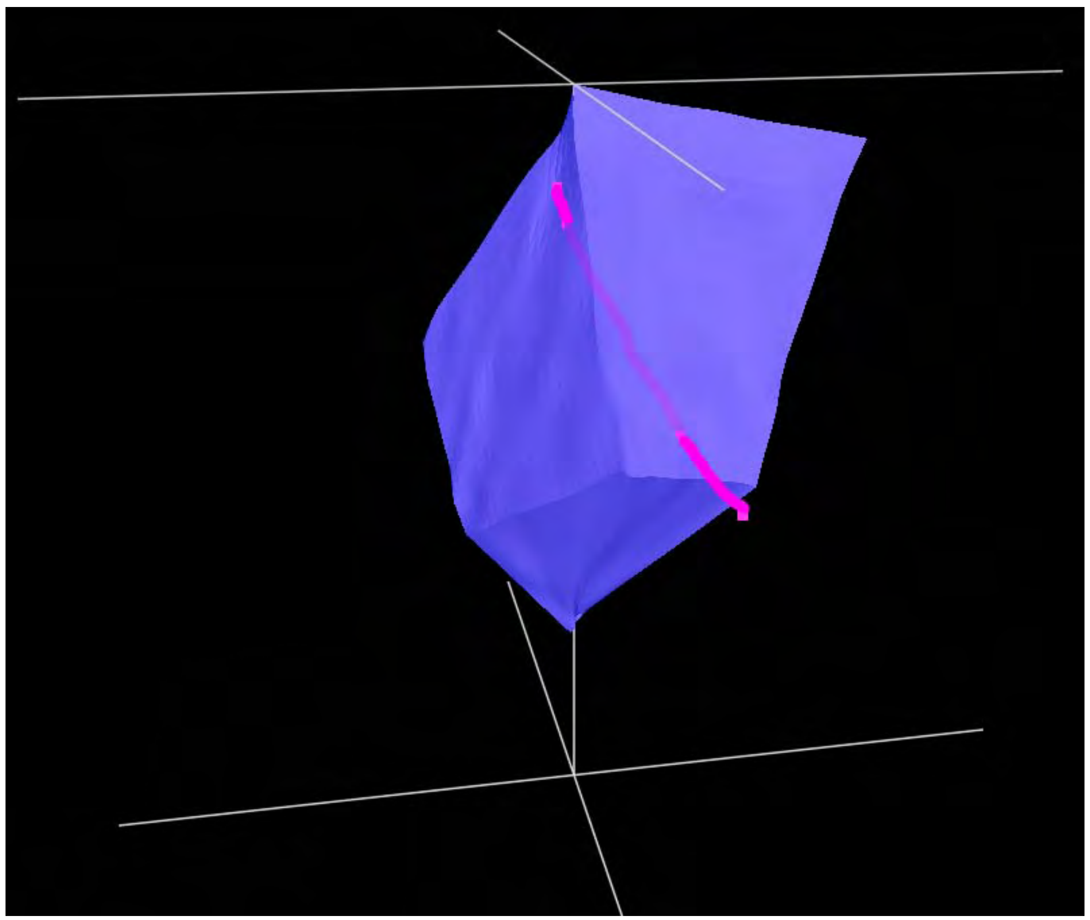
Goals for Named Color Profiles

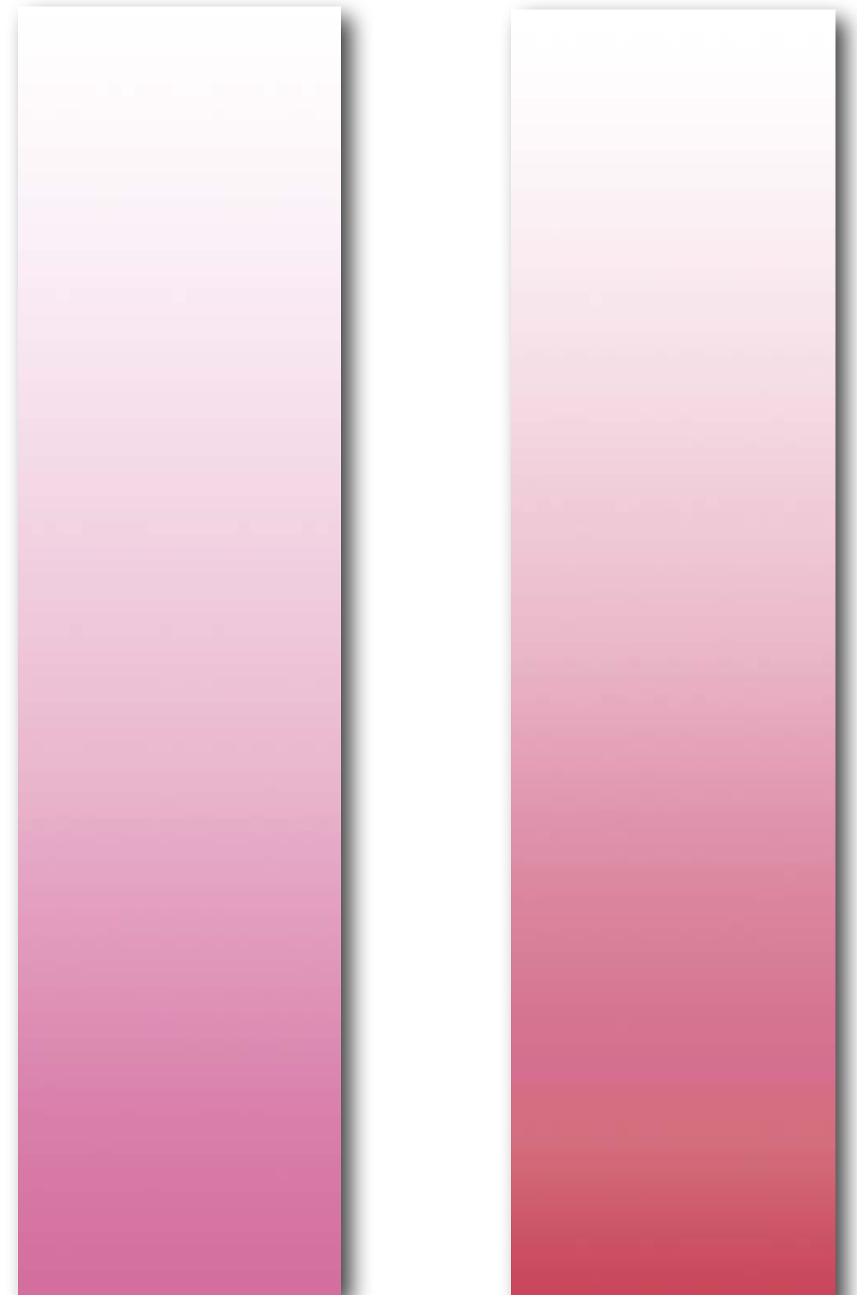
- Support of tints in a new version of named color profiles is desired by Pantone
- A named color could be specified at 100%, 75%, 50%, & 25%
- The CMM would use 1D interpolation to find the named color for any tint value

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?

vigc.be

Working together toward greater efficiency

Application of ISO 12647-7

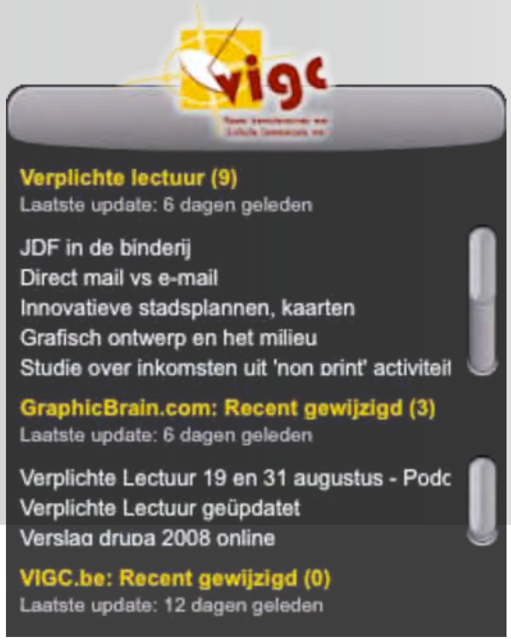
Fons Put

VIGC – 4 March 2009

Introduction

- Flemish Innovationcenter for Graphic Communication

GraphicBrain.com



Contents

- Introduction
- normative
- informative

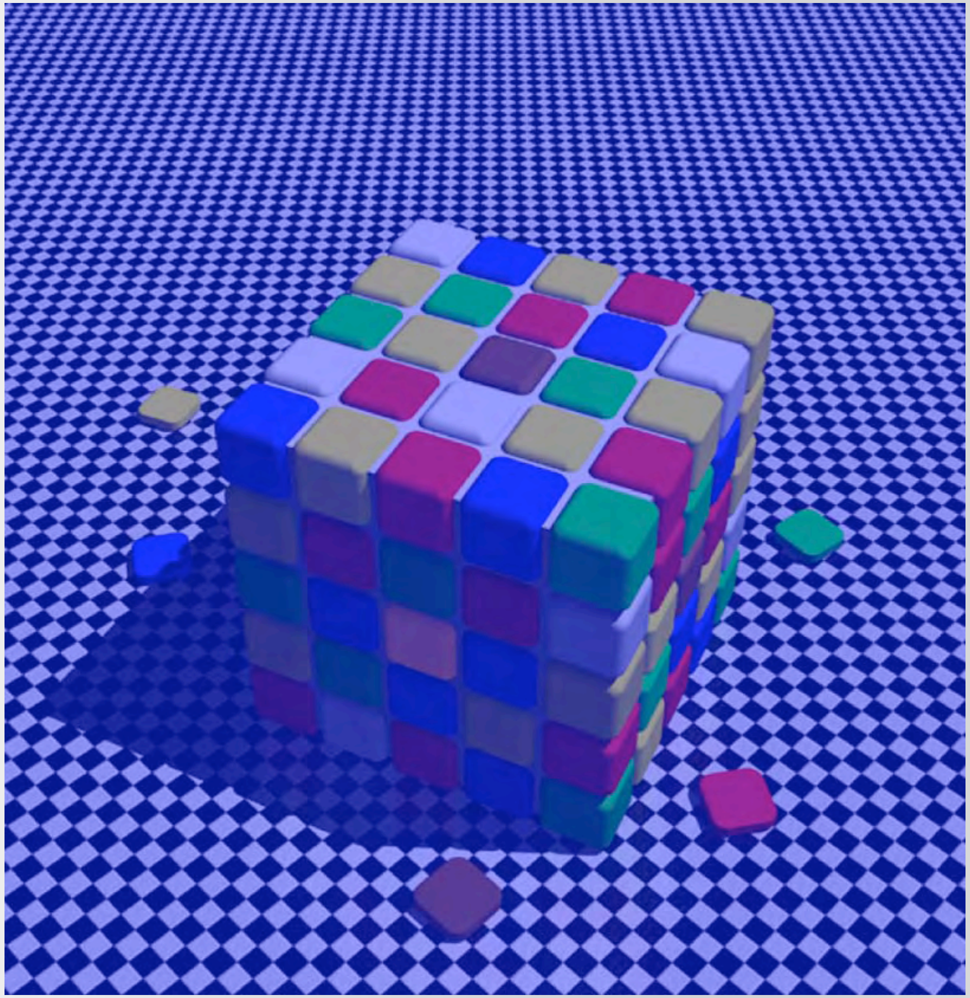
Introduction

Contents

- Introduction
- normative
- informative

- 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
    - …

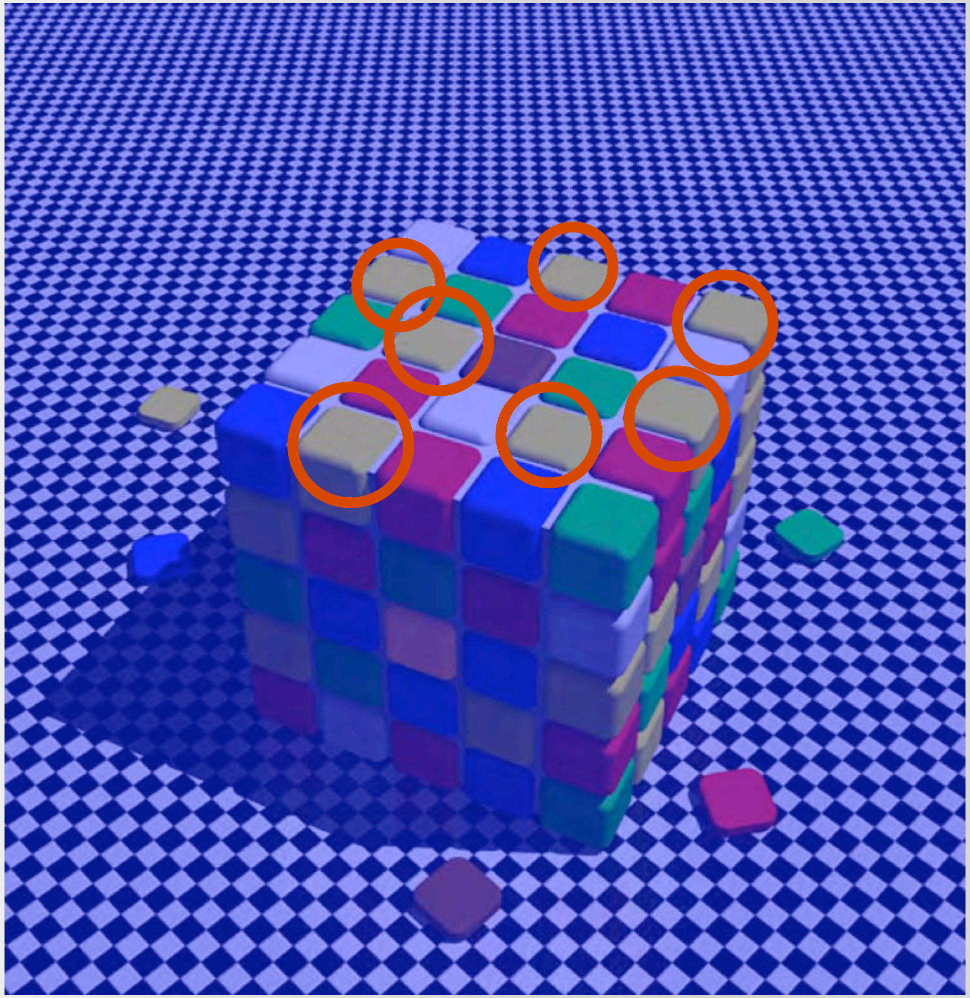
Introduction



Contents

- Introduction
- normative
- informative

Introduction



Contents

Introduction

Contents

- Introduction
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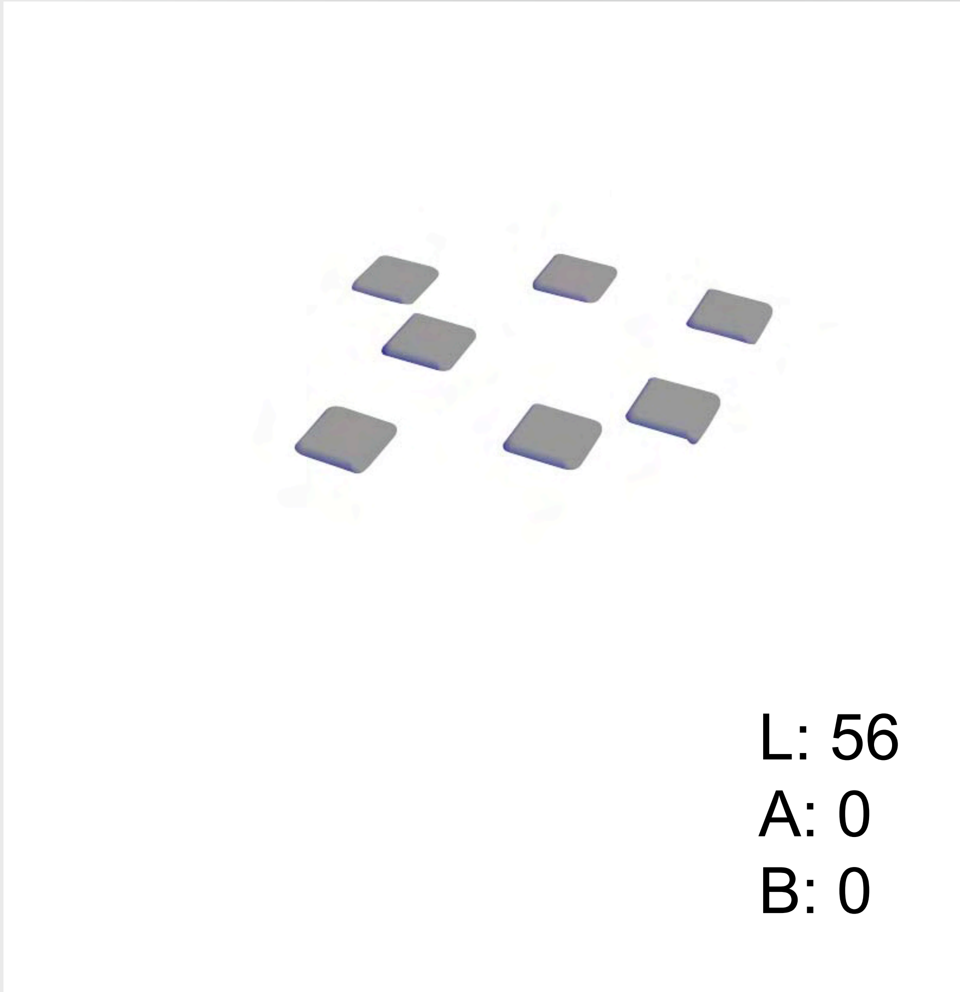
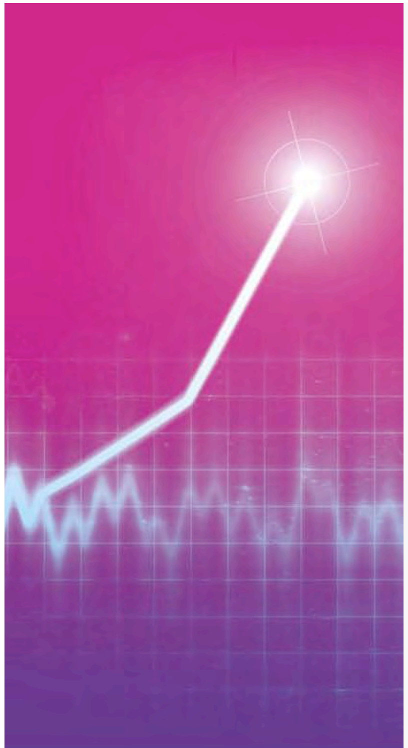


Introduction



Contents

- 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

Introduction

Contents

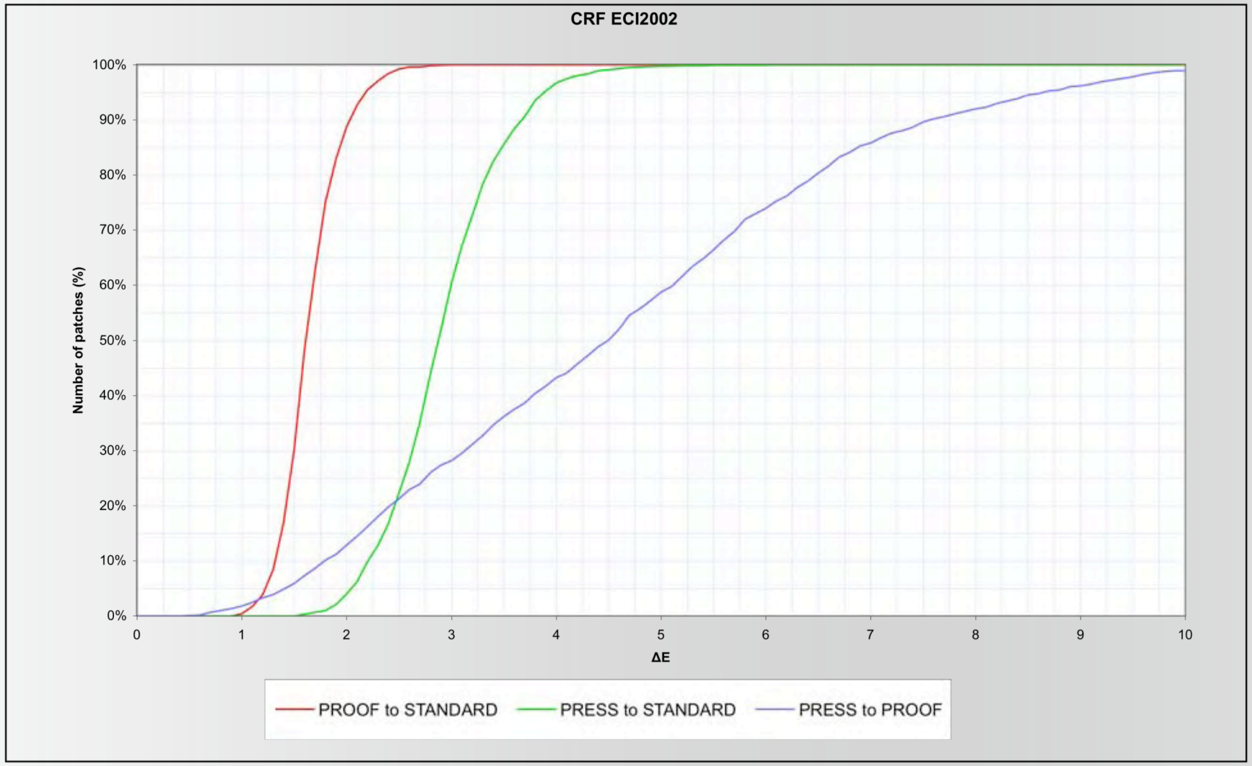
- Introduction
- normative
- informative

- How do proofs match with prints?

	PROOF 1			PROOF 2		
	ΔE*ab	tol	Status	ΔE*ab	tol	Status
Average 46 patches	3.4	4.0	OK	3.5	4.0	OK
Maximum 46 patches	9.4	10.0	OK	8.5	10.0	OK
Maximum CMYK patches	4.2	5.0	OK	3.6	5.0	OK
Maximum Paper patch	2.7	3.0	OK	1.0	3.0	OK

Introduction

- How do proofs match with prints (2)?



Contents

- Introduction
- Title part 1
- Title part 2
- Conclusions


ISO 12647-7 requirements

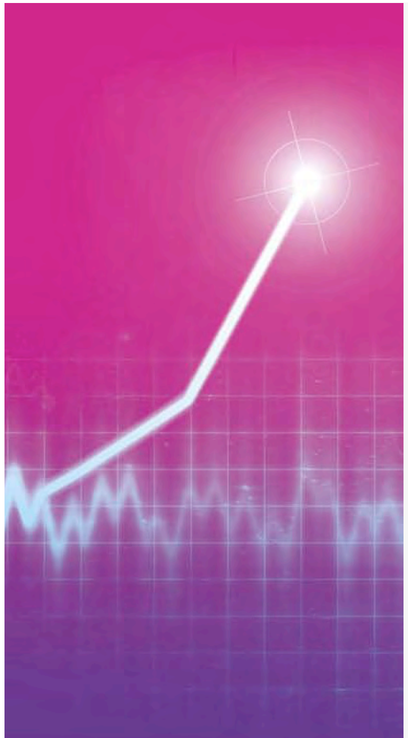
ISO 12647-7 requirements - normative

- Test Page

Contents

- Introduction
- Normative
- Informative

ISO 12647-7 requirements - normative

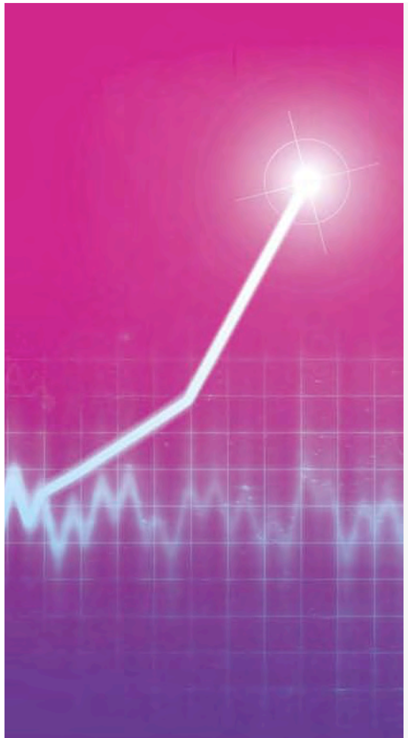


Contents

• 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

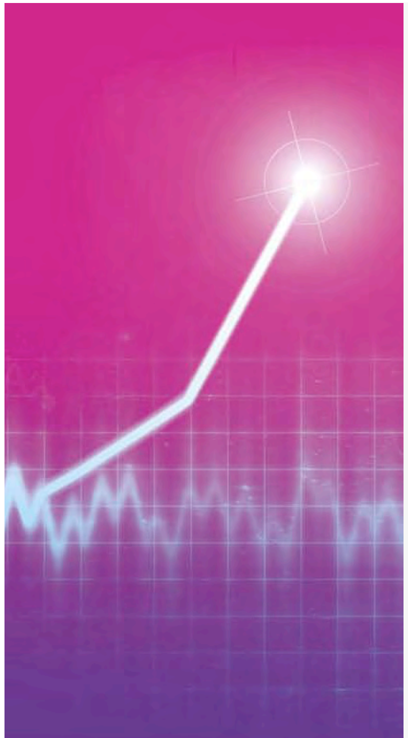


- ## Proofing Substrate
  - **Results**

Substraat	DATASET			PROOF			Deviation PROOF/DATASET				
	L	a*	b*	L	a*	b*	ΔE*ab			tolerantie	status
Color	94.3	1.0	-4.5	95.4	1.4	-5.4	1.5	ΔL	1.2	2.0	OK
								Δa	0.4	2.0	OK
								Δb	-0.8	2.0	OK
Dark keeping conditions	**Before**			**After**			**Deviation before after dark keeping**				
	L	a*	b*	L	a*	b*	ΔE*ab			tolerantie	status
24 h at 25°C, RH 25%	95.1	0.1	-1.4	-	-	-	-			1.5	-
24 h at 40°C, RH 80%				-	-	-	-			1.5	-
1 week at 40°C, RH 10%				95.3	0.1	-1.5	0.2			1.5	OK
Light Fastness	**Before**			**After**			**Deviation before/after UV radiation**				
	L	a*	b*	L	a*	b*	ΔE*2000			tolerantie	status
Step 3 Blue Wool scale	37.1	10.1	-54.0	38.9	3.5	-40.1	2.9			2.0	OK
Step 4 Blue Wool scale	35.1	-7.4	-32.7	34.5	-5.8	-28.4	1.8			2.0	OK
Proofing Substrate	94.2	0.0	-1.5	94.0	0.1	-1.6	0.2			2.0	OK

Contents

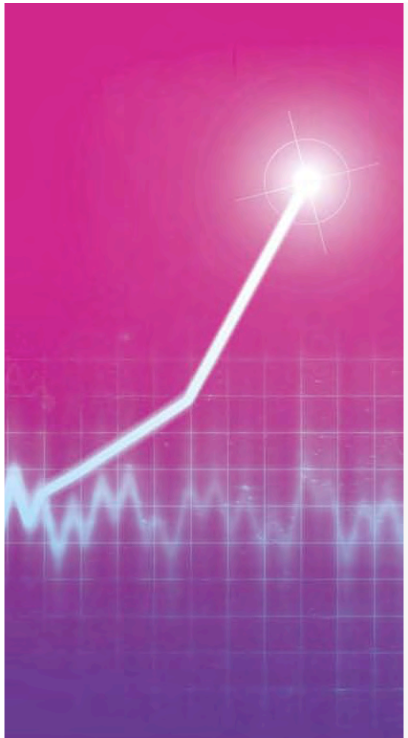
ISO 12647-7 requirements - normative



Contents

- Color
  - **Process colors**
    - Deviation
      - CIELAB dE
      - CIELAB dH
    - Variation
    - Light fastness
  - **Stabilization**
  - **Control Strip**
  - **Repeatability**
  - **Outer gamut patches**

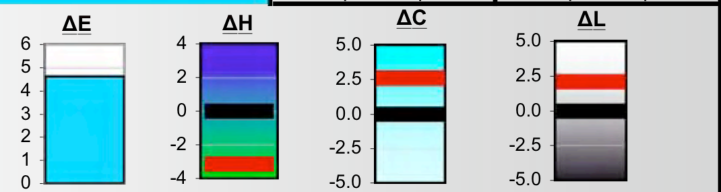
ISO 12647-7 requirements - normative



- Color
  - **Process colors**

De volvlakkleuren van de PROEF-vellen worden gemeten volgens ISO 12647-1: D50 verlichting, 2° observer, 0/45 or 45/0 geometry, white backing.

Process colors	DATASET			PROOF			Deviation PROOF/DATASET			
	L	a*	b*	L	a*	b*	result		tolerance	status
CYAAN	56.8	-31.2	-49.3	58.9	-35.3	-49.7	ΔE	4.6	5.0	OK
							ΔH	-3.2	2.5	FOUT
							ΔC	2.6		
							ΔL	2.1		



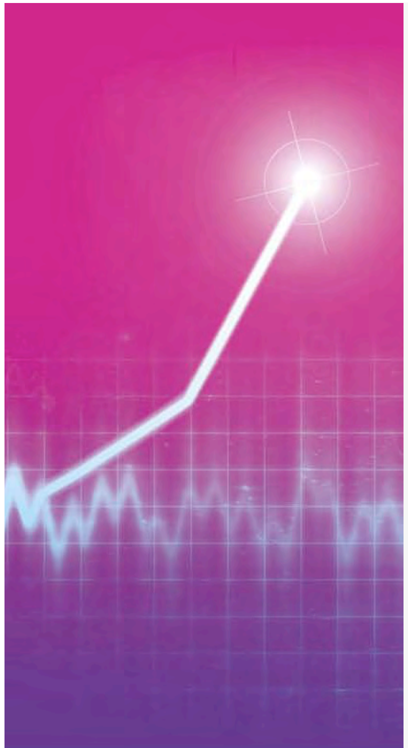
Variation PROEF (zonder simulatie)				
result			tolerance	status
Stdev.	L	0.3	0.5	OK
	a	0.3	0.5	OK
	b	0.4	0.5	OK
Max. ΔE*ab (AVG)		0.6	2.0	OK

Light Fastness	Before			After			Deviation before/after UV radiation		
	L	a*	b*	L	a*	b*	ΔE*2000	tolerance	status
Step 3 Blue Wool scale	37.1	10.1	-54.0	38.9	3.5	-40.1	2.9	2.0	OK
Step 4 Blue Wool scale	35.1	-7.4	-32.7	34.5	-5.8	-28.4	1.8	2.0	OK
Cyan	54.9	-36.7	-50.0	54.8	-36.4	-50.1	0.2	1.5	OK
Dark keeping conditions	Before			After			Deviation before/after dark keeping		
	L	a*	b*	L	a*	b*	ΔE*ab	tolerance	status
24h after print stabiliation period	55.1	-36.5	-50.6	55.0	-36.1	-50.7	0.4	1.5	OK
Repeatability	Day 1			Day 2			Deviatie Day 1/Day 2		
	L	a*	b*	L	a*	b*	ΔE*ab	tolerance	status
1 day between 2 proofs	55.1	-36.5	-50.6	-	-	-	-	1.5	-

Contents

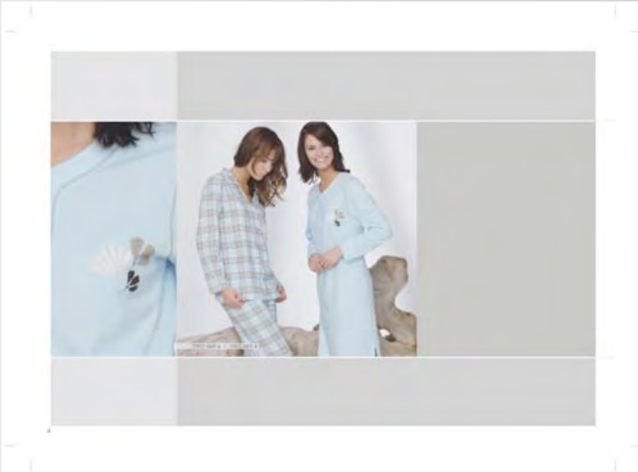
- Introduction
- Normative
- Informative

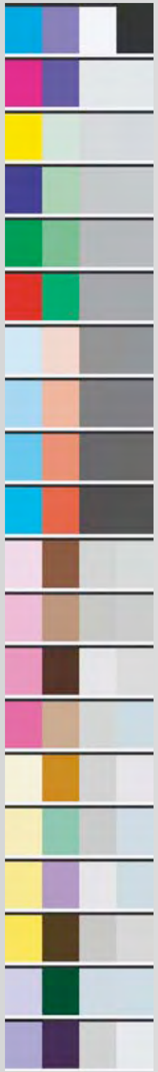
ISO 12647-7 requirements - normative



Contents

- 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

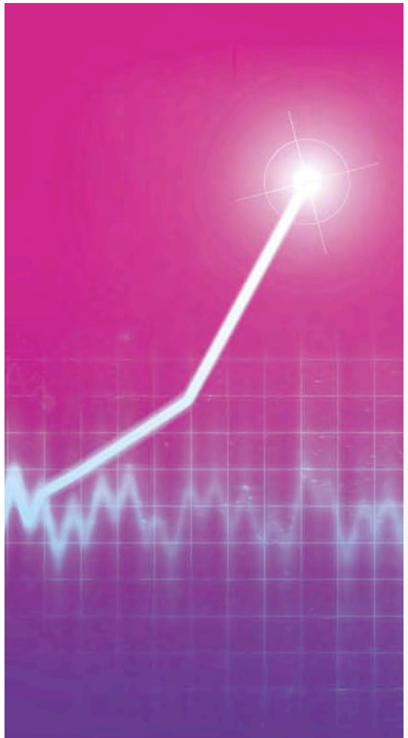
- Color
  - Control strip (CMY halftones)

ΔH	tol.	status
0.1	1.5	OK
0.0		OK
0.2		OK
0.4		OK
0.6		OK
0.2		OK
0.5		OK
1.6		FOUT
2.2		FOUT

ΔH	tol.	status
0.4	1.5	OK
0.2		OK
1.1		OK
0.2		OK
0.2		OK
0.1		OK
0.2		OK
0.7		OK
0.1		OK

Contents

ISO 12647-7 requirements - normative

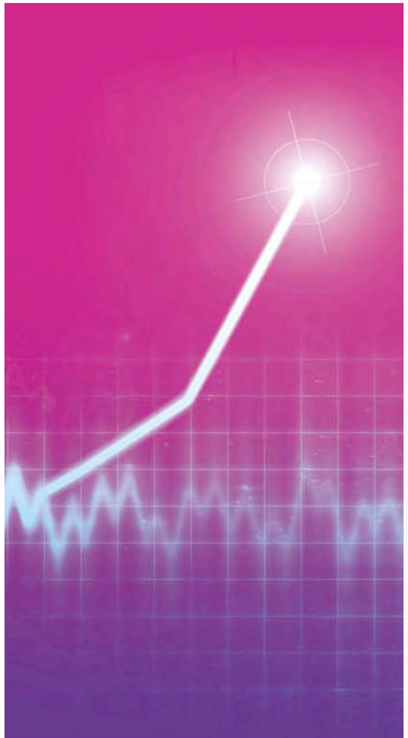


Contents

- Introduction
- Normative
- Informative

- 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
  - …

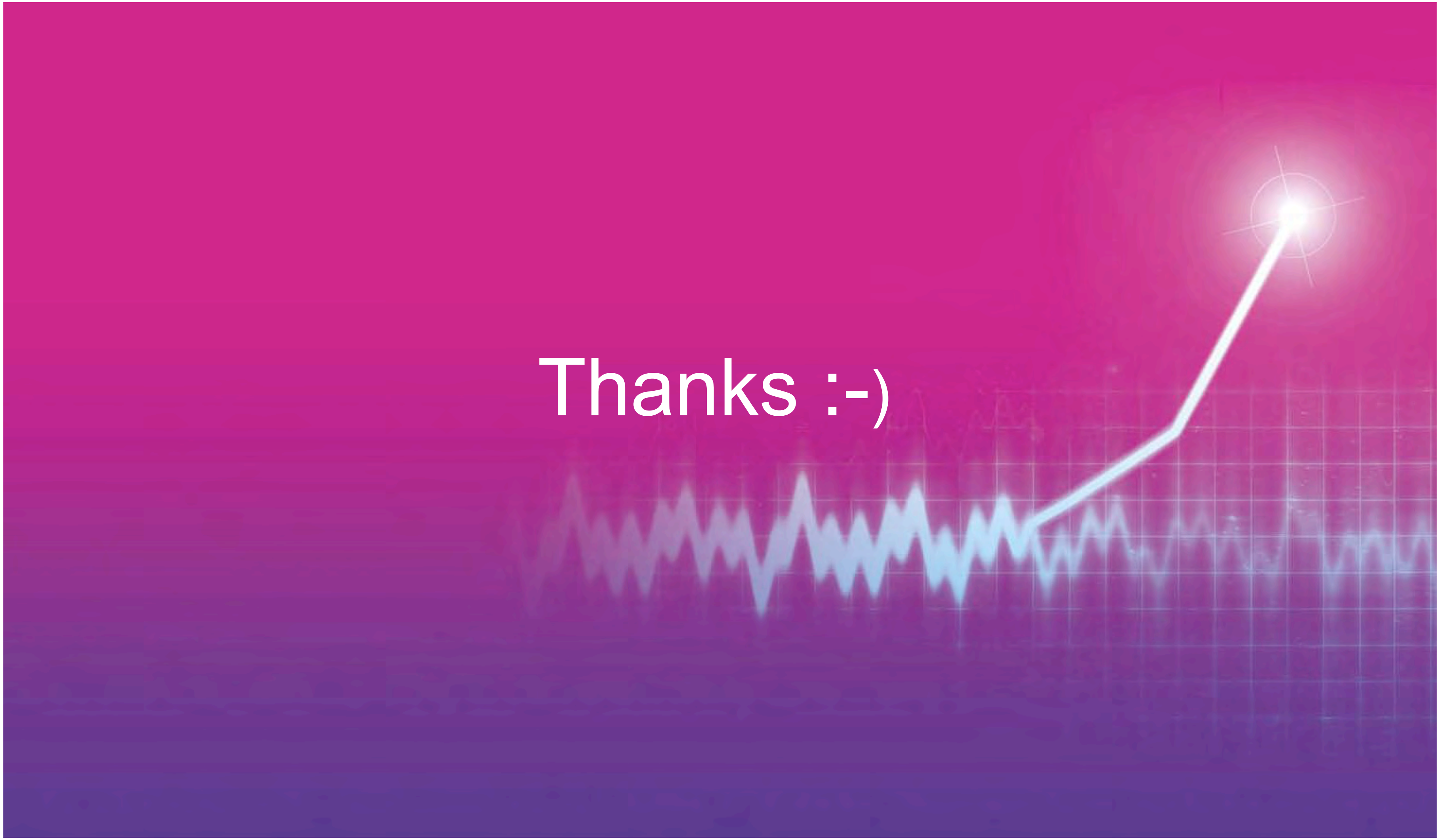
ISO 12647-7 requirements - informative



Contents

- Introduction
- Normative
- Informative

- Data delivery
  - **PDF/X, TIFF/IT**
  - **Color information**
- Screening
  - **Frequency, Angle, Dot shape**
- Substrate
  - **Gloss, UV-response**
- Rub resistance
- Ink gloss


Thanks :-)

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Working together toward greater efficiency

Vlaams innovatienetwerk
met steun van IWT

Strategic partners VIGC

AGFA Agfa

ESKO artwork

HIFLEX
MIS & Web2Print
Business Automation Systems

Kodak

océ

Plantin
business partner of
HEIDELBERG

Optimizing CMYK for Digital

ICC Digital Print Day, Paris March 2009

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

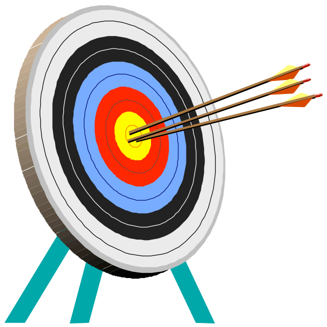
- Describe available Color Options
- Understand what each Option provides
- Benefits of each in a Digital Press environment
- New ways to use Color Options to Optimize Results

How many paper stocks?

- 1-3
- 4-6
- More than 6

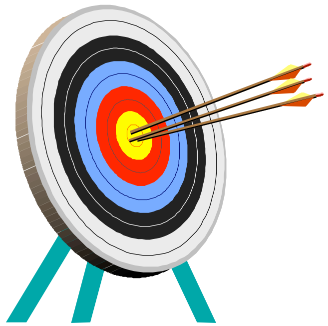
Two Main Questions

- 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:

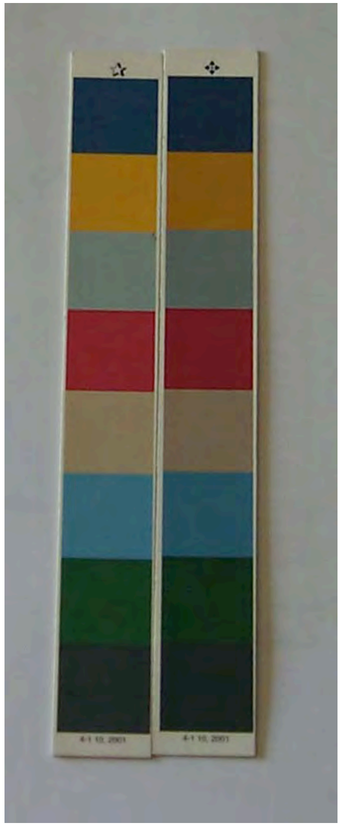
- How often to Calibrate
- How many substrates to profile?
- How many presses to profile
- If Calibration is “enough”
- What you can do in addition to calibration

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?

=8



=4

=2

- Color Tolerance Exercise
- Qualify Color Difference in delta E (ΔE76, ΔE94, ΔE2000, 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*

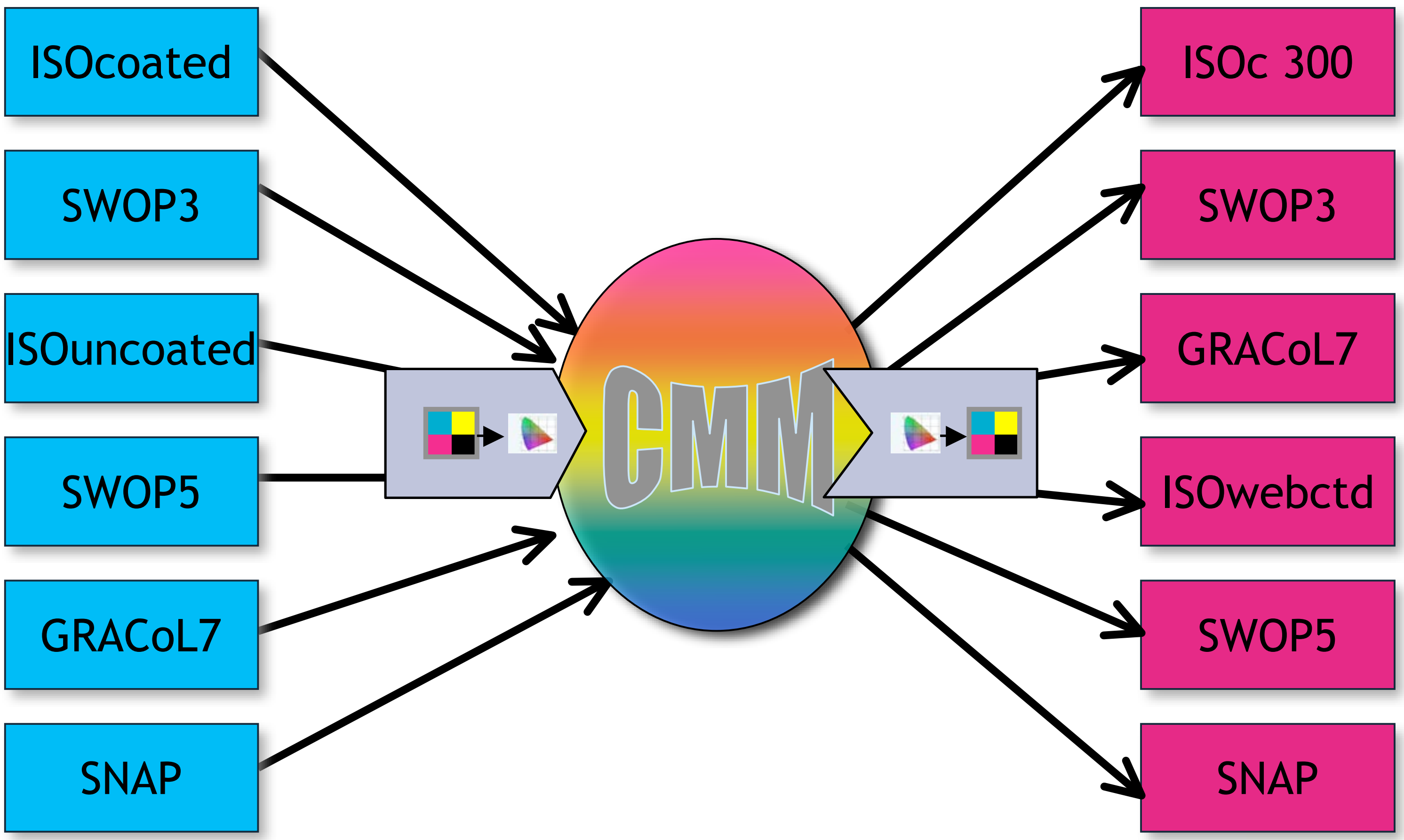
Why Digital Presses handled differently

- 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

Destination Gamut



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

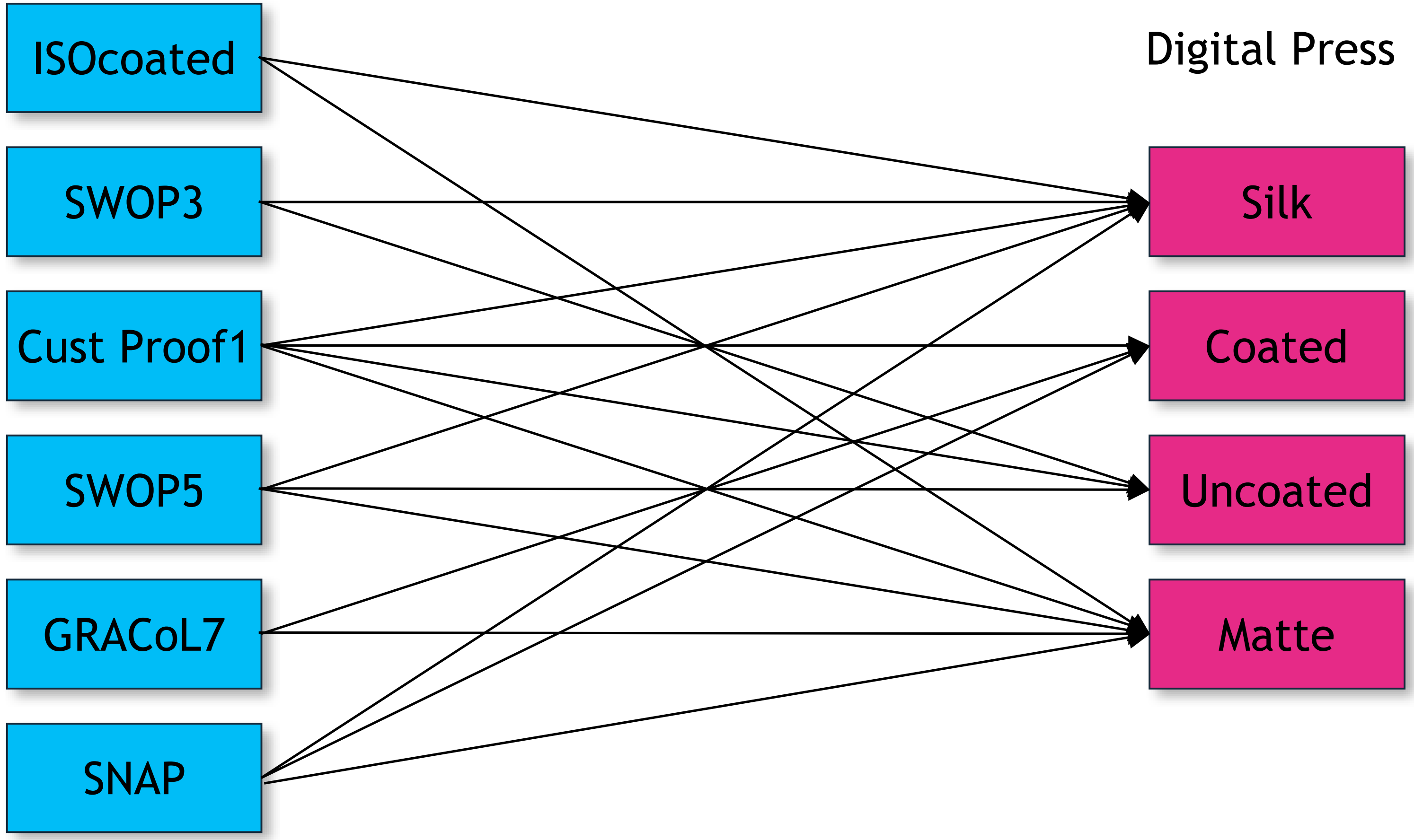
Pro's

- *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)



- 24 Device Links for 1 Digital Press, 4 substrates

Static ICC DeviceLink Profiles

Pro

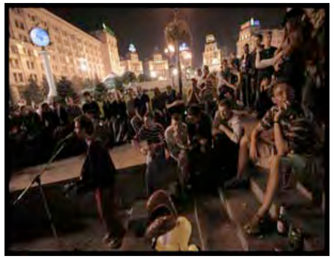
- Transformations have both source and destination information (gamut, viewing conditions)
- Less Conversions, less rounding errors
- Control on output separations characteristics

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

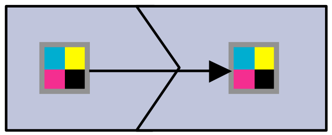
TAC 228
SNAP

TAC 300
SWOP

TAC 320
Gracol7

TAC 310
Japan

TAC 360
G7 Uncoated

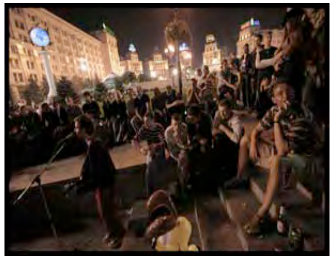


TAC 300
USWebSWOP

TAC 280
DigitalPress

One Conversion does not fit all…

- One Page, Multiple Images



TAC 380
Default CMYK

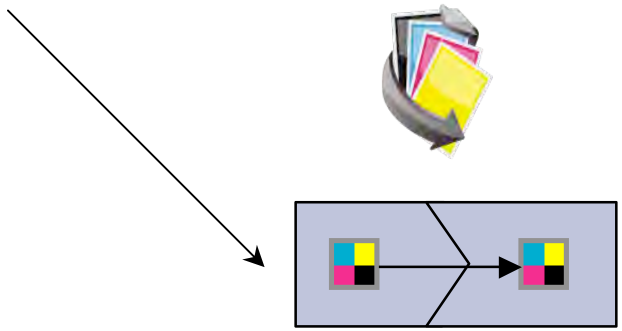
TAC 228
SNAP

TAC 300
SWOP

TAC 320
Gracol7

TAC 310
Japan

TAC 360
G7 Uncoated



TAC 300
USWebSWOP

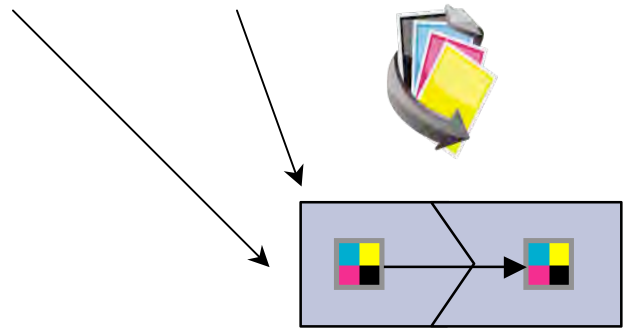
TAC 280
DigitalPress

<u>Resultant TAC</u>
300

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

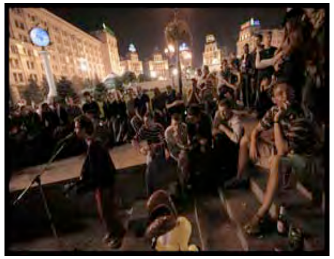
Resultant TAC

300

148

One Conversion does not fit all…

- One Page, Multiple Images



TAC 380
Default CMYK

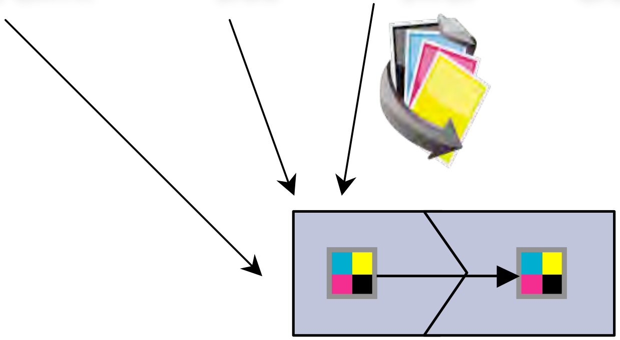
TAC 228
SNAP

TAC 300
SWOP

TAC 320
Gracol7

TAC 310
Japan

TAC 360
G7 Uncoated



TAC 300
USWebSWOP

TAC 280
DigitalPress

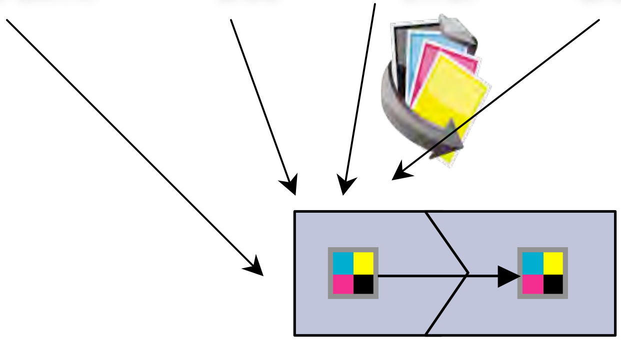
<u>Resultant TAC</u>

300
148
220

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



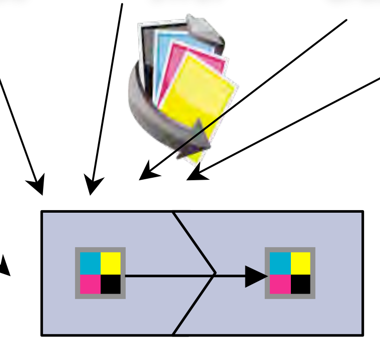
Resultant TAC

300
148
220
240

One Conversion does not fit all…

- One Page, Multiple Images

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



TAC 300
USWebSWOP

TAC 280
DigitalPress

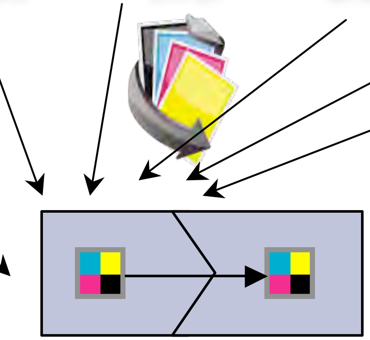
Resultant TAC

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

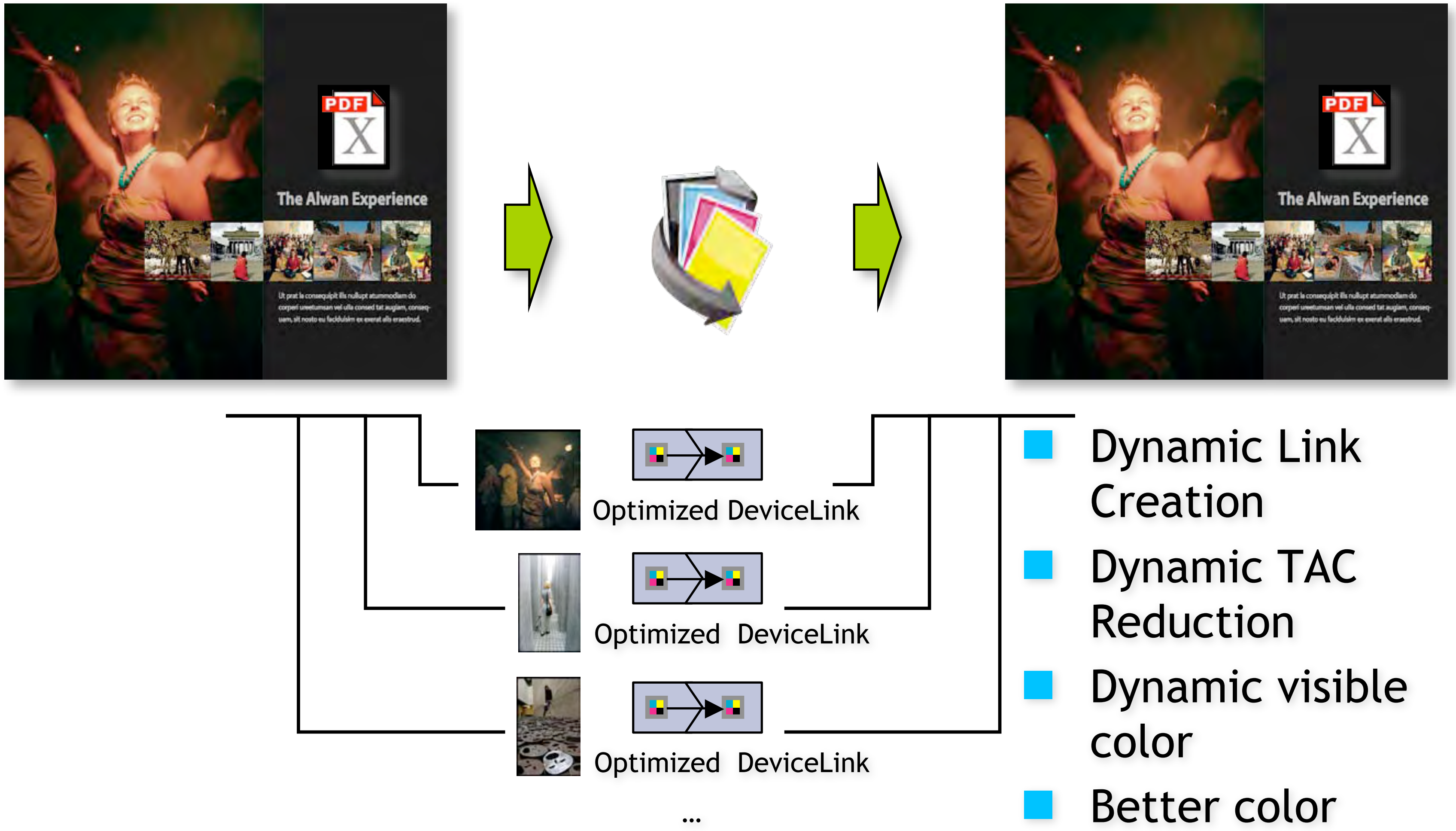


TAC 300 USWebSWOP | TAC 280 DigitalPress

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 sensitometry and psychophisic to characterise a color appearance phenomenon.

We will ask experienced observers to adjust a digital picture corpus in a variable luminance environment. These adjustements will be made on extended information files, through a console.

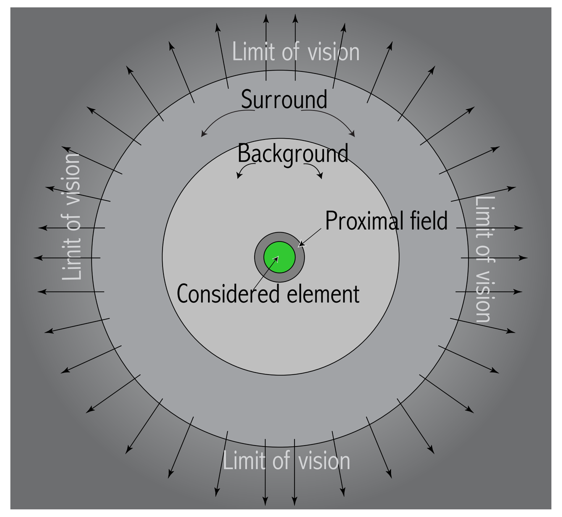
The collected data should allow us to determine a function we could apply to a model to obtain preferred tonal reproduction according to the luminance environment.

Context

There is one known color appearance phenomenon we are particulary interested in, Bartelson-Breneman Equations[A]. It specifies that image contrast changes according to surround. In our case, surround and background could vary.

Here is an adapting field diagram:

ADAPTING FIELD[A]



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

- A - Fairchild, Marc D. *Color Appearance Model*, 2nd edition. Wiley, 2005.
- B - Gay, Sébastien. *Modélisation mathématique de la réponse des films argentiques négatifs noir et blanc*. ENS Louis-Lumière: Graduate research thesis, 1999.
- C - Hunt, Robert W.G. *The reproduction of colour*, 6th edition. Wiley, 2004.
- D - Jones, Loyd A. *Recent developments in the theory and practice of tone reproduction*. Photo. Jl: 89B 126, 1949.
- E - Debevec, Paul E. - Malik, Jitendra. *Recovering HDR Radiance Maps from Photographs*. University of California at Berkeley.
- F - Sève, Robert. *Physique de la couleur*. Masson, 1996.
- E - Laborie, Baptiste. *CIECAM02 et rendu des couleurs*. ENS Louis-Lumière: Graduate research thesis, 2007.

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

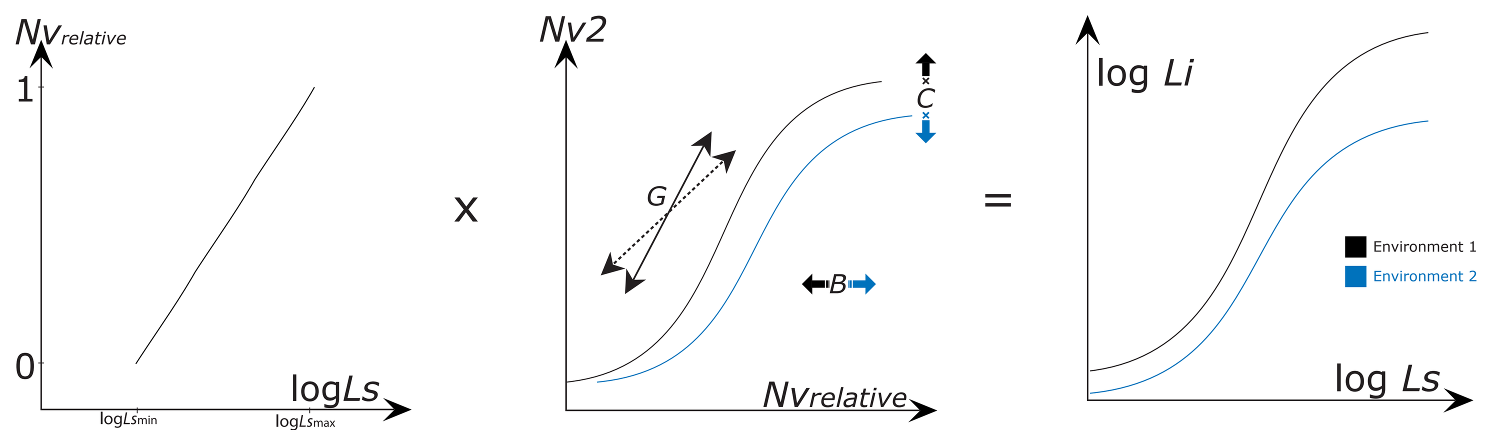
We have determined a three-parameter function to act on the image displayed:

- 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.



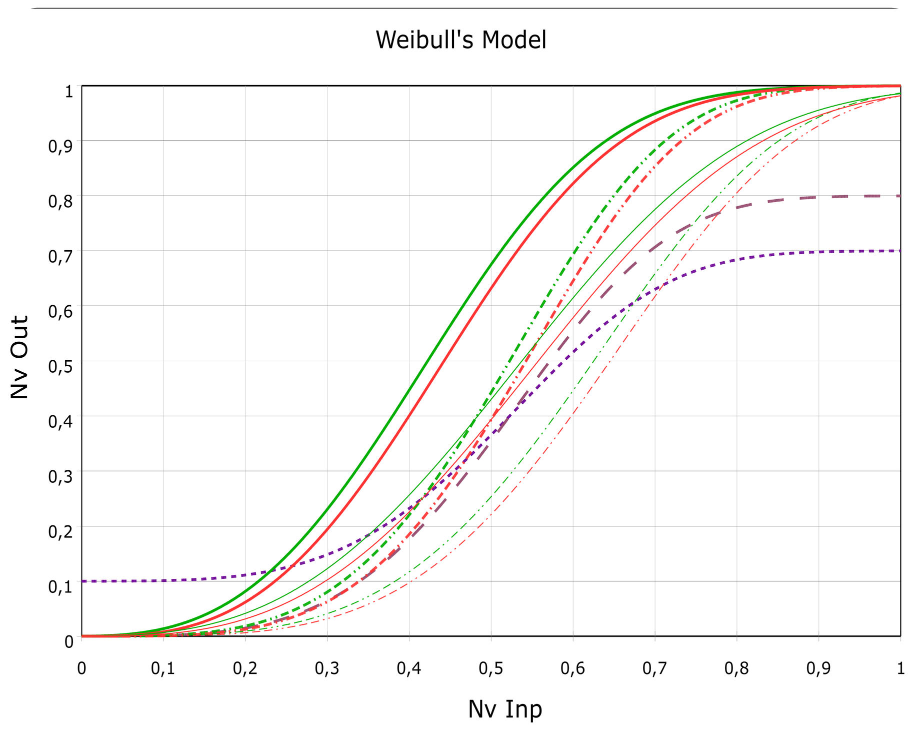
Linear file — Our functions with observer parameters — Curves of preferred tonal reproduction

Selected function

We have used a function based on Weibull distribution[B] :

$$Nv_{Out} = C_1 - C_2 * e^{\left(-G_1 * (Nv_{Inp} + B)\right)^{G_2}}$$

- Thick/thin: G_1 variation
- Continuous/discontinuous: G_2 variation
- Green/red: B variation
- Purple lines: C_1 and C_2 variation

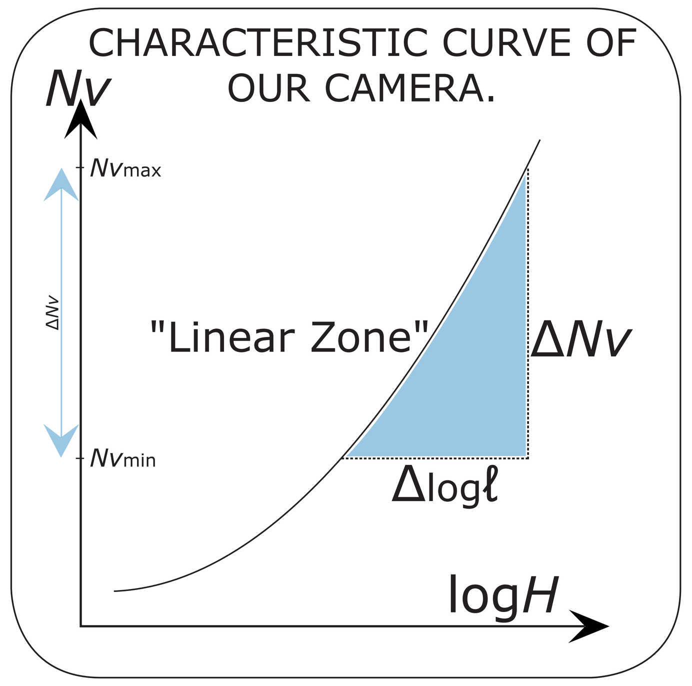


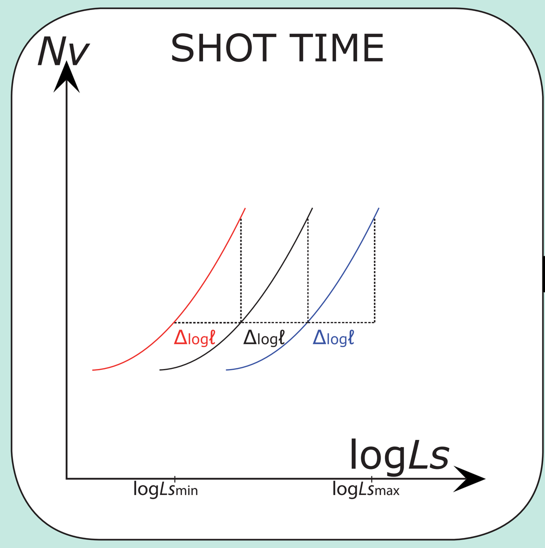
Source file construction

The signal response of the camera sensor is linear with regard to radiance. According to Fechner's[F] experiment on human perception, visual perception is proportional to the logarithm of the radiance. Therefore, we have studied the following function:

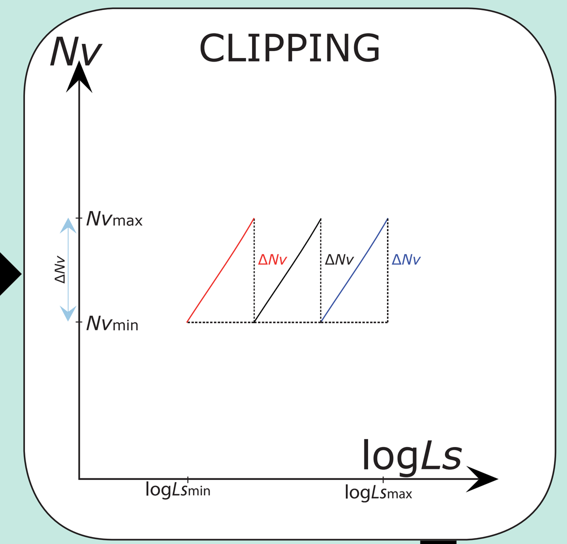
- $f(\log L_S) = \log L_I$

For this reason, our source images should have a linear response with regard to $\log L_S$. We will have to use several images to make one. We want to analyse the effect of a wide range of brightness. Observers will have to operate along the given scale. Consequently, we will need to use a display which can return a wide range of brightness. Similarly, digital images will need to have very detailed information about the luminance of the subject. Therefore a corpus of pictures will be composed according to linear high dynamic range files.

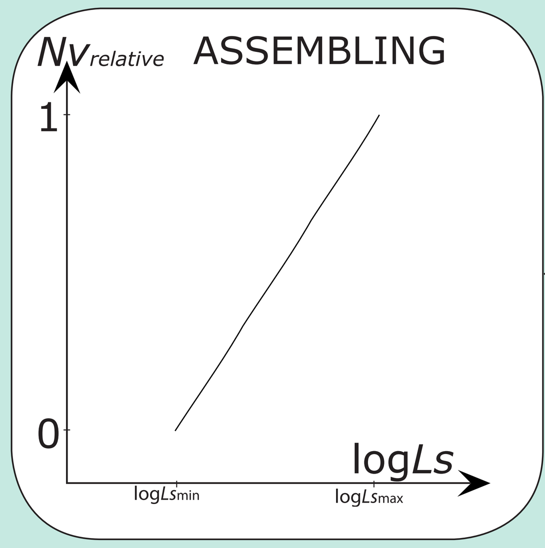




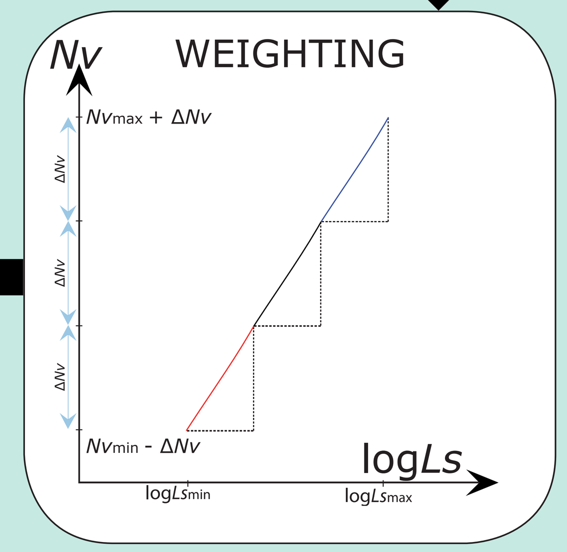
The Δlogℓ, according to the subject luminance contrast determines the number of pictures taken.



To select only the linear zone of each picture.



Our source file, has a relative set of values from 0 to 1.



The numeric value of each file will be weighted according to the total number of files.

With: *Nv* for numeric value; L_S for subject Luminance; *H* for exposure; L_I for image luminance.

Findings & future work

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

- Compare our results with existing Color Appareance Models or equations.
- Design a model for preferred tonal reproduction.
- Examine the data for both B/W and colour images and visual correspondances 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[1,2], Nicolas Bonnier [1], Christophe Leynadier [1] and Alain Sarlat [2]

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Abstract

The International Colour Consortium (ICC) has published their 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 perceptual workflow. 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 those two workflows.

Motivation

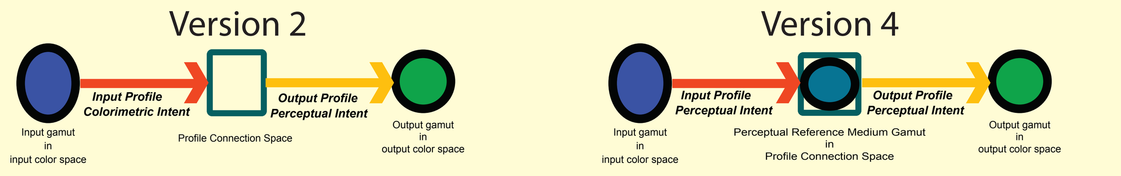
The motivation of this work is to determine if the use of the PRMG perceptually improve colour quality in printing system. To do so, we will compare two workflows: one using the PRMG, the other not.

Perceptual Rendering Intent

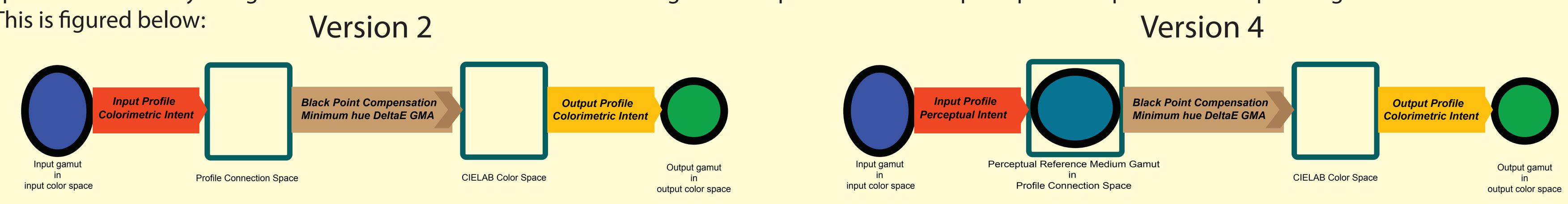
The goal of the perceptual rendering intent is to produce a pleasing reproduction of an original on some destination output medium. It is also called preferred reproduction. The exact colour rendering of the perceptual intent is vendor specific. The perceptual intent is useful for general reproduction of pictorial images, when it is not required to exactly maintain image colorimetry and the input and output media are substantially different.

ICC Perceptual Workflows

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 (sRGB) to an output colour space (e.g. a printer CMYK colour space). One workflow, the version 4, will use the PRMG and the other, the version 2, will not. The two workflows are figured below:



In particular, for the both situations after the first conversion we apply Black Point Compensation (BPC) followed by the gamut mapping algorithm hue minimum DeltaE to re-render the L*a*b* values to the printer gamut (in CIELAB colour space). Then the last conversion from L*a*b* values to the output colour space is achieved by using the media-relative colorimetric rendering intent to preserve our own perceptual adaptation to the printer gamut.
This is figured below:



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

The Perceptual Reference Medium (PRM) and the Perceptual Reference Medium Gamut (PRMG) have been introduced in the ICC specifications version 4.
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 gamuts. The PRMG boundaries and specific characteristics are enounced in the Annex B of ISO 12640-3 [ISO12640-3].

The PRMG is represented Figure I in the CIELAB colour space.

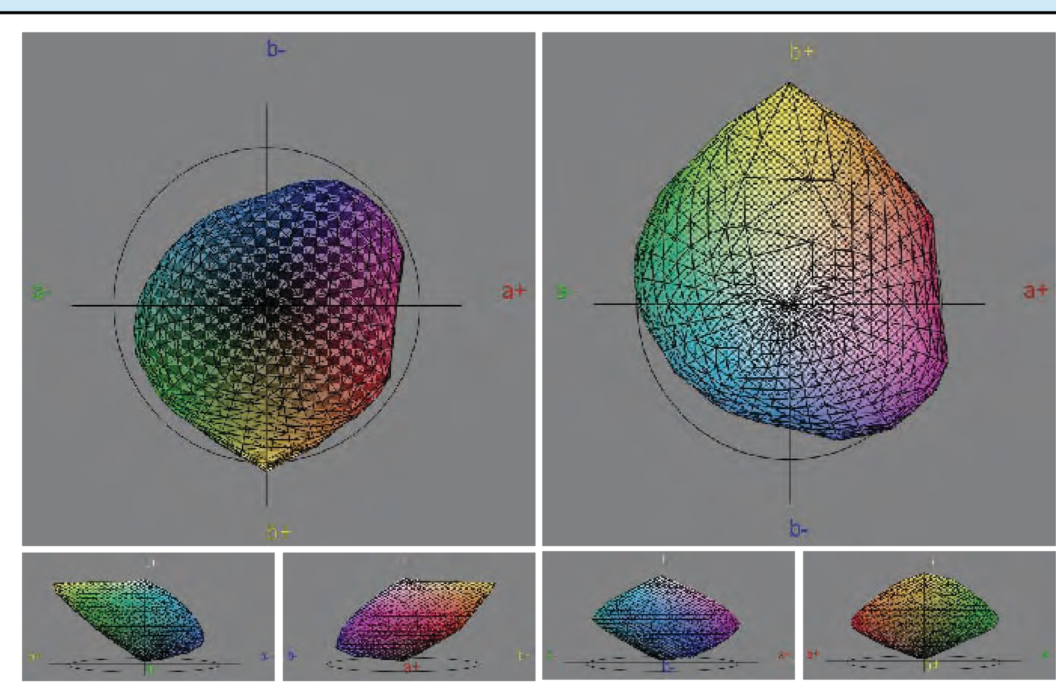


Figure I: 3D representation of the Perceptual Reference Medium Gamut in the CIELAB color space

Why using the PRMG and what is the impact of its use on image reproduction?

Compared with the version 2 of the ICC specifications which does not define a target gamut in the PCS, the PRMG defined in the version 4 allows the creation of look up tables for the perceptual colour rendering intent in the input profile. This will allow perceptual re-rendering from input colour space to PCS in input profiles (as done in the standard ICC input profile sRGB version 4). Furthermore, the PRMG and the gamuts of typical inkjet printers have similar shapes. This will simplify transformations in output profiles from the PCS to the output device colour space, and possibly help obtaining better quality. This allows us to hope for a gain of quality in colour rendering.

To evaluate the improvement in using the PRMG we will consider:

- The perceptual quality of resulting printed images for which we will conduct a psychophysical evaluation on a set of printed images.
- The evaluation of colour reproduction quality in using a set of images containing:
  - Flesh colours;
  - Greenness of vegetation colours;
  - Sky-blue colours;
  - Vivid and saturated colours;
  - Neutral colours.
- The improved coherence of image rendering when using different printers.

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

Task to perform

This psychophysical experiment is based on pair comparisons of images between prints produced from the ICC version 4 perceptual workflow and from the ICC version 2 perceptual workflow.
Pair images are compared respectively to their referent image displayed on a sRGB monitor.
The expert observers are asked to choose the best printed reproduction from the reference image displayed on the sRGB monitor.

Experimental setup

Printing systems

We have chosen two different printing systems:

- Epson R800
  - o Paper: Premium Glossy Photo Paper A4;
  - o Print Mode: Photo RPM without Gloss Optimizer.
- Océ Color Wave 600
  - o Paper: Océ Red Label LFM 050;
  - o Print Mode: 'Presentation' (600x600 dpi).

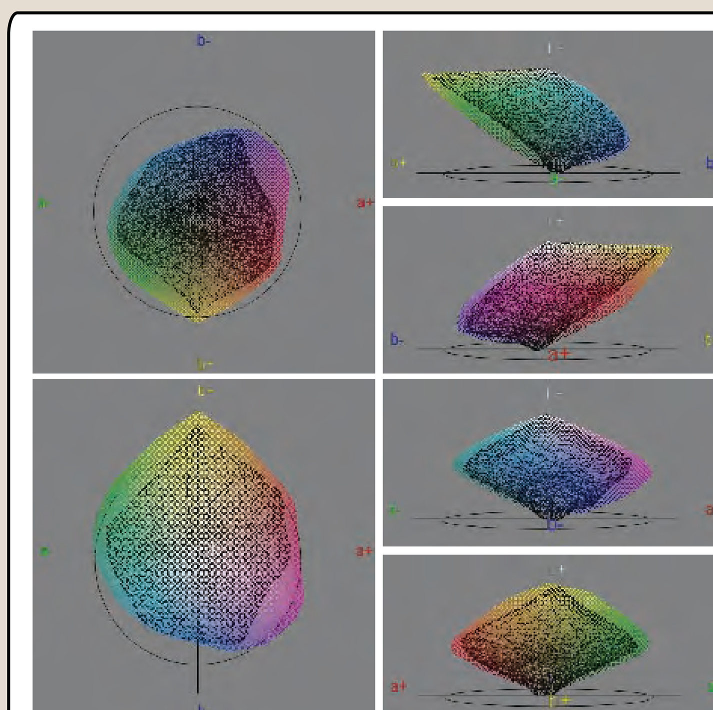


Figure II: 3D representation of the gamut obtained from the Epson R800 (Black lines) and of the PRMG (Solid colours shape)

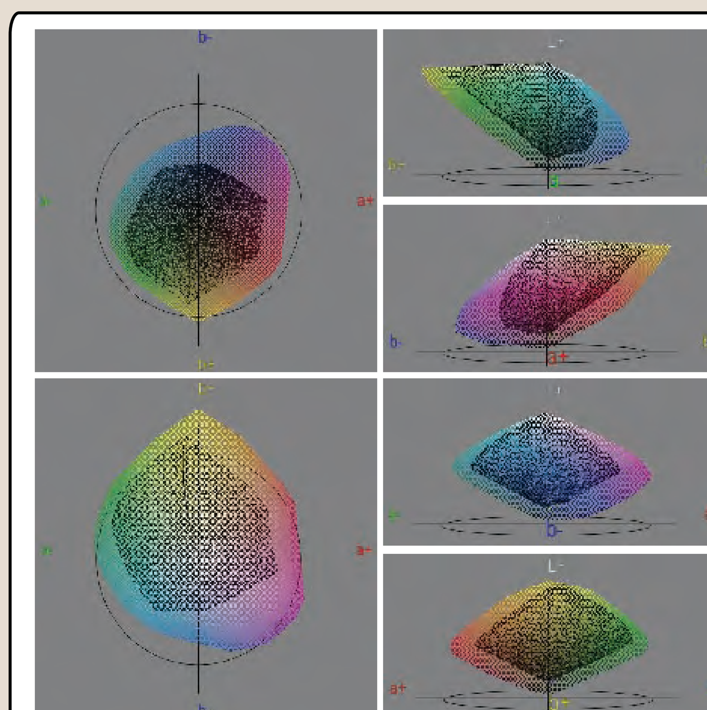


Figure III: 3D representation of the gamut obtained from the Océ Color Wave 600 (Black lines) and of the PRMG (Solid colours shape)

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 sRGB images from the ISO 12640-2:2004 set of images and from personal photographs.
The set of sRGB ISO images are chosen because they nicely fill most of the sRGB gamut. The personal photographs are chosen because their colours content is less saturated.

ISO images

Personal photographs

Viewing conditions

Glossy and non glossy reflection prints (210 x 297 mm) are placed on a rack mounted on a drafting table which was angled to produce a ~45° illumination angle and a perpendicular viewing angle. Viewing distance of printed images was restricted to 720 mm under the control of the operator. The illuminance of the plane is 450 +/- 150 lux and with a 5200 Kelvin illumination.

Monitor features

We use the EIZO Color Edge CG221 monitor to display the reference images because we can calibrate it to reproduce the sRGB color space (with a Color Temperature of 6500 Kelvins, a gamma of 2.2 and a luminance for the white point of 80 Cd/m^2).

Eizo Colour Edge CG221

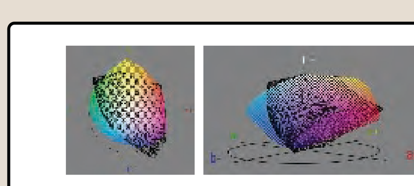


Figure IV: 3D representation of the sRGB gamut (Black lines) and of the PRMG (Solid colours shape)

Preliminary results and observations

The preliminary study

As of today, four expert observers have been confronted to the sets of images printed from the Océ Color Wave 600 and from the Epson R800. Eleven images were printed with the Océ Color Wave 600 and seven with the Epson R800.

Global observations

In prints resulting from the version 2 workflow we observe a closer reproduction of colours regarding the referent images. And we notice several times in printed images from the version 4 workflow, colours more saturated and less brightness.

The colour hues in original images are often reproduced with the version 4 more vivid or deeper than with the version 2. Nevertheless, in parallel it seams that we lost details in smooth variation of colours with the version 4. In particular, this is observed in the '*Flowers*' and in the '*Street under the snow*' images, respectively in the blue and orange colours.

We present here the preliminary results we obtained from the four expert observers (EO):

IMAGES	EO 1	EO 2	EO 3	EO 4
'Chinese woman with glass'	V4	V4	V4	V2
'Sky and ocean landscape'	No differences	V4	No differences	V2
'Eucalyptus forest'	V2	V2	No differences	No differences
'Flowers'	V2	V2	V4	V2
'Japanese goods'	V2	V4	V4	V2
'Mountain landscape'	V4	V2	V4	V2
'Shoes'	V4	V2	V2	V4
'Street under the snow'	V2	V2	V2	V2
'Wool balls'	V2	V2	V2	V2
'Gargoyles'	No differences	V2	No differences	No differences
'Fishing goods'	V2	V4	V4	V2

Océ Color Wave 600

IMAGES	EO 1	EO 2	EO 3	EO 4
'Chinese woman with glass'	V2	V2	V2	V2
'Eucalyptus forest'	No differences	V4	V4	No differences
'Flowers'	V2	V2	V4	V2
'Japanese goods'	V4	V4	V2	V4
'Mountain landscape'	V4	V2	V4	V2
'Wool balls'	No preferences	V2	V4	V2
'Fishing goods'	V4	V4	V4	V4

EPSON R800

V2: Version 2 printed images preferred; V4: Version 4 printed images preferred; No differences: No differences perceived; No preferences: No printed images with differences preferred.

Océ Color Wave 600

NUMBER OF	EO 1	EO 2	EO 3	EO 4	TOTAL
No differences perceived between version 2 and version 4 images	2	0	3	2	**7**
Version 2 images preferred	6	7	3	8	**24**
Version 4 images preferred	3	4	5	1	**13**
Differences perceived, no images preferred	0	0	0	0	**0**

EO: Expert observer

For the printed images with the Océ Color Wave 600, 3 out of 4 expert observers prefer images reproduced from the version 2 than from the version 4 workflow.
The total number of images preferred for the version 2 compared to the total of printed images preferred for the version 4 workflow indicate that the version 2 workflow tend to give better results.

Epson R800

NUMBER OF	EO 1	EO 2	EO 3	EO 4	TOTAL
No differences perceived between version 2 and version 4 images	1	0	0	1	**2**
Version 2 images preferred	2	4	2	4	**12**
Version 4 images preferred	3	3	5	2	**13**
Differences perceived, no images preferred	1	0	0	0	**1**

For the printed images with the Epson R800 results are more balanced. Two expert observers prefer more printed images which come from a version 2 workflow than from a version 4 and we got the inverse preference from the two other observers.

Conclusion

It seams that results depend of the printing system. Nevertheless, there were fewer images printed with the Epson R800 and this is through this printing system than we get more balanced results. This involves that we need to take these first results with caution. We need to continue our study with more images, with other printing systems and with more observers.

Bibliography

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[ICCwp2] International Color Consortium – "White Paper #2 – Perceptual Rendering Intent Use Case Issues" – 9 pages, 2005-01
[ISO12640-2] International Standard ISO – "ISO 12640-2:2004 Graphic technology – Prepress digital data exchange – Part 2: XYZ/sRGB encoded standard colour image data (XYZ/SCID)" – 25 pages, 2004-07-15
[ISO12640-3] International Standard ISO – "ISO 12640-3:2007 Graphic technology – Prepress digital data exchange – part 3: Cielab standard colour image data (cielab/scid)" – 33 pages, 2007.
[ISO20462-1] International Standard ISO – "ISO 20462-1:2004(E) Photography – Psychophysical experimental methods to estimate image quality – Part 1: Overview of psychophysical elements" – 14 pages, 2004
[ISO3664] International Standard ISO – "ISO 3664:2000 viewing conditions – graphic technology and photography" – 20 pages, 2000.

Future works

- Introduction of a workflow with ROM images in input.
- Psychometric studies
  - Determine a set of images selected from specific colour criteria to define;
  - Several printing systems will be used to determine the coherence of colour rendering from a workflow who uses the PRMG and another who do not.
- Colorimetric analysis
  - Determine objective criteria to analyse ICC profile version 4 transformations for colour reproduc tion.

Poster printed with an Océ Colorwave 600 inkjet printer on Red Label uncoated paper

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

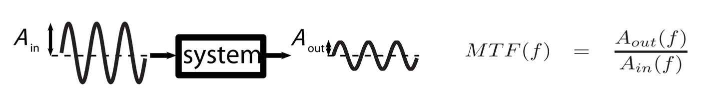
Printer is not able to accurately reproduce high-frequencies on uncoated paper

The motivation of this work is to obtain an accurate measure of the ability of a printer to reproduce details.

In this study, we consider the relation between the measurement of the MTF by a scanner and the perception of the MTF by the human visual system.

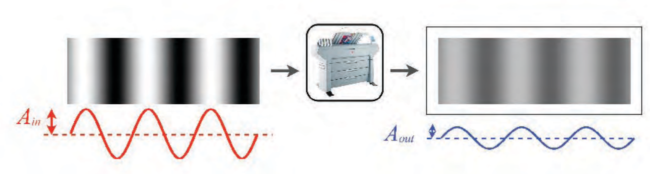
Scanner-based Measure of the Printer Modulation Transfer Function [01,04]

MTF



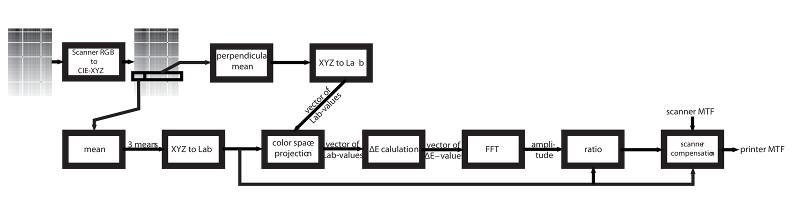
$$MTF(f) = \frac{A_{out}(f)}{A_{in}(f)}$$

Printer MTF

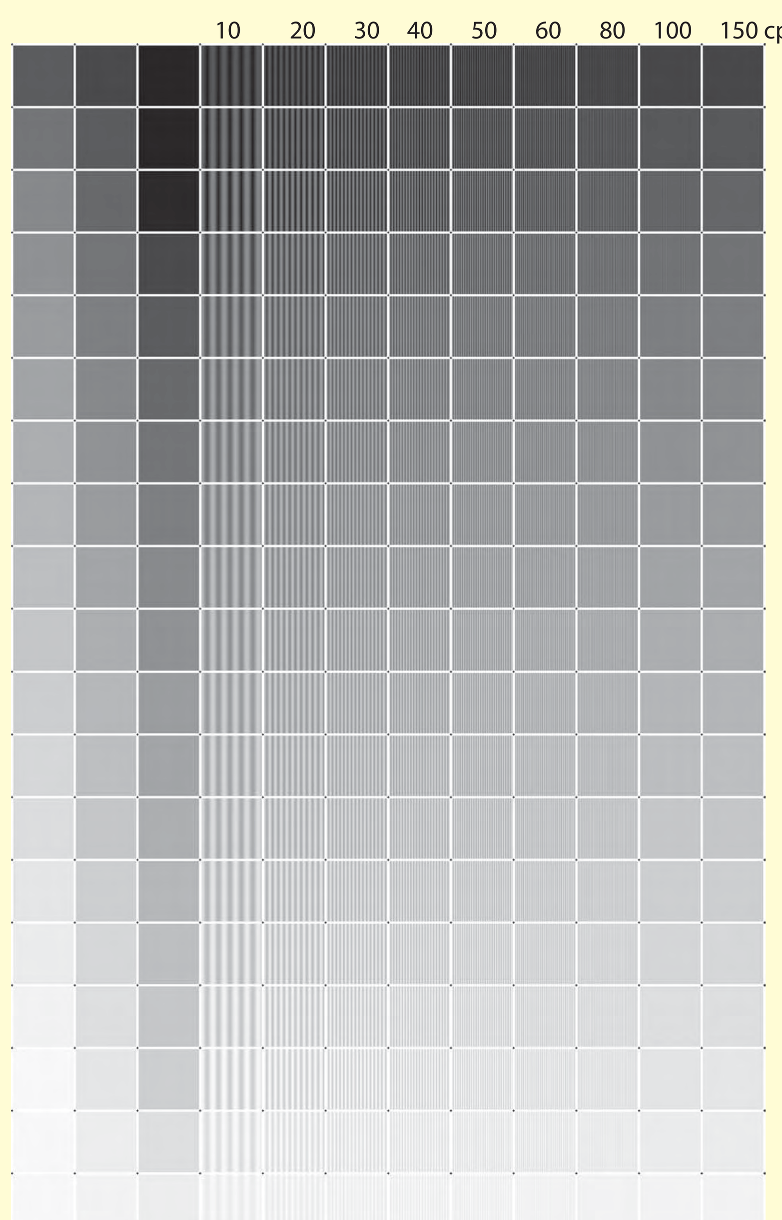


The MTF of a printing system depends on the image content:
bias,
amplitude,
color
and direction

Jang and Allebach's Method



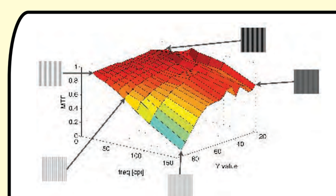
The test page is printed, scanned and analyzed.
(The test page grayscale values were modified to improve the accuracy of the results)



Jang and Allebach's test page consisting of series of patches with 1D sinusoidal modulations with different biases and frequencies (actual size)

Measured MTF

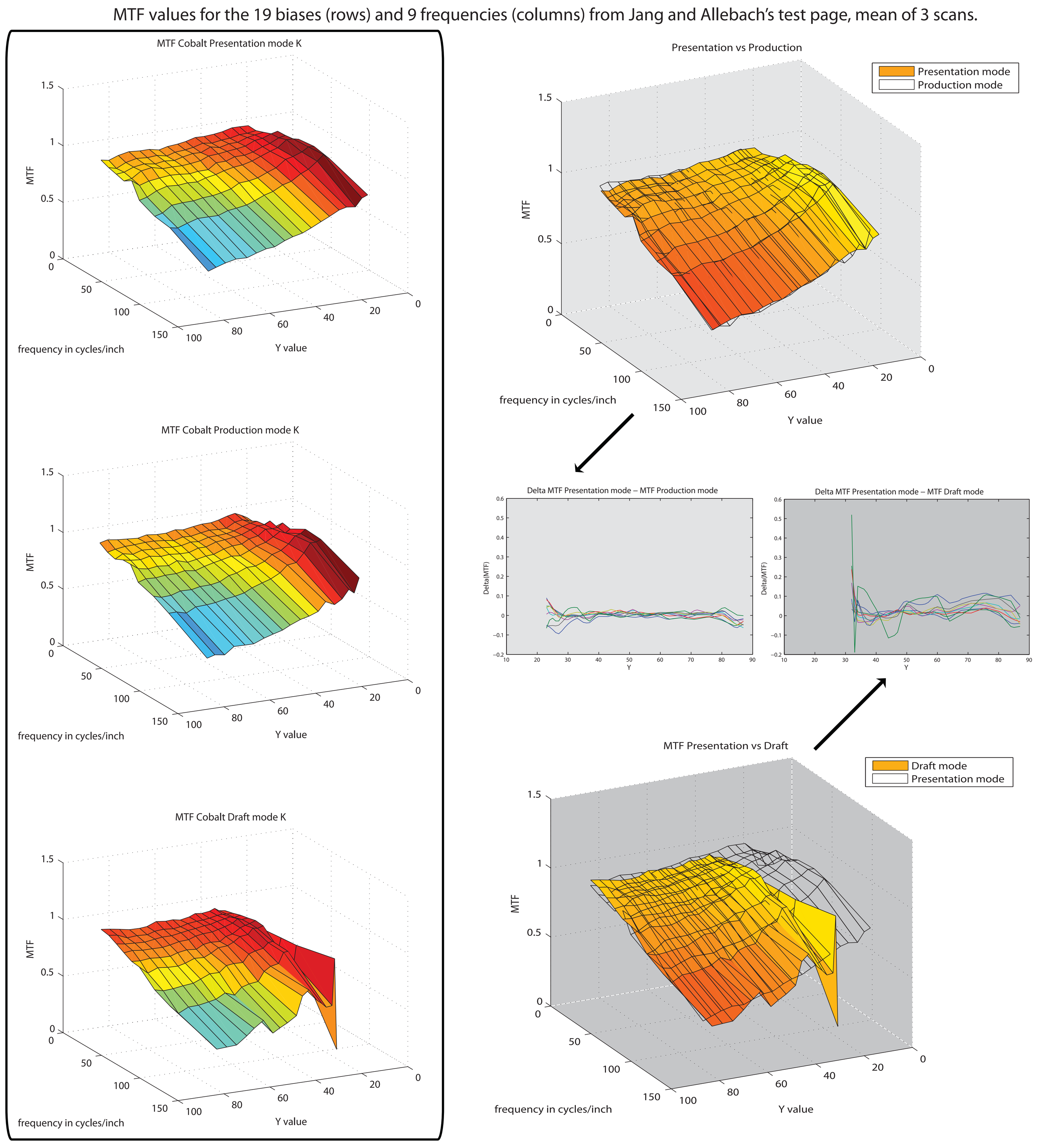
Océ Colorwave 600 inkjet printer and Red Label uncoated paper



Printing system:

Océ Colorwave 600
Red label uncoated Paper

MTF values for the 19 biases (rows) and 9 frequencies (columns) from Jang and Allebach's test page, mean of 3 scans.



Observations

Scanner-based measurements give us information about the quality of the reproduction of details by the printer in three print modes, which appear lower with a lower number of dots per inch.
We can notice that for all modes the MTF values are slightly lower for higher Y values.
MTF measurements of the printer in Presentation and Production modes are similar.
Océ Colorwave 600 in these print modes produces prints in 600 dpi. In Draft mode it produces prints in 300 dpi.
MTF measurements of the printer in Draft mode appear very different, presenting lower values and strong variations, particularly for the highest frequency (150cpi) and the lowest biases. It can be explained by the fact that it reaches the maximum number of dots per inch the printer in Draft mode is capable of.
All differences between Presentation and Production MTFs are less than 0.1 (absolute values) whereas differences between Presentation and Draft varie above 0.2 (absolute values), except for 150 cpi where the difference reaches 0.5.

Perception by the Human Visual System, Psychophysical Experiment

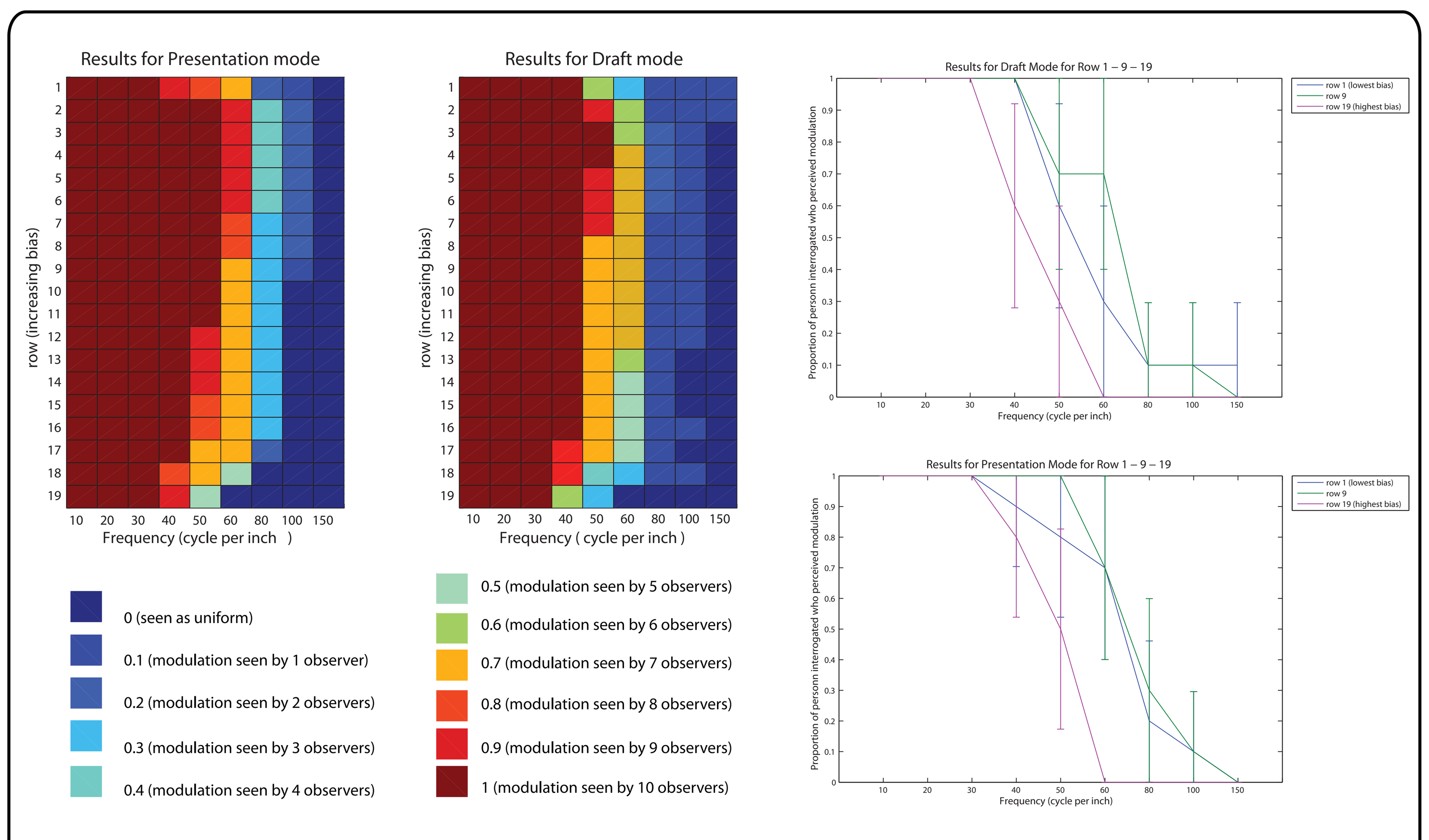
Introduction

MTF measurements show differences between the three modes. MTF for lower Y values and higher frequencies are more attenuated with Production and Draft modes. Ideally, the MTF should represent the loss of details and the quality of the reproduction. But do observers perceive these differences? Are they able to see modulation in the highest frequencies? Do they really see more details with a higher number of printed dots per inch? Do halftoning noise hide fine details? To answer these questions we proceed in a psychophysical experiment to assess the limits of human perception of details. Images are presented to a panel of observers and are composed of sinusoidal patches of increasing frequency. The observers are asked to draw a limit between the patches where they can perceive the original sinusoidal modulation and the ones which looks uniform or noisy. Our main goal is to link MTF values with perception.

Protocol

10 persons constitute the test panel, 3 females and 7 males. The observers are presented with two graphic images (Jang and Allebach [01] test chart without uniform patches) printed with Océ Colorwave 600 on Océ Red Label paper with two different print quality modes (Presentation and Draft).
The observers view the prints from a distance of around 50 cm.
The viewing conditions follow the ISO-20462 2005 recommendations [08].
The samples are displayed on a white board which has the same properties as the medium used.
They are told :"For each row, draw a line between the patch where you can still see modulation and the one which looks uniform."

Results



Results show two important trends:

For both cases and for each bias lower frequency patterns are systematically perceived. Observers perceive less modulation when frequency increases. The frequency level where original sinusoidal modulation can not be perceived depends on the bias. This level is the lowest for highest biases and slowly increases with bias decreasing. Reaching lower biases, the frequency level quickly decreases. Some pattern are never perceived.

Observers interrogated perceived more details in reproduction printed with Presentation mode than with Draft mode. For Draft mode the perception of modulation reaches approximately one frequency less. One observer saw modulation until the highest frequency. Yet it seems that he did not see the original signal but certainly either the halftone pattern or aliasing.

This comparison between the two modes allows us to conclude that a higher number of printed dots per inch increases the perceived accuracy of the reproduced details.
We are measuring in this experiment the combination of the printing system (its ability to reproduce fine details) and the human visual system (its ability to perceive high frequencies).

MTF measurements vs. Perception

In the first part of this study, scanner-based MTF measurements give us information about the accuracy of the printer to reproduce a pattern for various frequency and biases.
In the second part we proceed in a psychophysical experiment which give us a measure of threshold of pattern visibility for various frequencies and biases and not perceived amplitudes.
In both measurements we observe that :
- the quality of the reproduction of details decreases when frequency increases,
- the quality also decreases when the print mode goes from Presentation to Draft,
- when bias decreases the quality of the reproduction of details increases until the lowest values where it decreases.

We can see that the scanned-based measurements are always significantly above 0. Yet the human visual system is not capable of perceiving the highest frequency patterns.
This result may be due to
- the ability of the human visual system to distinguish high frequencies [12],
- to the halftoning characteristics,
- to the psychophysical experiment which produces a treshold
- or to the scanner-based MTF measurement method.

This points the need of linking MTF values with human perception of details searching for more than a threshold.

Conclusions and Future Work

In this study we have proposed a comparison between different print quality modes. First we have used scanner-based MTF measurements and then we have proceeded with a psychophysical experiment. We actually found 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 them.
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.

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Poster printed with an Océ Colorwave 600 inkjet printer on Red Label uncoated paper