M1 Simulation by Varying Printing and Proofing Substrates

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Standardization in color management and color printing, by means of reference printing conditions, enables repeatability and predictability in color reproduction workflows.

Market does not want to standardize paper color.

- When paper colors are not accounted for in the color reproduction workflow, color repeatability and predictability suffer.
  - One of the factors that affects paper color is the addition of OBA.
New Level of Standards

- GCATS.21 Standard (2013)
  - Establishes principles for using color characterization data as the definition of printing across multiple technologies.
  - Specifies color measurement according to ISO 13655 M1 with white backing.
  - Uses the substrate correction method, defined in ISO 13655, to adjust the data before proofing and printing.
Literature Review

- Chung studied how OBA affects white point of the substrate and printing conformance (Advanced Materials Research, 2011).
- Chung studied printing conformance to substrate-corrected dataset (TAGA Proceedings, 2013).
- Chung invited four proofing solution providers to participate in the proof-to-brightened print color match study (IARIGAI, 2013).
Literature Review

- ISO/FDIS 15397 states that the difference of the CIE-b* values (D50, 2-deg) indicates the OBA amount or degree of fluorescence in a substrate.
  - \( OBA = b^*_{M2} - b^*_{M1} \)

- While OBA is a material characteristic, \( \Delta OBA \) is the OBA difference between two substrates, e.g., print and proof.
  - \( \Delta OBA = OBA_{\text{Proof}} - OBA_{\text{Print}} \)
Literature Review

- RIT studied the perceptibility of color difference of printed color pairs, due to OBA difference in paper, and its relationship with $\Delta E_{00}$ (TAGA, 2015).
  - *Fluorescent agents affect CIE-\(b^*\) value of a substrate, but its \(L^*\) stays the same.*
  - *There is a linear relationship between visual difference and $\Delta E_{00}$.*
  - *Since $\Delta OBA$ is the main contributor of $\Delta E_{00}$, there is also a linear relationship between visual difference and $\Delta OBA$.***
Objectives

- Given that color measurement and color viewing conform to M1, this research sets out to answer two questions:

  1) In what way, the white point and the OBA amount of a substrate influence the print-to-proof color match, and

  2) What are the recommended practices in achieving the proof-to-print visual match when printing and proofing substrates varying in OBA amounts?
Methodology

1) Select a CRPC or a reference dataset.
2) Select three printing and three proofing conditions (varying in OBA amount).
3) Study the relationship between white point and OBA amount.
4) Select a pictorial color (SCID) image.
5) Simulate the SCID image, as printed, in relation to CRPC.
6) Simulate the SCID image, as printed and proofed, visually.
7) Simulate the SCID image, as printed and proofed, quantitatively.
8) Estimate the simulation error.
Methodology

- Reference dataset and ICC profile
  - *CGATS.21-2 CRPC6*
  - *ICC profile: GRACoL2013_CRPC6.icc*
- Three printing conditions
  - *Papers with similar L* (93~95), but varying OBA*S*
  - *ICC Profiles, built from substrate-corrected dataset, using i1 Profiler*

<table>
<thead>
<tr>
<th>CGATS 2010 Database</th>
<th>LAB_L</th>
<th>LAB_A</th>
<th>LAB_B</th>
<th>LAB_L</th>
<th>LAB_A</th>
<th>LAB_B</th>
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</tbody>
</table>
Methodology

- Three proofing conditions
  - Low OBA: Epson Standard Proofing Paper 205
  - Medium OBA: Epson Proofing Paper Production
  - High OBA: Mid-States FSC 7S Paper Outre

- ICC profiles (courtesy of Bruce Bayne, Alder Technology, Inc.)

<table>
<thead>
<tr>
<th>Substrate</th>
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<th>LAB_B</th>
<th>M1</th>
<th>LAB_L</th>
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<td></td>
<td></td>
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</table>
Methodology

- SCID image, ISO 12640, N4A (Bar set)
  - Re-size the image (300 ppi, CMYK) to 3” wide with borders for visual assessment.
  - Re-sample the image to 5 ppi for quantitative assessment.
Methodology

- Simulate the SCID image, as printed, visually.
  - Open the SCID image in Adobe Photoshop.
  - Assign a printer ICC profile, sccaX, where X is OBA amount (L, M, and H).
  - Convert the image from the CMYK space to Adobe RGB space using absolute colorimetric rendering.
  - Save as Scene_sccaX_adobe.jpg.
Methodology

- Simulate the SCID image, as proofed, visually.
  - Open a SCID image in Adobe Photoshop.
  - Convert the image via a device link profile, DL(sccaX-pfY).icc using absolute colorimetric rendering.
    - Device link profiles are built using i1 Profiler.
  - Assign the proofer profile, pfY.icc, to the converted image.
  - Convert the above image from pfY space to Adobe RGB space using absolute colorimetric rendering.
  - Save as Scene_sccaX-pfY_adobe.jpg.
Methodology

- Simulate print-to-proof visual comparison
  - Place simulated print (adobe.jpg) and simulated proofs (adobe.jpg) in Microsoft PowerPoint.
    - Place print and proof in edge contact.
    - Add legends.
    - Add a neutral background.
Methodology

- Simulate SCID image, as printed and proofed, quantitatively
  - *In ColorThink s/w,*
    - Generate a CIELAB color list from a print (reference) and color lists from three proofs (samples).
    - In Excel s/w, compare color difference ($\Delta E_{00}$) between reference and sample color lists.
Methodology

- Simulate device error
  - Begin with a CIELAB color list (reference).
  - Perform ‘round-trip’ by assigning the same ICC profile twice (B-to-A, then A-to-B) in absolute colorimetric rendering. This is the sample list.
  - Assess $\Delta E_{00}$ distribution between the two color lists.
Results – Device Error

- Round trip analyses of all three printing and proofing conditions show similar performance.
  - Color differences at 95th percentile of the distribution is about $1 \Delta E_{00}$. 

![Graph showing color differences](image-url)
Results – Visual Simulation of Printing

- CRPC as the print reference
  - Visual differences, due to substrate difference, are intentional.
Results – Quan. Simulation of Printing

- $\Delta E_{00}$ distribution of colorlists between CRPC6 and three SCCA datasets vary widely.
  - Low OBA print has the largest $\Delta E_{00}$ and visual difference to CRPC6.
  - Medium OBA print has the smallest $\Delta E_{00}$ and visual difference to CRPC6.
Results -- Print-to-Proof Simulation

- Case 1 – Low OBA print as the reference
  - The print substrate and the three proofing substrates show large variations in $\Delta OBA$ and $\Delta E_{00}$.

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<th>LAB_A</th>
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Results -- Print-to-Proof Simulation

- Case 1 -- Low OBA print as the reference
Results -- Print-to-Proof Simulation

- Case 1 -- Low OBA print as the reference
  - Color differences at 95\textsuperscript{th} percentile of the distribution is about 2 \( \Delta E_{00} \) or less.
Results -- Print-to-Proof Simulation

- Case 2 -- Medium OBA print as the reference
  - *The print substrate and the three proofing substrates show less $\Delta OBA$ and $\Delta E_{00}$ variation than those in Case 1.*

<table>
<thead>
<tr>
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<th>M2</th>
<th>OBA</th>
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Results -- Print-to-Proof Simulation

- Case 2 -- Medium OBA print as the reference
Results -- Print-to-Proof Simulation

- Case 2 -- Medium OBA print as the reference
  - Color differences at 95\textsuperscript{th} percentile of the distribution is 2 $\Delta E_{00}$ or less.
  - The high OBA proof has the smallest $\Delta E_{00}$ at 95\textsuperscript{th} percentile of the distribution.
Results -- Print-to-Proof Simulation

- **Case 3** -- High OBA print as the reference
  - *The print substrate and the three proofing substrates have more \( \Delta OBA \) and \( \Delta E_{00} \) variation than those in Case 2.*

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Results -- Print-to-Proof Simulation

- Case 3 – High OBA print as the reference

Highlight clipping is visible.
Results -- Print-to-Proof Simulation

- Case 3 – High OBA print as the reference
  - The low OBA proof has the largest $\Delta E_{00}$ at 95th percentile of the distribution.
  - Highlight clipping causes color mismatch between low OBA proof and high OBA print.
Discussions

- $\Delta E_{00}$, OBA, and pictorial color matching
  - $\Delta E_{00}$ metric, in the form of a distribution, is indicative of the pictorial color difference between two color images.
  - $\Delta OBA$ is one of many factors that contributes to $\Delta E_{00}$.
  - $\Delta L^*$ and $\Delta b^*$ between two substrates can cause gamut clipping that contribute to the $\Delta E_{00}$ magnitude and influence the visual match between a proof and a print.
Discussions

- ΔOBA and the viewing illumination
  - Color match between a high OBA proof and a low OBA print depends more on the viewing light source than the color match between a low OBA proof and a low OBA print.
  - ΔOBA is indicative of the criticalness of lighting in color match, i.e., the match becomes more metameric when ΔOBA is high.
Conclusions

- Guidelines for proof-to-print visual match where OBA amounts of the print vary
  - Viewing and color measurement are in M1 compliance.
  - Printing is calibrated to the substrate-corrected dataset.
  - Select a proofing substrate that has adequate “head room” to avoid gamut clipping and proof to the substrate-corrected dataset.

  - In order to match OBA-loaded prints, experiences have shown that a proofing substrate should have
    - A slightly larger L* value (no higher than 2 L*) and
    - A larger negative CIE-b* value (no more than 5) than the printing paper.
Thank You.

Any Questions?