THE FUTURE OF COLOR MANAGEMENT

iccMAX

Color Management in the 21st Century

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Introduction

Traditional Image Reproduction Was a Thriving Industry

- Color image reproduction had been the domain of photographic science
  - In image reproduction status density was king.
    - Everyone had at least one and often two or three densitometers
  - Image reproduction was moving from the large labs of the film makers to smaller local or regional job shops.
  - Film was exposed, images recorded, the films taken to the lab and developed then positives were printed from the negative films.
- Instant print film was a game changer – no middle man needed
  - It was still film based but the camera film became the take-away
- Life was pretty good for the film maker, the process lab and the consumer.

Microprocessors Changed Everything

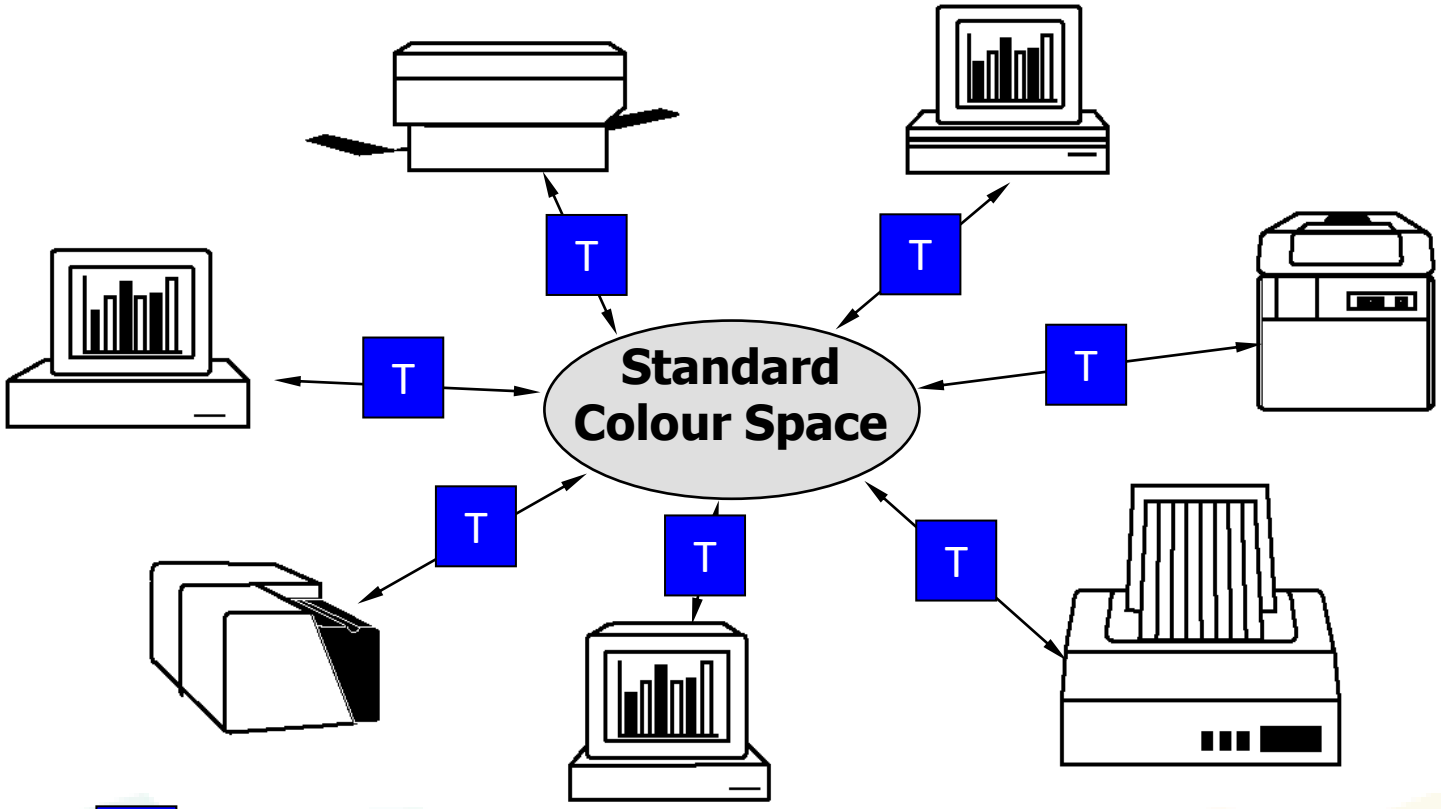
- Computers became personal – not giant boxes in refrigerated warehouses.
- Initially the production was B/W images and then digital prints of those images.
- A better typewriter, now called a word processor.
- Then someone said, if I can print black ink why can't I print yellow ink and magenta ink and cyan ink – just like the big printing presses
- Almost overnight, image reproduction devices went from B/W to a few colors to 256 color to 16.8 million colors.
- At that time, one of the largest retailers in north America, Sears Roebuck was reporting $1 000 000 annually in legitimate catalog returns, solely on the basis of the wrong color (this is about $1 850 000 today).

Review of the ICC

Formation of the ICC

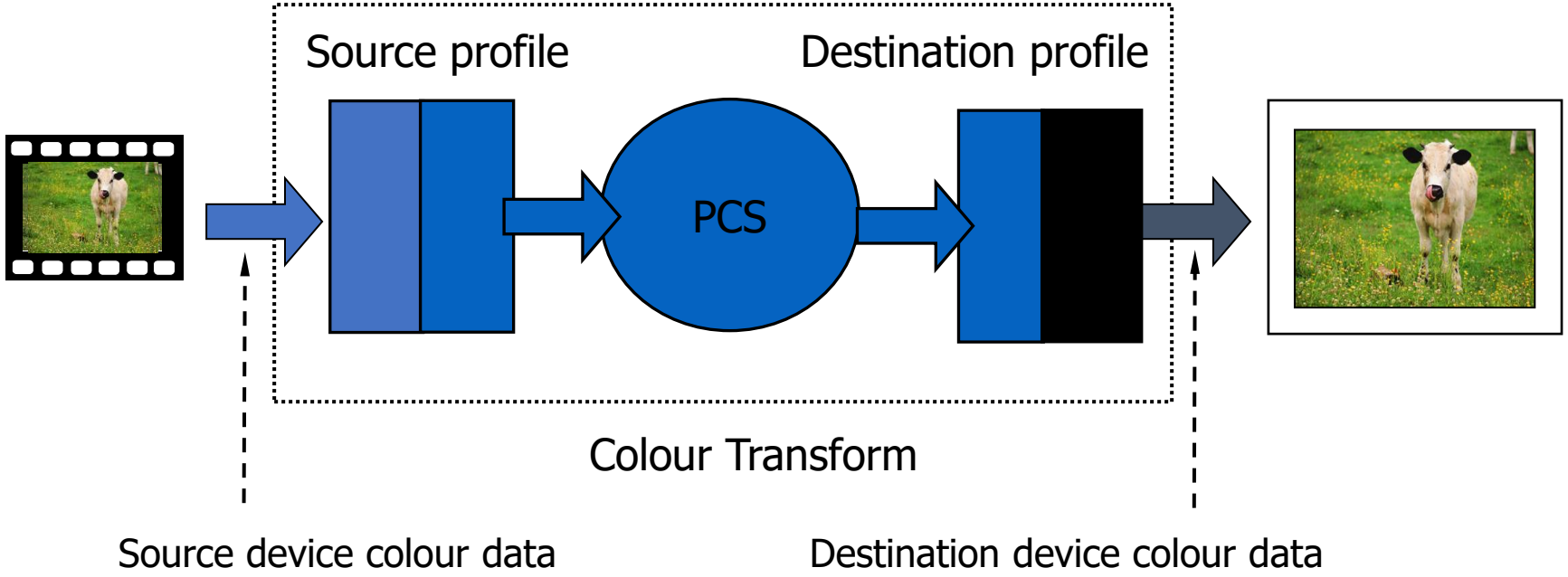
- An industry consortium
- Established in 1993 by eight industry vendors
- Now approximately 70 members
- Goals:
  - Create
  - Promote
  - Encourage
  - Evolution of an open, vendor-neutral, cross-platform color management system architecture and components

Device-Independent Color Transformation



T = each a device-to-standard colour space transform

ICC Workflow



ICC Chose CIE D50 and the CIE 1931 2° Observer

- It was claimed that color reproduction relied on gray tones and D65 made the tones appear too blue.
- It was claimed that color reproduction relied on examining small picture elements, much smaller than the 4° limit of the 1964 color-matching functions
- It was claimed that the well-known errors in the 1931 color-matching functions were too small to matter.
- The white of the background / substrate was often not equal to the D50 white point.
  - To achive a common white point, the colorimetry was then made substrate relative

ICC Max and ISO 20677

- With the publication of ISO 20677 in 2019 things changed again
  - New hardware and software capabilities allow increased freedom in color reproduction
  - Algorithms in ICCMax can allow the reproduction to quantify and reproduce not just isolated process colors but the total color appearance
- Advances in Solid State Lighting produce new effect and behaviors for reproduced and metameric colors
- Packaging printing includes images of people and scenes but also brand equity colors and attention capturing appearances
  - Metallic flakes, pearlescent pigments and even interference effects.

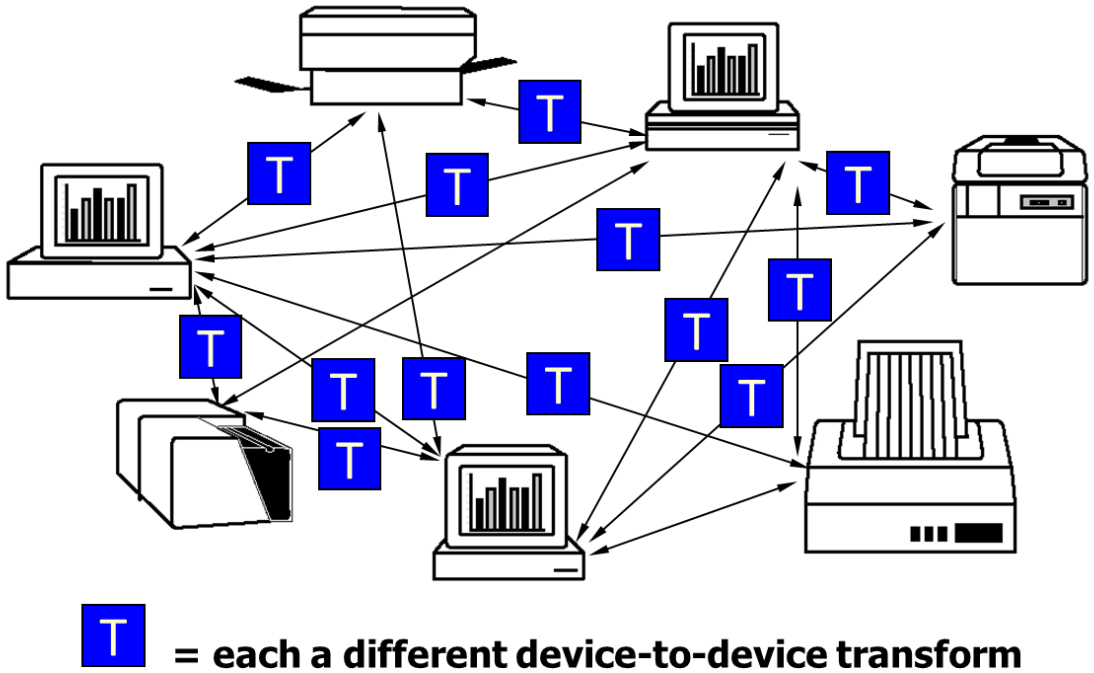
Color Management in Non-Imaging Industries

Pre-History of Color Management

- In the 1980s a lot was happening in color technology
  - CIELAB was less than a decade old and its warts were showing
  - Traditional chemical and process industries, textile dyeing, paint tinting and plastic extrusion were becoming digitized.
  - The 3rd generation of color-measurement instruments had been introduced
- The traditional industries had demonstrated that the 1931 Standard Observer was not well suited to predict the colors of the products
- Illuminant C had been replaced by D65 and CWF was being replaced by Ultralume and TL84 fluorescent lamps.
- Computerized color-matching of fabrics, consumer coatings and engineering plastics was common place.
  - Industrial and automotive coatings needed 1 more decade to be equivalent

The Old Color Industry Responded

- The fabric, coatings and platics industry responded.
  - Digital examples of materials were mapped onto imaging media.
  - Color was moved to point of sale
  - What held back this progress was the need for every device to be uniquely mapped to every other device.



The Formation of the ICC in 1993 Held Great Hope

- Unfortunately – the hope of the traditional product producers was not fulfilled.
- Being dominated by the photographic image reproduction industry was not good for them
  - The image reproductions were based on handheld densitometers or at the very least small desktop transmission densitometers
  - Traditional color was based on integrating spheres, introduced in 1931 by Arthur Hardy at MIT.
  - Traditional color went through its 16 point spectral phase in the late 1960s and early 1970s.
  - More importantly, the textile and coatings industries had selected, some years earlier, the use of CIE D65 and the CIE 1964 10° color-matching functions (Standard Observer)

Technological Gap Between Imaging & Non-Imaging

- Digital colored image reproduction focused on CIE D50/2°
- Digital colored material reproduction focused on CIE D65/10°
- Digital image reproduction used small, portable instruments reading test targets
- Digital material reproduction used larger, benchtop instruments, reading swatches
- Digital image reproduction used 0° : 45° measurements
- Digital material reproduction used di : 8° measurements
- What can be done to resolve this disconnect?

Documentary Standards

The CIE and the ISO Have New Documents on Measurements

- CIE Documents on Colorimetry and Measurements
  - Publication 176:2006 Geometric Tolerances for Colour Measurements
  - Publication 15:2018 Colorimetry, 4th Edition
- CIE Technical Committees on Colorimetry and Metrology
  - 1-91: Methods for evaluating the colour quality of white-light sources
  - 1-96: A comprehensive model of volour vision
  - 1-98: A roadmap toward basing CIE colorimetry on cone fundamentals
  - 2-80: Spectroradiometric measurement of light sources
  - 2-90: LED reference spectrum for photometer calibration
  - 2-94: Measurement of total transmittance, diffuse transmittance and transmittance haze
  - 8-17: Methods for evaluating colour difference between 3D colour objects
  - JTC 17 (D1/D2/D8): Gloss measurement and gloss perception: A framework for the definition and standardization of visual cues to gloss

The CIE and the ISO Have New Documents on Measurements

- ISO Documents on Color Measurement
  - ISO 3664: Viewing conditions — Graphic technology and photography
  - ISO 13655:2017 Graphic technology — Spectral measurement and colorimetric computation for graphic arts images
  - ISO 15397:2014 Graphic technology — Communication of graphic paper properties
  - ISO/WD 24585 Multispectral measurement and colorimetric computation for graphic arts and industrial applications
  - ISO 20677:2019 Image technology colour management — Extensions to architecture, profile format and data structure
  - ISO/TS 23031:2020 Graphic technology — Assessment and validation of the performance of spectrocolorimeters and spectrodensitometers
  - ISO 23498:2020 Graphic technology — Visual opacity of printed white ink

Conclusions

What will Color Management in the 21st Century Be?

- There will be more pressure on color management to be applied to viewing conditions other than D50
  - Traditional industries have used D65 since its first introduction
  - New LED sources will push out fluorescent lamps, including those in color management booths, and incandescent lamps in home and store use.
  - The new CIE observer functions based on cone fundamentals are already being tested in industrial applications and have shown an improvement in handling metamerism.
    - Judd reported in 1951 that the 2° CIE color-matching functions were deficient at all wavelengths below 460nm.
      - But the problem turned out to be not the CMF data but the V_λ data upon which the CMF data are normalized.
    - The Color Management program will need to be able to accommodate various multiple observer functions.

What will Color Management in the 21st Century Be?

- Multi-spectral imaging brings on new challenges.
  - ISO TC 130 has started a project on this. The CIE and ISO 13655 are in agreement on the requirements for geometric and spectrometric instruments for color measurement
  - The next generation of color-management tools will need to provide the ability to correlate and transform by deconvolution the measurement data from one instrument to another.
    - It will no long be acceptable to push off this problem onto the end user, forcing them to purchase one specific model of instrument for each client.
  - The next generation of color-management tools will need to provide the ability to communicate brand colors and special effect materials used in packaging printing.
    - This will include metallic appearance, colored ink over metallic substrates, polychromatics (absorption pigments blended with metallic or pearlescent pigments)
    - It is unlikely that this will require goniocolorimetry but that is always a possibility.
    - X-Rite has already extended the ISO standard CxF to include spectral image data.

What will Color Management in the 21st Century Be?

- Color management in the 21st century will need to be smarter and easier to implement on new substrates.
  - HDPE, LDPE, LLDPE, EPE (pearl)
  - EVOH
  - PET, MPET,
  - OPP / BOPP / CPP
  - PVDC
- These are all clear or translucent plastic films.
  - The CMM should be able to accommodate for the minor variations in color reproduction across such substrates.
  - OBA correction should become less of an issue as the Imura method is expanded to the new illuminants and sources.
- ISO 20677:2019 Image technology colour management — Extensions to architecture, profile format and data structure
  - Color management needs to adopt the material transforms and other advanced control methods in this latest standard – making it easier to be adopted.

Imaging and Non-Imaging Color Management