International Color Consortium

Fundamentals of ICC Color Management

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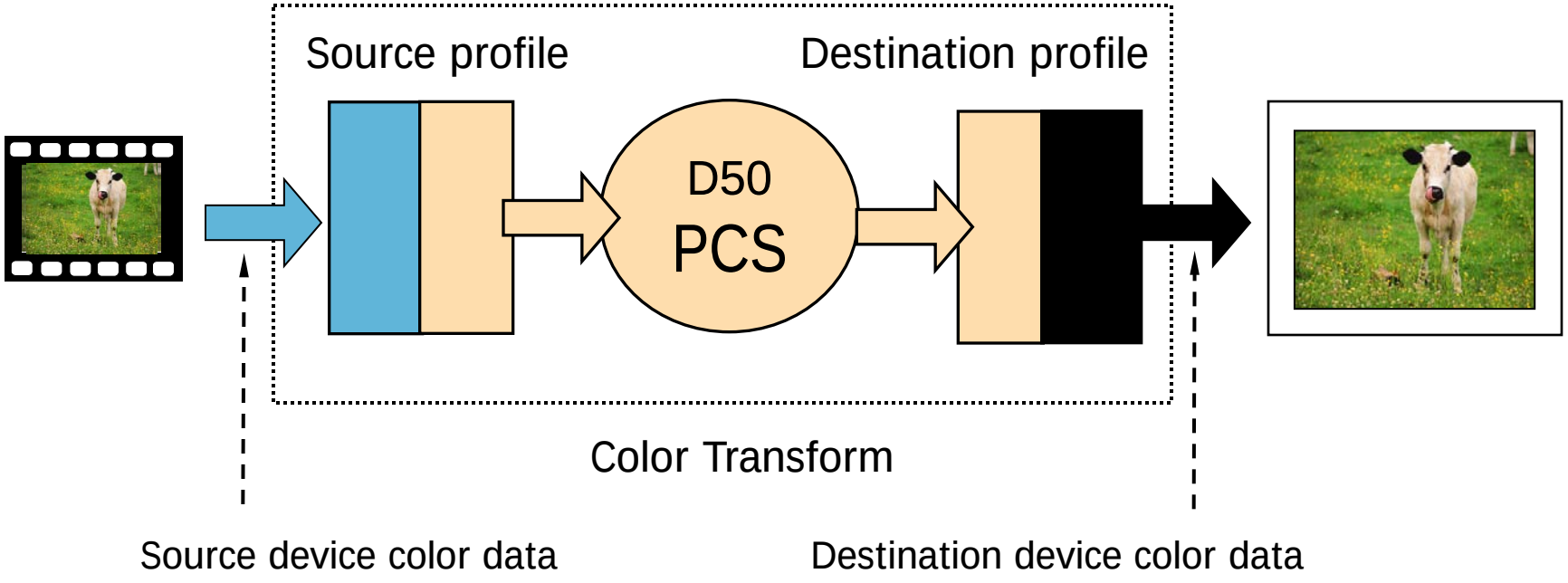
Agenda

- Goals of Color Management
- Color Management Workflows
- Value of ICC
- How Does ICC Work?
- Current and Future ICC Work

ICC Color Management

- **In ICC color management, profiles are used to transform between source and destination color encodings.**
- **Combining chains of profile transformations completes the color management workflow.**



Goals of Colour Management

1. **Proof or copy colour.**
2. **Render impression of colour.**

Color Management Workflows

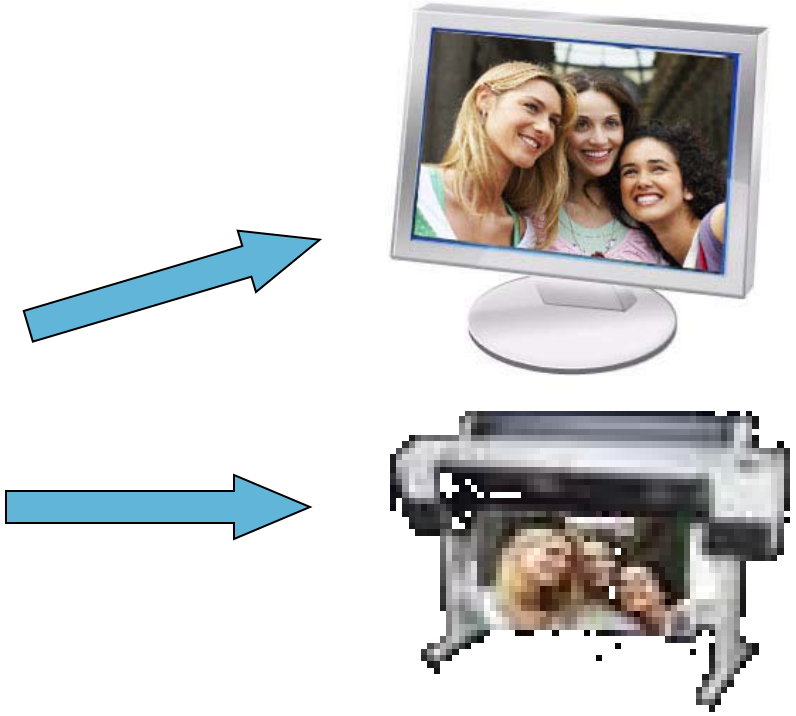
- **Many different types of color management workflow:**
  - Camera to Print
  - Repurpose/Retarget Print
  - Multi-Device Standardization

- **ICC color management workflows built by combining chains of ICC profile transforms together.**

- **Understanding workflows helps understanding of proper use of ICC color management.**

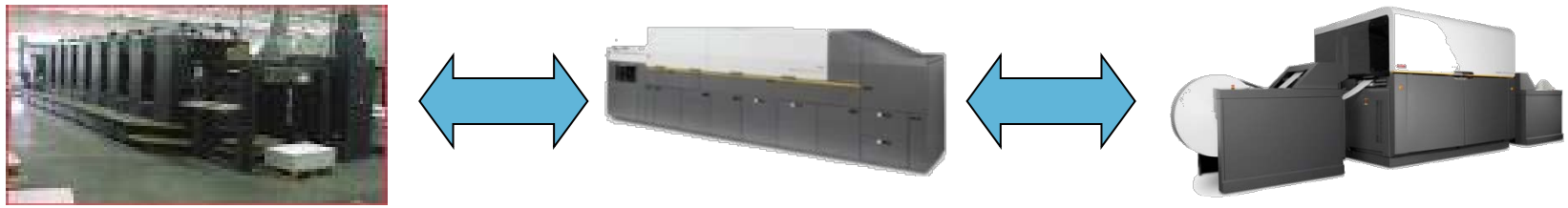
Camera to Print

- **Typically, much dynamic compression takes place, so rendering involves some art.**
- **ICC color management encodes rendering.**



Repurpose/Retarget Print

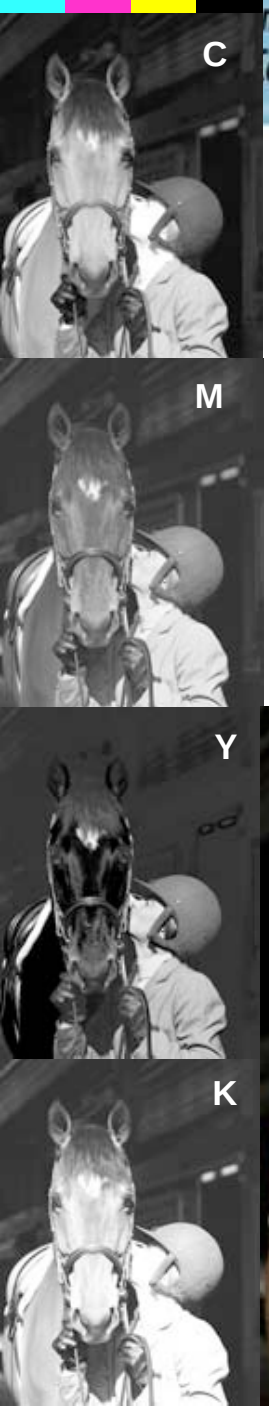
- **Given:**
  - Images and graphics already separated for final device space of a device (for example, offset press).
- **Then:**
  - Use ICC color management to convert color to output to another device.
    - Hybrid digital + offset print
    - Monitor viewing
  - If needed, constrain ICC transform with smart CMM (**Reseparation**)



Applying GCR with ICC

- **GCR is a re-separation of a file that replaces chromatic colors (CMY) with an achromatic color (K)**

Before Ink Optimizing Solution applied



After with Ink Optimizing Solution applied

Multi-Device Standardization

- **Many devices, all similar.**
  - Multiple presses or proofers, each with different natural printing point.
  - Set each device to individual most stable printing point.
  - Use ICC color management to adjust for small differences among presses:
    - Print to standard (ISO 15339, GRACoL, FOGRA)
    - Print to common point (more applicable for proofers)

ICC architecture and the role of the CMM

What is a profile?

—An ICC profile is a carrier of a colour transform plus information about the intended use of the transform.

—Profile is in binary form (can be read as hex) and includes numeric and textual data

—Profile consists of header and ‘tags’ – each tag has a format defined in specification

—All numeric data is encoded using specified data types

ICC architecture and the role of the CMM

- **What is a profile?**
  - A profile can be thought of as a ‘method’ to be applied to data.
  - A transform method can be ‘encapsulated’ with a given set of data (e.g. embedded in an image) or can be free-standing
- **What is a profile not?**
  - A profile cannot itself select the transform to use for a given workflow or data – this is done by the CMM
  - A profile as defined today cannot apply conditional operations depending (e.g.) on image content
- **Examples of things that cannot be done by a profile:**
  - Conditional rendering intent selection
  - Spatial operations
  - Variable transforms
  - Channel preservation

What are the basic characteristics of ICC specification versions?

- **ICC v2**
  - Fixed transform, all choices ‘baked in’ to profile
  - Data encodings poorly connected (gamut, chromatic adaptation to D50 PCS)
- **ICC v4**
  - Also fixed transform
  - Better connected (PRMG, chad)
  - Interoperable with v2
- **iccLabs (in development)**
  - Support for smart, dynamic and programmable CMM operations including spectral processing, rendering and gamut operations, use of standard encodings
  - V5 features mostly not interoperable with v4, but built on top of v4:
  - V5 CMMs are intended to be backwards-compatible with v2 and v4.

Some future colour management workflow requirements

- **Content-dependent transforms**
  E.g.
  — Local appearance-based transforms
  — Depend on semantic content of original (e.g. image vs graphic or text)
- **Spectral transforms**
- **More complex transforms**
  — cannot be encoded in existing profile classes
- **Minimal transforms**
  — where the profile defines only the colour encoding, and leaves the CMM to select the transform)
- **Automated profile selection and use**

What can ICC do to address these requirements?

1. Enhance functionality of existing transforms in profile specification
2. Provide a framework for encoding of metadata that can be used for transform selection and implementation by CMM
3. Extend the precision and range of data types
4. Extend the PCS definition, especially to support spectral data and transforms, and alternate (non-D50) illuminants and observers
5. Provide a reference implementation of new features
6. Provide guidance to users on the implementation of these features>

What progress was made in v4 towards these goals?

- **Clarification of the requirement for chromatic adaptation of all colorimetry to D50 PCS**
- **Adoption of common reference gamut for Perceptual intent (PRMG)**
- **Clarification of over-range white (PCS Y = 200) in specification**
- **Addition of Multi-Process Elements (MPE) and DToBx transform tags to specification**
  - Allowing different combinations of curve, matrix and LUT
- **Addition of unbounded floating-point data in DToBx tags**
- **Addition of metadata tag**

ICC-Labs key features

- **Support for alternate illuminants and viewers for PCS connection**
- **Support spectral communication of color information through an optional spectral PCS (reflectance, emission, fluorescence)**
  - Spectral data, Bi-spectral (fluorescence)
  - BRDF support
  - Specification of Illuminant and observer in spectral viewing conditions tag
- **Extendable encoding of Named Colors**
  - Support for tints, spectral information etc
  - Using hierarchical data encoding (tag arrays and tag structures)
- **Extended MultiProcessing Elements for greater flexibility and simpler encoding of transforms**
- **Placeholder profiles**
- **Direct encoding of Gamut Boundary**
- **Support for including CxF data**

ICC-Labs Profile Connection Spaces

- **Types of connection color spaces can be defined in header**
  - Colorimetric (XYZ/Lab/CAM) PCS
  - Spectral Reflectance/Transmission PCS
  - Spectral Emission PCS
  - Bi-Spectral PCS (supports Fluorescence)
- **Colorimetric PCS associated with A2Bx/B2Ax tags,**
- **Spectral PCS's associated with D2Bx/B2Dx tags**
  - Colorimetric only , "spectral" only, or both can be present in profile
  - Both colorimetric and spectral can be defined using the MPE tag type
- **Meaningful connections between spectral PCS and data encoding are still to be identified and operations defined**

Requirements for spectral reproduction

i. Encoding spectral data from the source and achieving a close match to these in the reproduction

ii. Encoding spectral data from the source and converting these to trichromatic data that will result in a metameric match under a chosen illumination

iii. Encoding three-component (RGB) data from the source, estimating reflectances from the three-component data and matching these in the reproduction

iv. Encoding three-component (RGB) data from the source, converting these to scene colorimetry and estimating reflectances that will result in a metameric match under a given illumination.

Spectral PCS

Requirements for spectral reproduction

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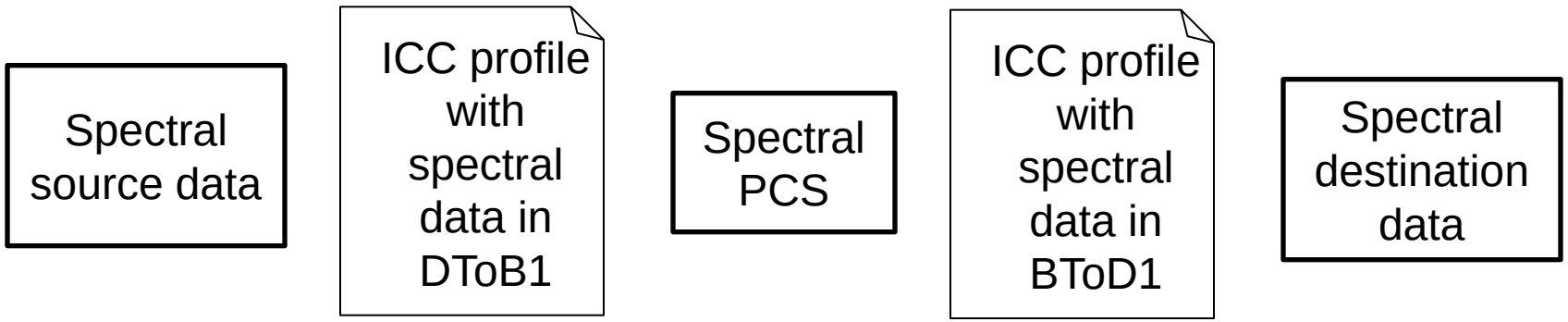

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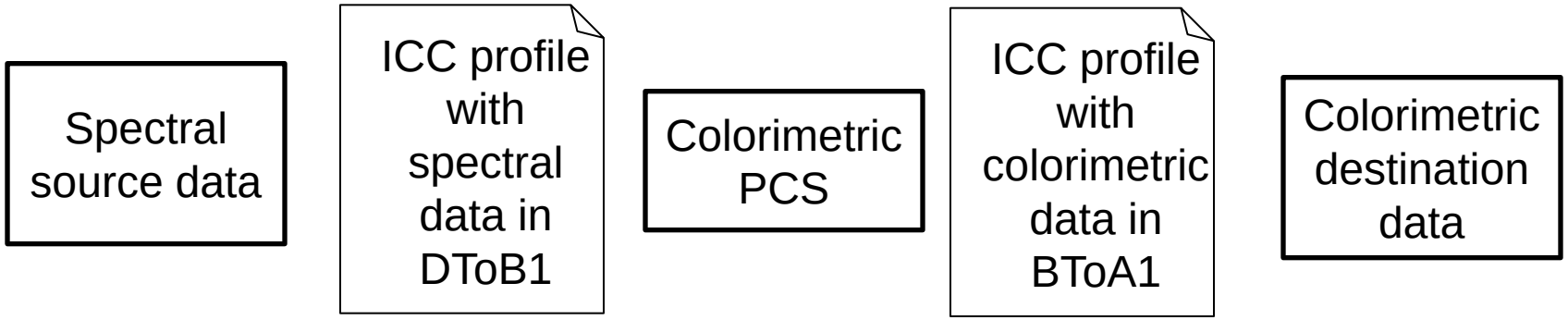

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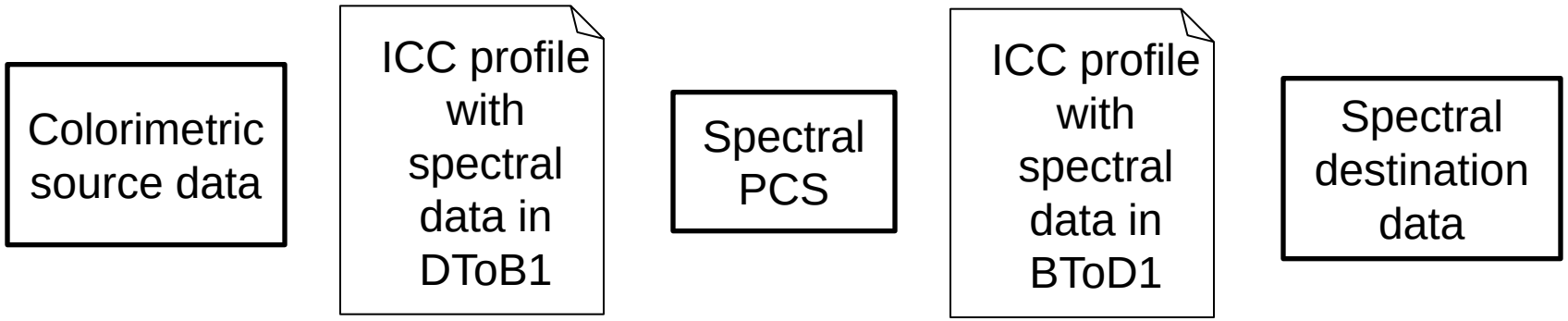

Requirements for spectral reproduction

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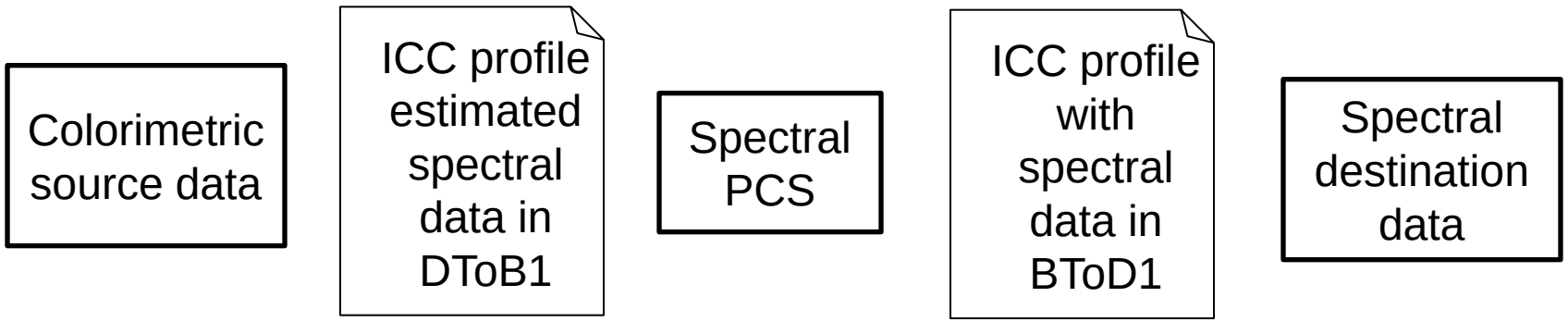

Estimate of spectral reflectances can be carried out by profile or by smart CMM

This workflow allows different illumination conditions to be specified at the output side

Previously Extended MultiProcessingElements functionality

- **singleCurveSegment type for segmented curves**
  - Defines a single sampled curve segment with simple endpoint extension
  - Curve can be defined using uInt8, uInt16, float16, and float32 number arrays
- **ExtendedCLUT element type**
  - Allows CLUT to be defined using uInt8Number, uInt16Number, float16Number, and float32Number types
  - Interpolation hint can be provided
- **Calculator element type**
  - Functionally extendable replacement for Lut tags

ICC Labs implementation support

- **Icc v4 adoption was slow because ICC failed to provide a reference CMM or example profiles**
- **New open source project “ReflccLabs” based on SampleICC**
  - Extended icProfileHeader.h
  - Added new profile class
  - Added new data types
  - Added new Tag Types
  - Added new Tags
  - Additional MultiProcessingElements functionality
  - Added support (in parallel) for above in included IccXML based utilities
- **Able to read/write/verify profiles as both XML and binary ICC profiles**

SampleICC and RefIcc

- SampleIcc and RefIcc are open-source projects maintained on SourceForge
- SampleIcc and RefIcc projects are led by Max Derhak, chair of the ICC Architecture Working Group
- ICC does not distribute or support SampleIcc and RefIcc
- Status of SampleIcc and RefIcc discussed at every ICC meeting
- Contributions to RefIcc and SampleIcc come mainly from ICC members, others are welcome to participate
- SampleIcc and RefIcc are distributed under GNU license terms

ICC Labs current status

- **Profile specification proposals have been drafted; most still to be finalised**
- **RefIcc labs allows prototyping, implementation and evaluation of current proposals**
- **When individual proposals have been finalised, a v5 specification will be balloted**

Potential adoption issues

- **Many ICC Labs features are complex (relative to v4)**
- **Based on experience with v4, adoption is likely to be slow**
- **Anticipated that functionality available will depend on workflow requirements**
  - greater diversification at level of CMMs, RIPs, applications, profile generators etc
- **Results more likely to be implementation-dependent**

Other areas of current ICC development

- Spot colours (measurement, overprint prediction)
- Colour management in medical imaging
- Scene-referred digital photography
- Colour management in video and motion picture
- Profile metadata for automated selection
- Profile assessment using image quality metrics
- Colour management of displays (transform methods, communication of display status)
- Reference data colour space encodings