ICC Colour Management

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ICC Colour Management

- What is the ICC?
- Why Colour Management?
- ICC Profiles and the PCS
- Future Directions of the ICC

The International Color Consortium (ICC)

- An industry consortium
- Established in 1993 by eight industry vendors
- Now approximately 70 members
- Goal: Create, promote and encourage evolution of an open, vendor-neutral, cross-platform colour management system architecture and components

ICC Membership

- Founders:
  - Adobe Systems Incorporated
  - Agfa-Gevaert N.V.
  - Apple Computer, Inc.
  - Eastman Kodak Company
  - FOGRA-Institute (Honorary)
  - Microsoft Corporation
  - Silicon Graphics Inc.
  - Sun Microsystems, Inc.
  - Taligent, Inc.

ICC Membership

- Founding members comprise the ICC Steering Committee together with an additional eight members.
- Currently approximately 70 members from all areas of the imaging and computer industry.

The ICC Profile

- ICC develops and promotes a standard colour profile specification (ICC Profile).
- Available as PDF at

  www.color.org
- The current version of the ICC Profile Specification is 4.0.
  - ICC.1:2001-12

The Heritage

- Several profile-like formats appeared in early 1990s
  - Kodak (Precision Transforms)
  - Apple (ColorSync)
  - EFI (EFI Color)
  - Adobe (PostScript CSA/CRD, PDF CalRGB)
- ICC's profile specification based on the Apple ColorSync profile format

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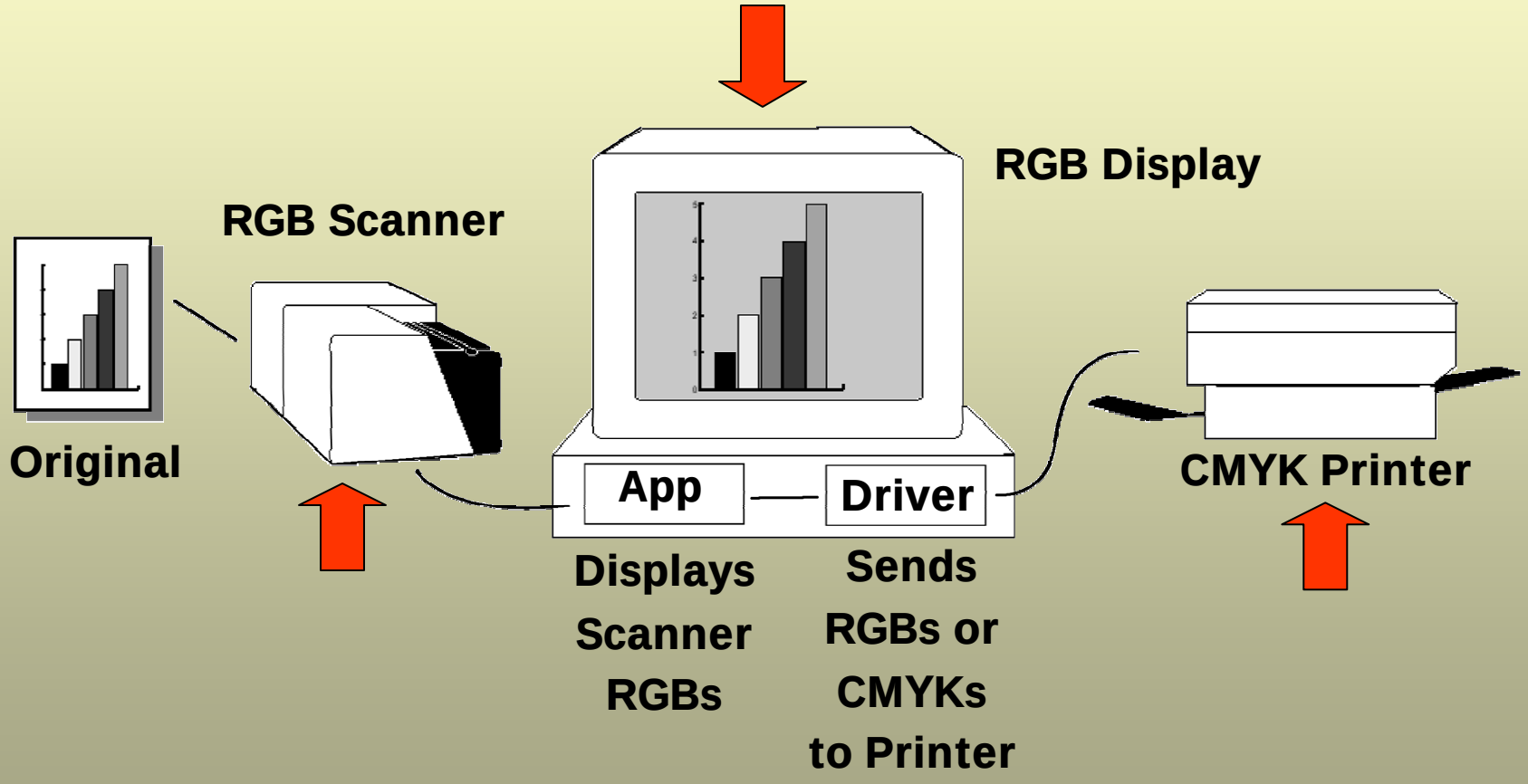
"Colour" Workflow



Everyday problems...

- *The same document looks different when*
  - printed on different printers
  - viewed on different monitors
  - printed on a printer and viewed on a monitor
  - viewed in a light booth and under office lighting

Why ?

- Devices, drivers, operating systems, and applications can all interpret and reproduce colours differently.
- Input --
  Scanners, digital cameras often have different spectral responses
- Output --
  Printing: offset, gravure, inkjet, laser
  Display: CRT, LCD, PMP, DMD, video projectors…

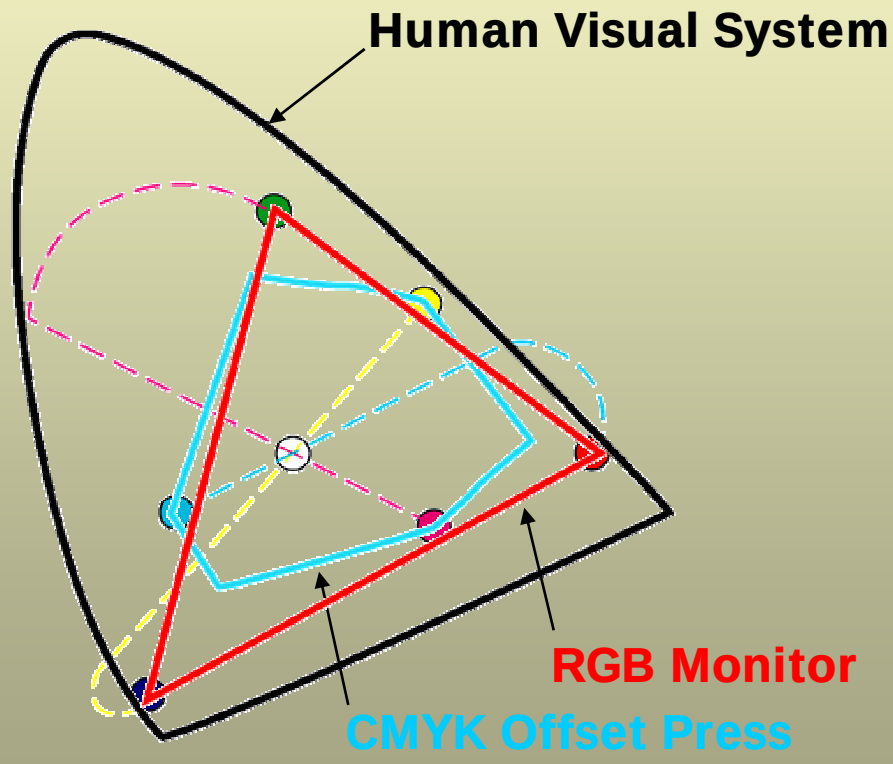
Device Colour Gamuts

- Gamut = range of realisable colours.
- A colour gamut for a device depends on the device, media and viewing conditions:
  - e.g. dynamic range and separation quality for input, or ink and substrate for printers.
  - chromaticity and illumination level of the illuminant, and colour and luminance of the surround, for viewing the image.
- A gamut can be visualised as a plane or volume in a standard colour space

Offset Press vs. Monitor Gamuts

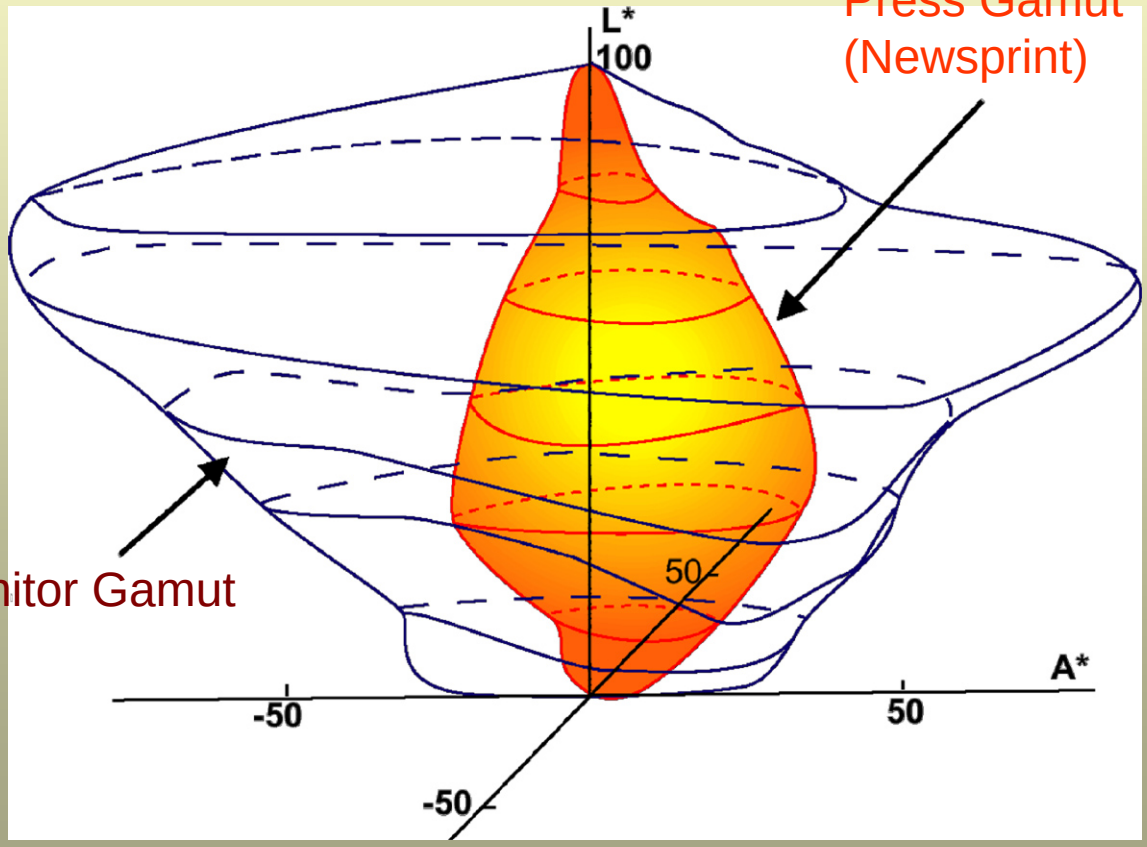
- CIE x,y chromaticity diagram of an offset press and monitor gamut.
- Can be misleading.

Note that:
Red is not 1 - Cyan
Green is not 1 - Magenta
Blue is not 1 - Yellow



Offset Press vs. Monitor Gamuts

- Gamuts should be represented as volumes.
- Monitor and press gamuts in CIELAB space.



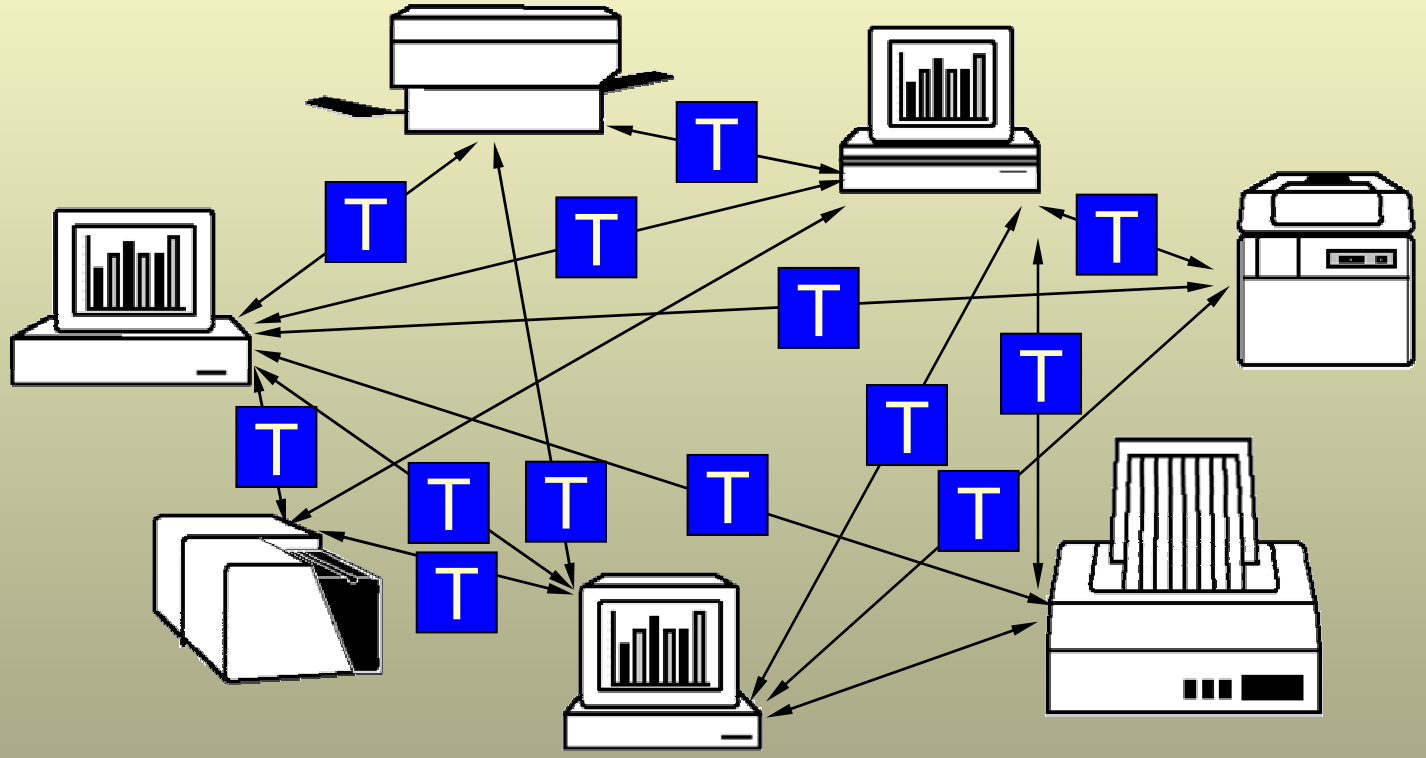
What's the solution?

- A transform is needed to map the colours from one (source) device colour space to another (destination) device colour space.
  - The transform must account for the colour characteristics of both source and destination devices as well as the viewing condition.

Two transformation approaches

- Device-dependent colour transformation
- Device-independent colour transformation

Device-dependent Colour Transformations



T = each a different device-to-device transform

Device-dependent Colour Transformations

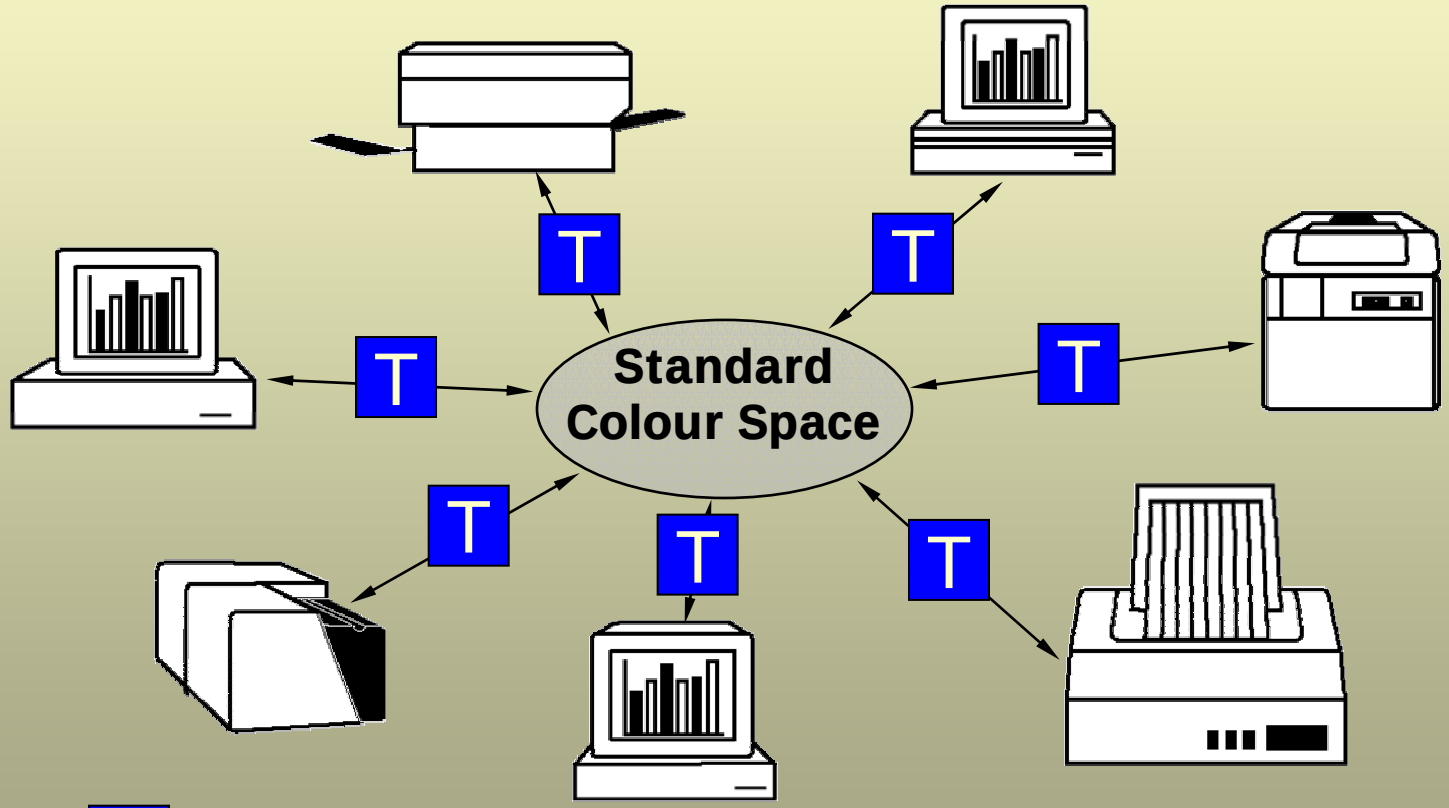
- Primarily used in high-end proprietary systems.
- Dedicated, pair-wise transformation from source to destination.
- Transformations have both source and destination information (gamut, viewing conditions).
- Can be optimised for a device pair.

Device-dependent Colour Transformations

Disadvantages:

- For a system of *n* devices, n^2 transforms are needed.
- Adding a device requires *n* new colour transforms.
- Re-calibrating a device requires *n* new colour transforms.

Device-independent Colour Transformation



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

Device-independent Colour Transformation

- For each device, there is a transformation from device to standard colour space.
- Transformations have source-to-standard colour space or destination-to-standard colour space information.

Device-independent Colour Transformation

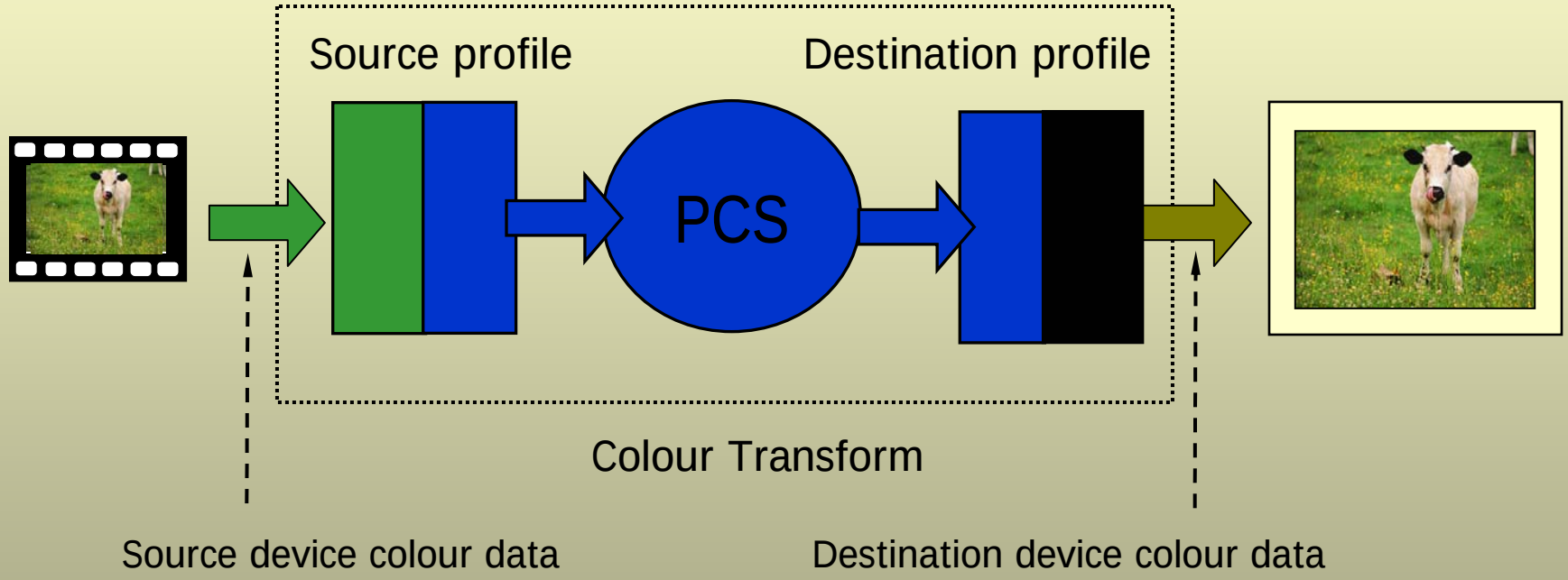
Advantages:

- For a system of *n* devices, *n* transforms are needed.
- Adding a new device requires *only one* new colour transform.
- Re-calibrating a device requires *only one* new colour transform.

ICC Workflow

- The transforms from device to standard colour space are embedded in the ICC profile.
- The standard colour space is called PCS (profile connection space).

ICC Workflow



ICC Colour Management

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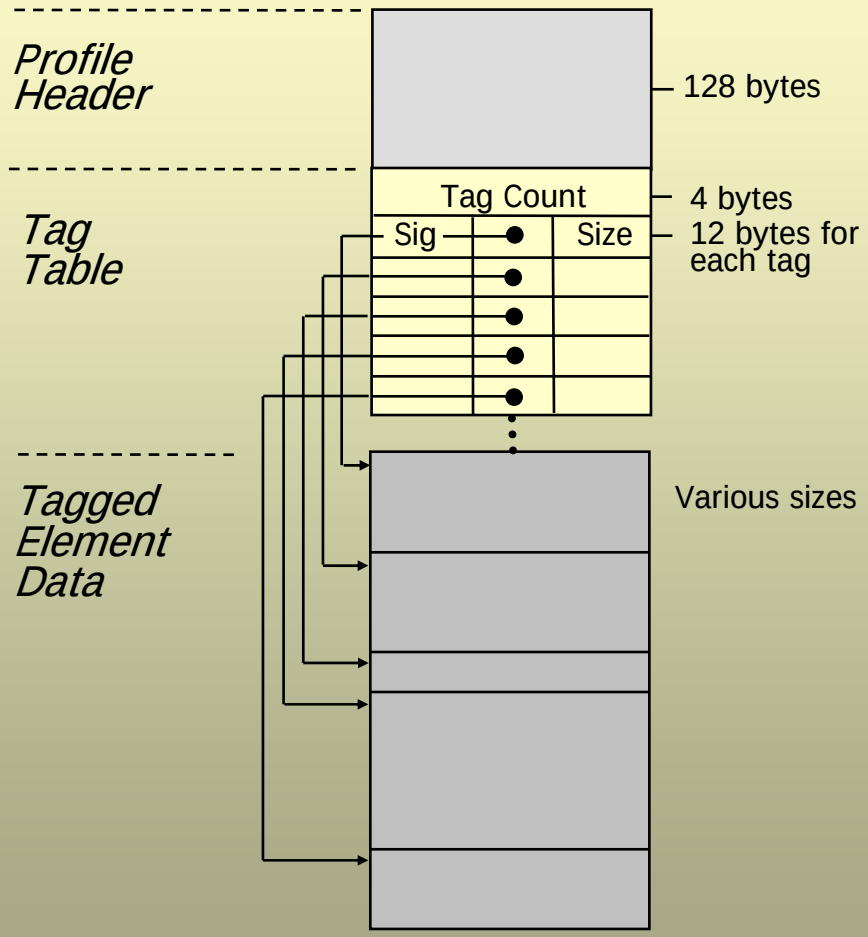
The ICC Profile

- The ICC profile contains the transforms from "device" to PCS.
- There are several kinds of profiles:
  - *Input device* (scanner, digital camera, etc.)
  - *Output device* (printers, film recorders, etc.)
  - *Display* (CRTs, LCDs, projectors, etc.)
  - *Device Link* (dedicated device-to-device)
  - *Colour space* (sRGB, CIE XYZ, L*a*b*, etc.)
  - *Abstract* (effects, PCS-to-PCS, etc.)
  - *Named Colour* (Pantone®, Truematch®, etc.)

ICC Profile Format

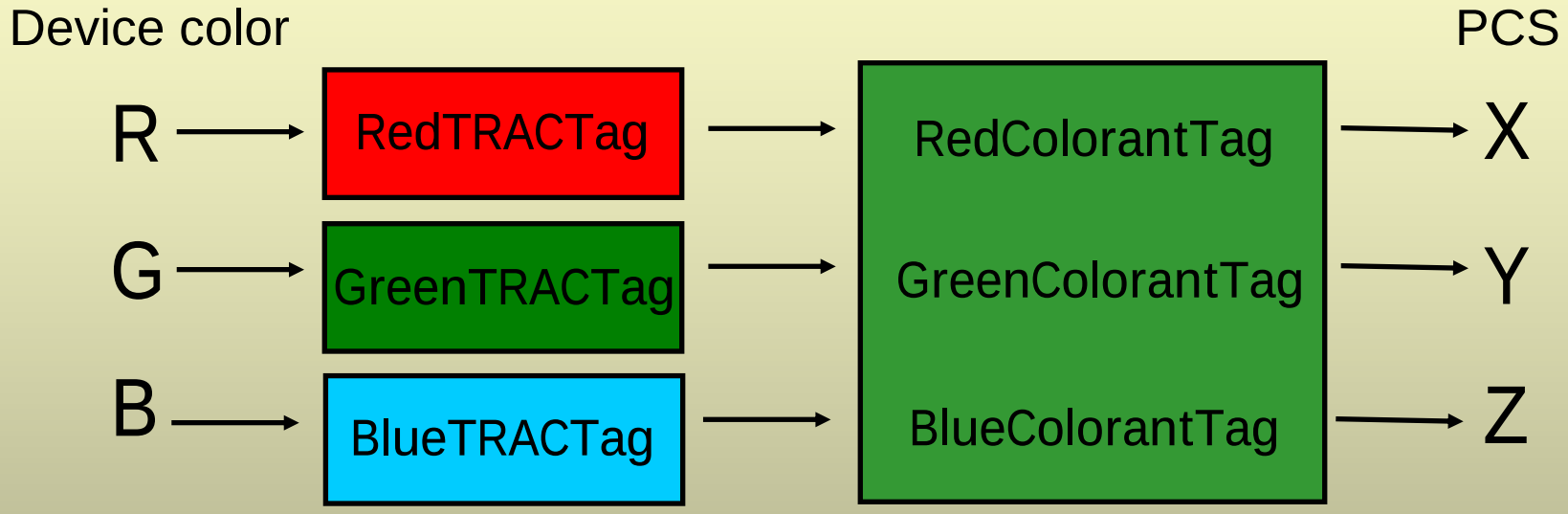


- 128 byte header
- Tag-based (like TIFF)
- Public required tags
- Public optional tags
- Private tags

ICC Profile Models

- Shaper/matrix profiles are used for RGB and single channel (grayscale) input and display profiles.
- Shaper/multi-functional-table (MFT) profiles are used for complex RGB and CMYK input, for RGB, CMYK and n-colorant output, colour space conversion, and abstract profiles.
- The construction and content of the matrices and LUTs in a profile are vendor specific, and not defined in the ICC specifications.

Shaper/matrix Processing: e.g. RGB input profile

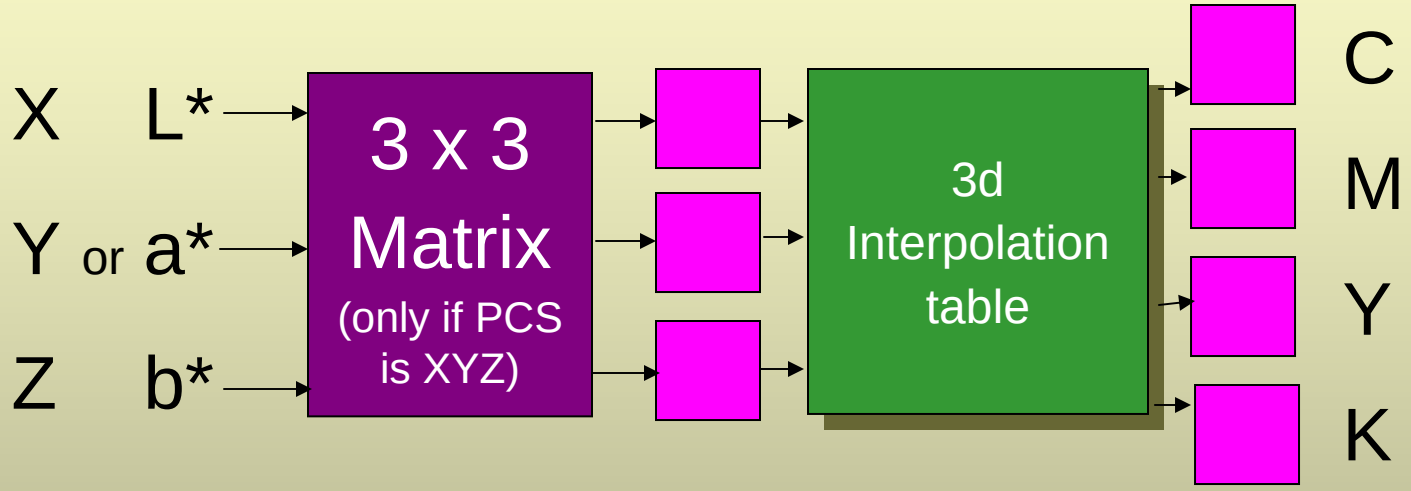


1D "shaper" LUTs (gamma tables) for linearization.

3x3 matrix, includes source to PCS white point scaling.

- *Invertible profile for simple RGB and grayscale devices*

Shaper/MFT Processing: e.g. CMYK output profile

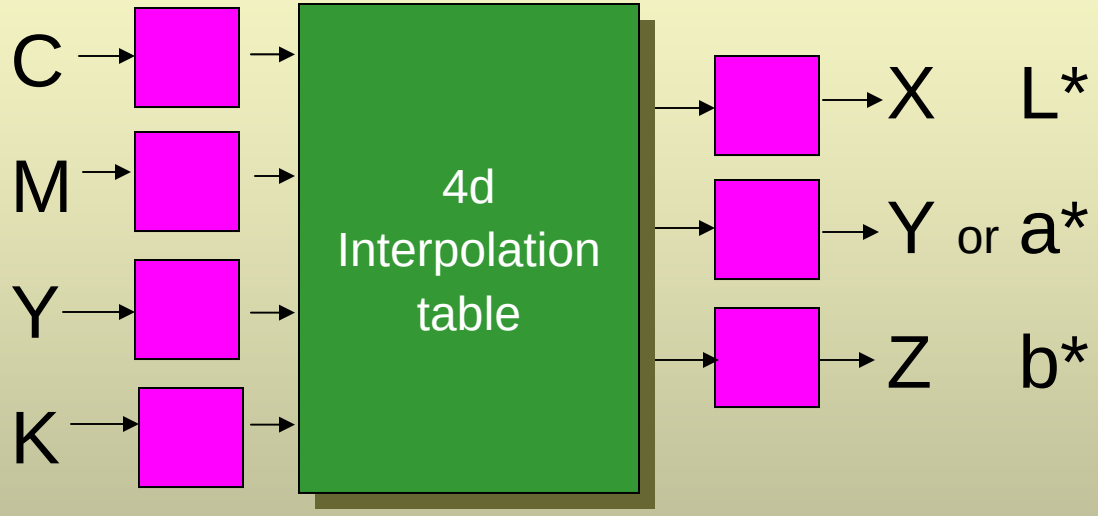


PCS to Device

BToAnTag (n=0, 1, 2 depending upon the rendering intent specified)

- *Non-invertible profile for complex RGB, CMYK and n-colorant devices*

Shaper/MFT Processing: e.g. CMYK input profile



Device to PCS

AToBnTag (n=0, 1, 2 depending upon the rendering intent specified)

- *Non-invertible profile for converting CMYK data to PCS*

Four Rendering Intents

- Relative colorimetric
  - the white point of the actual medium is mapped to the white point of the reference illuminant (i.e. L*a*b* = 100, 0, 0 for the medium). The colours map accordingly.
- Absolute colorimetric
  - the white-point of the illuminant maps to the white point of the reference illuminant (i.e. L*a*b* = 100, 0, 0 for D50). The colours map accordingly.
- Note: Both may allow for chromatic adaptation.

Four Rendering Intents

- Perceptual
  - the full gamut of the image is compressed or expanded to fill the gamut of the destination device. Grey balance is usually preserved, but colorimetric accuracy might not be.
- Saturation
  - the saturation of the pixels in the image is preserved, perhaps at the expense of accuracy in hue and lightness.

The PCS

- In the ICC workflow, the standard colour space is called the profile connection space (PCS).
- Each profile describes the transformation from source (device) space to PCS, and vice versa in case of output profiles.
- The PCS is based on a D50 illumination environment, but comes in two forms – one for the colorimetric renderings and one for the perceptual and saturation renderings.

PCS definitions

- Colorimetric renderings define black as L*a*b* = 0,0,0. White (100, 0, 0) is either the perfect diffuser (absolute) or the medium (relative).
- While the PCS is defined using D50 for all renderings, the illumination level and definition of the surround does not need to be specified for colorimetric renderings.
- Perceptual rendering requires a PCS definition which includes these.

Reference Viewing Condition and Medium

- Perceptual PCS (in v4.0 spec.) defines:
  - Viewing environment of D50 at 500 lux with a 20% reflectance surround
  - Reference medium of 89% reflectance for white and approximately 0.31% for black
- The use of a reference medium with a well defined dynamic range and viewing condition ensures less ambiguity in gamut mapping.

PCS Encoding

- The encoding to PCS can assume either:
  - CIEXYZ, relative colorimetry, D50 white point
  - CIELAB, relative colorimetry, D50 white point
- 8 and 16-bit/channel encoding is allowed.
  - Defines the output data format for input LUTs (AToBnTags) and the input data format for output LUTs (BToAnTags)
  - 16 bits only for CIEXYZ
- Matrix based profiles can only be used when the PCS encoding is in XYZ.

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ICC Today

- *The colour management architecture currently in place allows communication of colour across all applications, devices, and operating systems.*
- Currently at version 4.0 of the specification

ICC Support

- Operating System Support on Apple, Microsoft, Sun, SGI, Java.
- Support for most high-end graphic arts and photography input and output devices.
- Support in most professional graphic arts and photography applications.
- Support for many high-end consumer devices.

Registration

- The ICC registers all tags and CMMs to avoid ambiguity.
- The ICC allows vendors to register a unique signature of a device.
- The ICC has a characterisation data registry that can be accessed when building profiles for specific press or proofing conditions and three component colour spaces.

Current activity

- ICC is continually working to:
  - Clarify the profile specification to improve both understanding and inter-operability.
  - Ensure the profile specification addresses all workflows.
- Considering bringing the specification to an International Standard.
- Defining the default behaviour of a CMM.

Working Groups

- Working groups are investigating and working on recommendations and solutions for:
  - Specification editing
  - Graphic arts special interest (GASIG)
  - Architecture
  - Workflow
  - Communication
  - Profile Assessment

Specification Editing

- Responsible for maintenance of the specification
- Edits and publishes all revisions of the profile specification
- Working with ISO to develop an ISO version of the specification

Graphic Arts Special Interest Group

- Resolves colour management issues of interest to the graphic arts community. Current activities include:
  - Characterisation registries
  - A reference gamut for perceptual rendering
  - Working with the workflow group to propose solutions to user identified problems
  - CMYK to CMYK conversions that preserve black
  - Additional or modified rendering intents

Communication

- Develop and promote a message about ICC
- Produce press releases on ICC developments
- Expand ICC information on the web site
- Conduct surveys of Users to identify needs and perceptions
- Help identify obstacles to ICC implementation
- Identify and promote success stories on ICC implementations
- Produce articles for placement in publications

Architecture

- Defining the baseline behaviour required from a CMM
- Documenting the current architecture as a baseline for further work
- Investigating and proposing improvements and alternatives to the current architecture

Workflow

- Identify the most commonly used workflows
- Recommend user interfaces and effective ways for applications to use the ICC specification to satisfy those workflows
- Recommend improvements to the specification or architecture
- Identify where predictability and consistency are required in the workflow
- Make recommendations on ease of use

Profile Assessment

- Mission is to seek methods for assessing quality of ICC profiles.
  - Define a set of quality attributes for ICC profiles.
  - Identify analytical methods and metrics for defining and investigating performance of ICC profiles.
  - Recommend promising solutions to the ICC for their consideration.
  - Short term goal is to develop evaluation methods for use within the ICC
  - Longer term goal is to offer suggestions to users for evaluation

Challenges for ICC

- Vendors are confused
  - The specification is often misinterpreted which results in poor interoperability
- Users are confused
  - Surveys reveal that users are very confused about ICC's role in colour management, and its scope and capabilities
- Lack of time
  - All ICC representatives have another "day job", not enough time for ICC work

Challenges for ICC

- Existing central hub model questioned
  - Not optimal for device to device.
  - Current PCS not optimum for all applications.
  - Smart CMMs needed?
- Graphic Arts issues
  - Maintaining K level for CMYK files
  - Profile quality validation requested
  - Perceptual rendering - needs definition and better gamut?
  - Workflow and consistency issues

Challenges for ICC

- Competing standards, approaches
  - Standard colour encoding spaces
    - New sRGB draft
    - Extended gamut colour spaces (e.g. ROMM, bg-RGB, etc)
  - XML, CIP4, JDF or PDF/X for colour metadata
    - may work well with ICC profiles, but not favoured by some ICC members

Summary

- The ICC has achieved its initial goal: a colour management architecture that allows for the communication of colour across devices, applications, and operating systems.
- In the future, the architecture will be broadened to fit additional colour workflows, and specifications tightened further to improve interoperability.

Summary

- Joining the ICC enables you to participate and influence future colour management architectures for any colour image and document work flow!

How to contact the ICC

- www.color.org
- Chairman: Craig Revie
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  - Voice: +1.703.264.7200
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