

# The ICC Approach to Colour Management

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# Outline

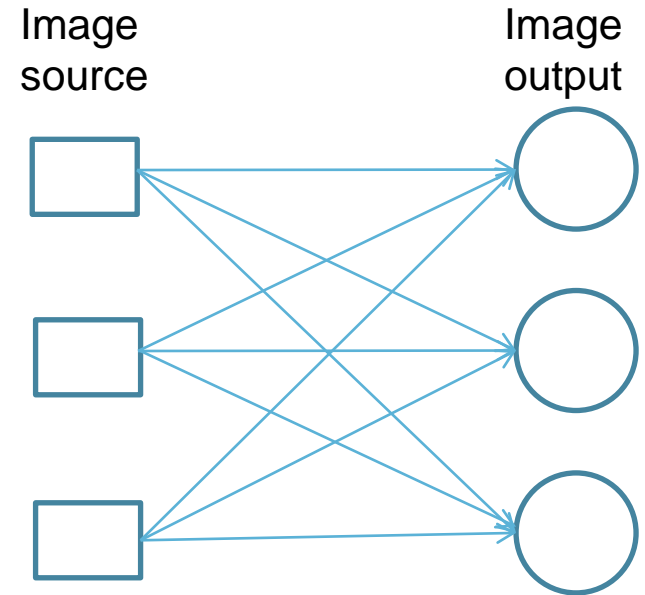
- **Why colour management?**
- **ICC workflow**
- **Implementation**
- **The Profile Connection Space**
- **Rendering intents**
- **Markets**
- **Support for the ICC format and architecture**
- **Limitations of the current specification**

# Why Colour Management?



# Why Colour Management

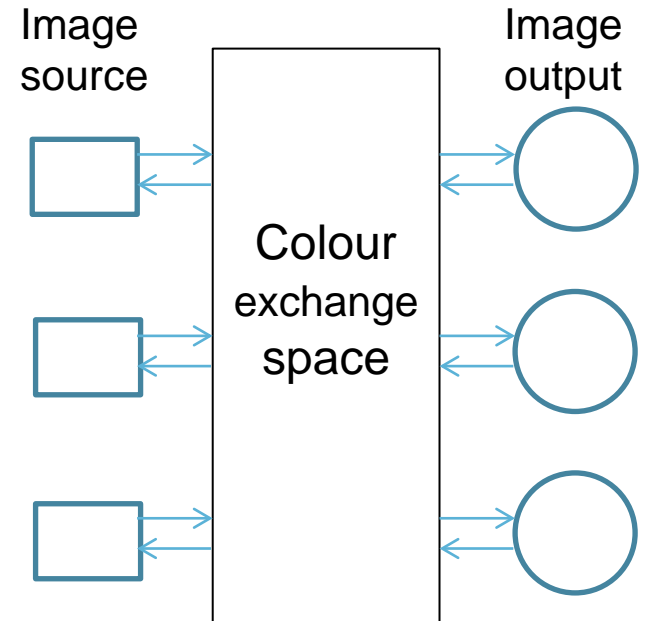
- **Goal of Colour Management**
  - Reliable, predictable reproduction of colour
  - “Seamless” colour across devices and documents
- **Reality: Output is device- and media-dependent**
  - The same device code values produce different colours
  - Gamuts are different
  - Colour appearance is unreliable
  - Code values must be adjusted to match appearance



No colour management:  
many-to-many transforms

# Why Colour Management

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With colour management:  
one transform per device

# International Color Consortium

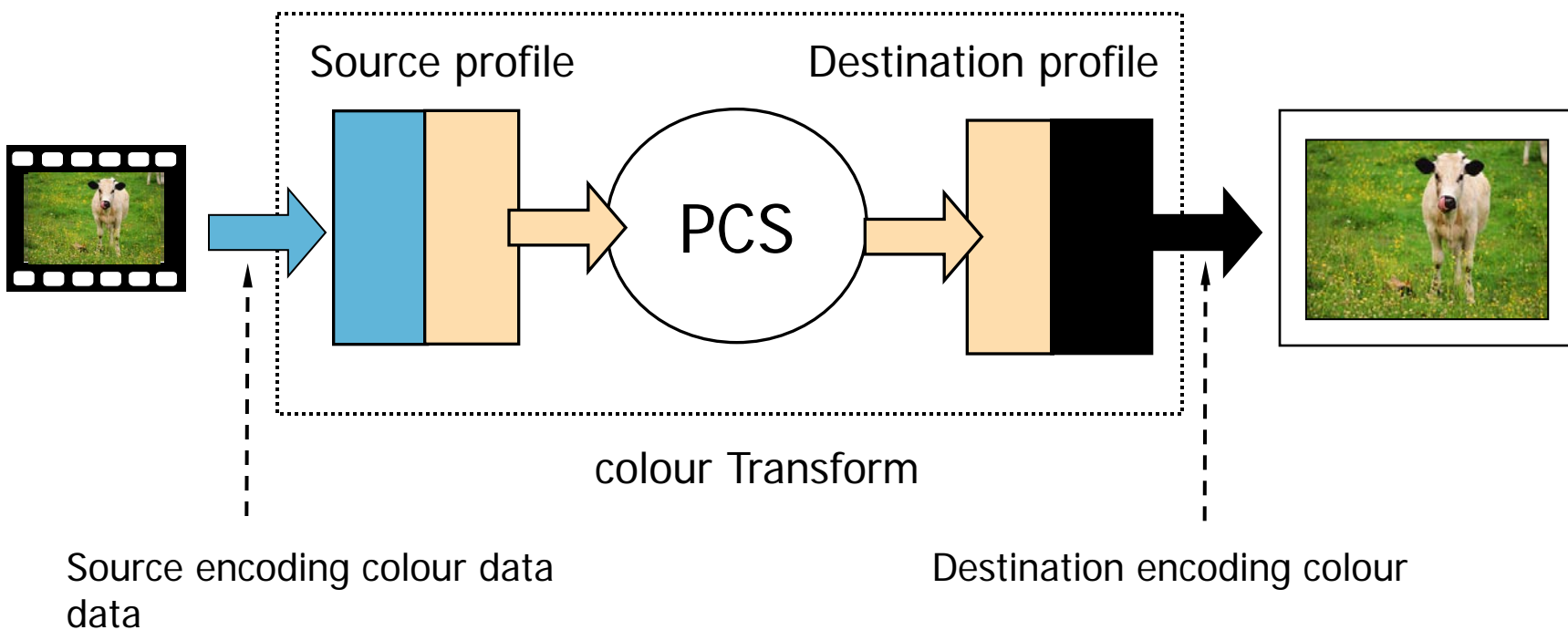
- **Early 1990's, several vendors marketed proprietary transform formats**
  - Apple, EFI, Kodak, Adobe (PostScript & PDF)
- **Incompatible formats led to a call for standards**
- **International Color Consortium formed in 1993**
  - Founding members: Adobe, Apple, Agfa, Kodak, Microsoft...  
+ other member companies from digital imaging industry
- **First published specification in 1994**
  - Based on Apple ColorSync
- **Now an ISO standard**
  - ISO 15076-1 published 2005, revised 2010

# International Color Consortium

- **ICC is a consortium of member companies (approx 50 members)**
  - Also some universities are honorary members
- **ICC maintains the profile format specification**
  - Co-published with ISO
- **ICC publishes White Papers, Technical notes and other information to aid developers and users through its web site**
- **ICC maintains a number of registries**
  - Tag signatures
  - Characterization data
  - Metadata
  - Standard profiles

# ICC colour workflow

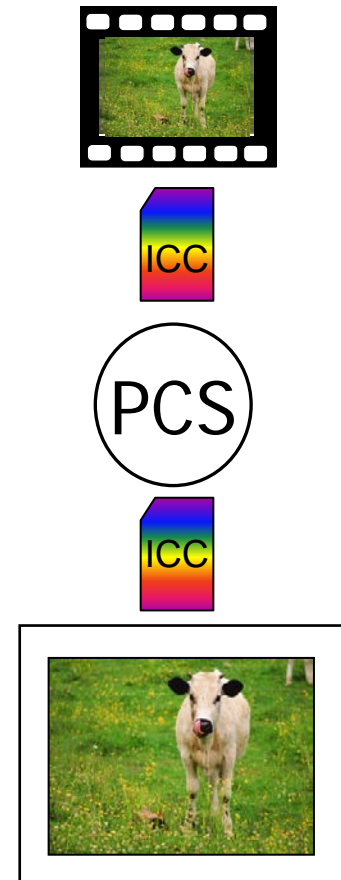
- In an ICC colour managed workflow, profiles are used to transform between a source and destination colour encoding via the Profile Connection Space (PCS)





# ICC colour workflow

- The source profile defines how the image is to be interpreted. It can be embedded in the image (in most image file formats)
- The destination profile defines how a specific output system converts colours into output code values. It can be associated with the output system in the device driver or operating system
- The source and destination profiles can be selected at any point up to the final conversion, so the choice of interpretation and rendering can be deferred until the point of conversion

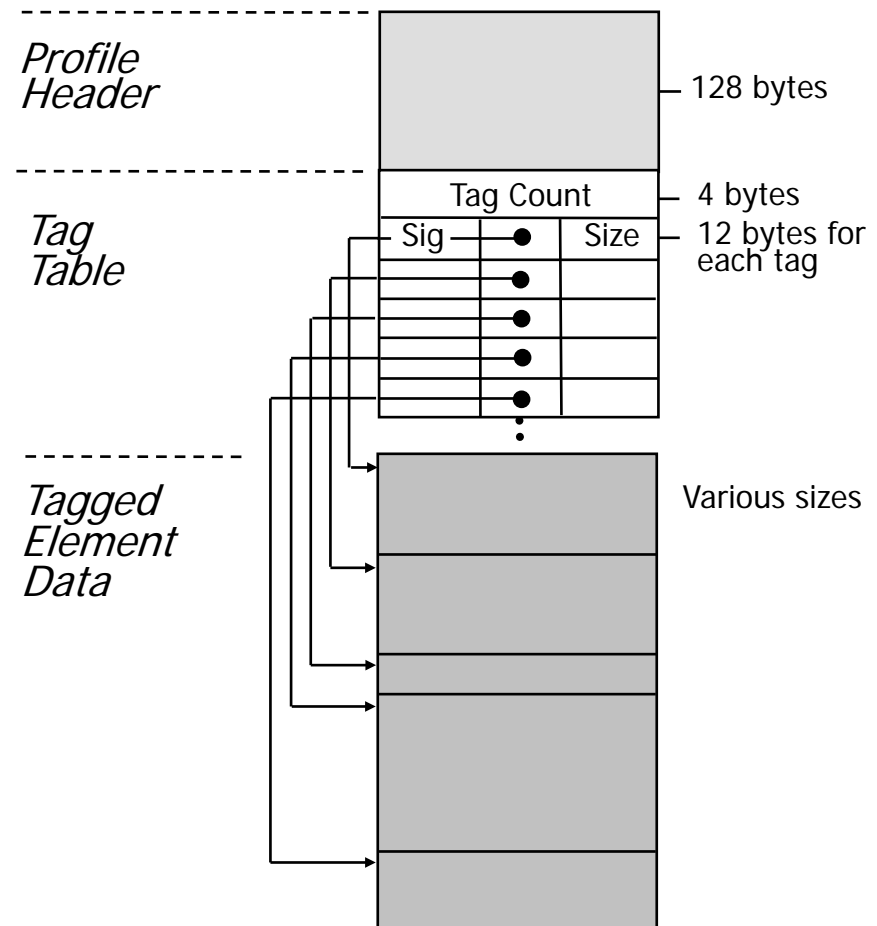


# Key ICC concepts

1. A profile is a container for a point-wise colour transform
2. Source and destination transforms are connected via a well-defined Connection Space
3. Default assumption is Media-relative colorimetry
4. Adjustments to compensate for differences in illumination, viewing condition, user adaptation etc are incorporated into the profile
5. A limited set of well-defined transforms (matrix, curve and LUT) are specified
6. Architecture and specification are open and vendor-neutral
7. Vendors can provide custom solutions

# Key ICC concepts

8. The ICC profile is a binary, platform-independent file format
9. Transform elements and metadata are stored in tags
  - Public required tags
  - Public optional tags
  - Private tags
10. Well-defined specification and data typing makes profile format unambiguous



# ICC profile specification – changes from v2

**Current version is ICC v4.3, ISO 15076-1:2010**

**Many users still use v2.x**

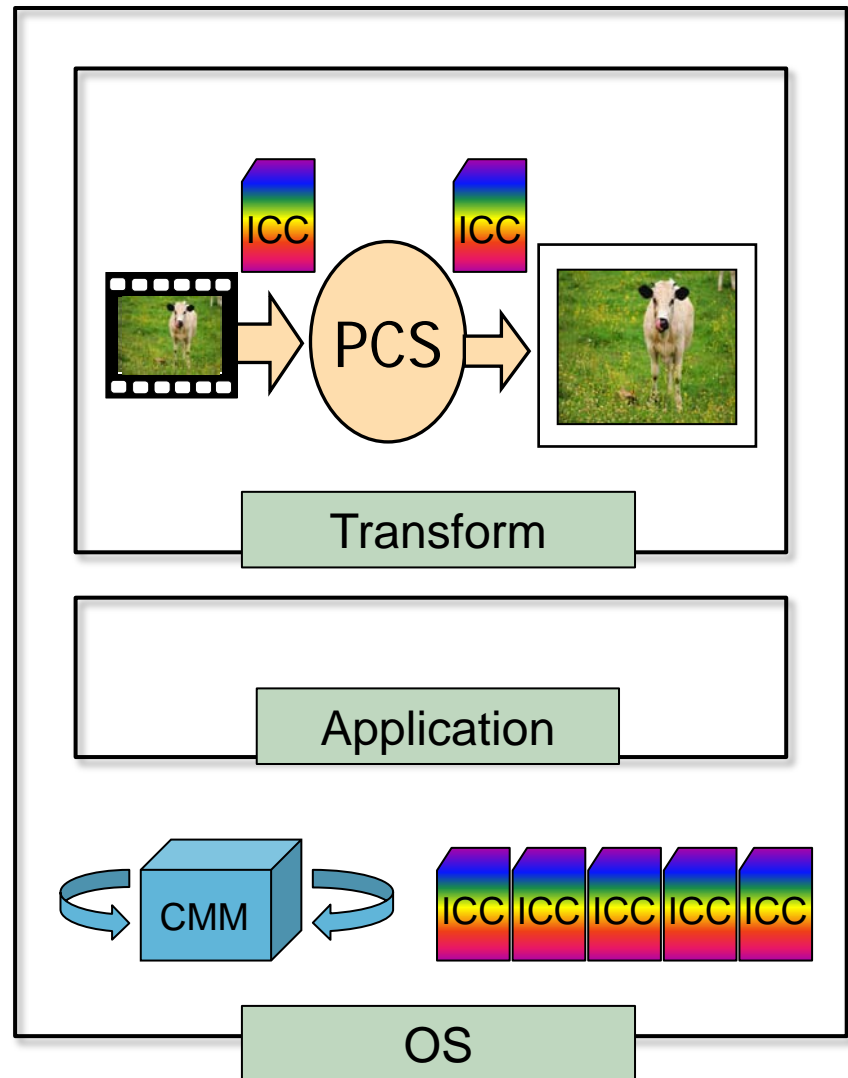
- Simpler file format, less rigorous requirements

**Key differences introduced in v4.x**

- Wording tightened up throughout
- Perceptual Intent based on Perceptual Reference Medium
  - Avoids ambiguity regarding source dynamic range and gamut
- Colorimetric Intents strictly measurement-based
- Chromatic adaptation required for non-D50 data; chad matrix must be included in profile

# Colour management implementation

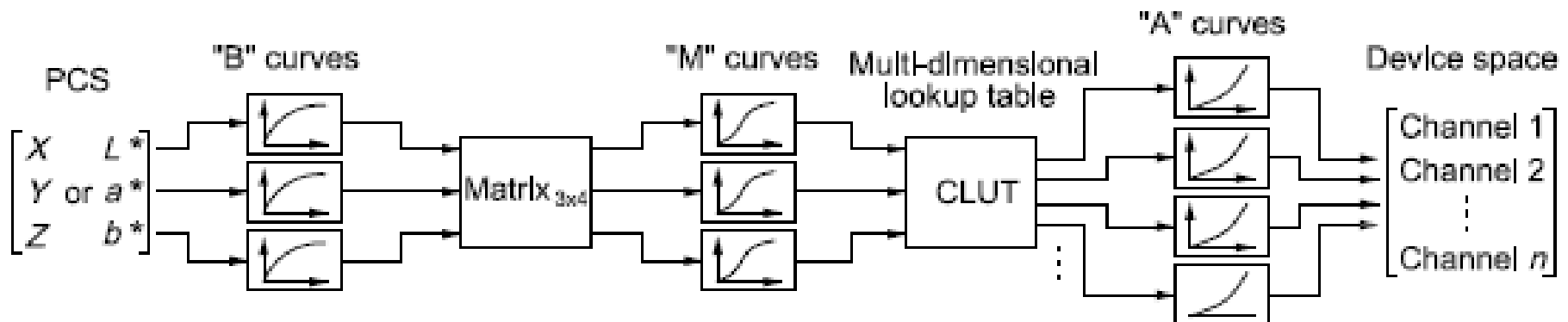
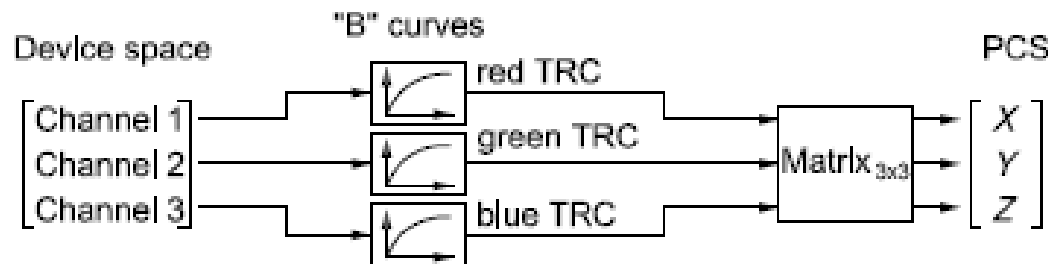
- **Transform**
  - Device model defined by platform-independent profile
- **Application**
  - Selects profiles, calls CMM to apply transform defined in profile
- **Operating system**
  - Provides framework for storing and locating profiles and CMM
  - Provides default CMM



# Encoding a colour transform

## Two types of transform: Matrix/TRC and look-up table

Matrix/TRC:  
1D curves +  
3x3 matrix



CLUT: 3 x 1D curves, 3x4 matrix + CLUT

# Components of a colour transform

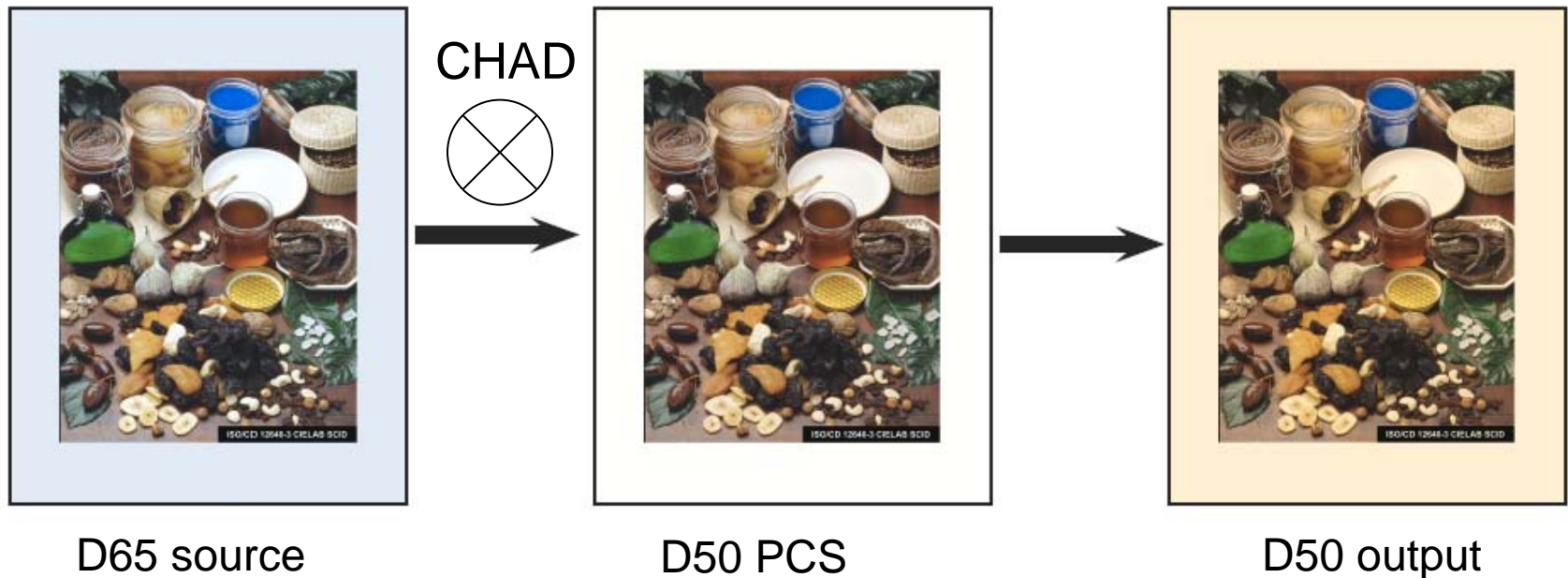
- **Device characterization** [device-to-CIE model]
- **Gamut mapping** [compensate for different gamuts]
- **Colour appearance** [compensate for different viewing conditions]
- **Colour rendering** [pleasing reproduction]

All of these can be handled in the current 'static' ICC profile with minimal intelligence in the CMM

They can also be handled at run-time by a smart or programmable CMM

# Chromatic adaptation

The ICC PCS is D50 and if the source or destination colorimetry is not D50, it must be transformed to D50 using a chromatic adaptation transform





# Profile Connection Space

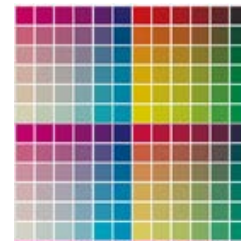
- Virtual exchange space for transforming colour data between encodings
- Described in annex E of ISO 15076-1:2010
- Actually 2 variants: Colorimetric and Perceptual
- Both CIE colorimetry – XYZ or CIELAB – computed using D50 illuminant and CIE 1931 Standard Colorimetric Observer

PCS range	White			Black		
	X	Y	Z	X	Y	Z
Colorimetric	96.42	100.00	82.49	0	0	0
Perceptual	85.81	89.00	73.42	0.298	0.309	0.255

- **Perceptual intent also has reference viewing environment**  
— D50, 500 lux, 20% surround reflectance

# Rendering intents

- **Colorimetric conversion is straightforward**
  - Calibrate, image colour patches, measure them, build LUT
  - Two flavours supported:
    - ICC-Absolute (match exactly)
    - Media-Relative (match relative to media white points)
- **Colour rendering can be highly variable**
  - Preferred rendering depends on the application and the user
  - Two flavours supported:
    - Perceptual (pleasing rendering of natural images)
    - Saturation (arbitrary rendering, usually applied to non-photographic images)



# Using rendering intents

## Rendering intents support different goals:

- **Match colorimetry**
  - ICC-Absolute Colorimetric intent
  - Colours are matched relative to perfect reflecting diffuser
  - Widely used in matching single colours in isolation ('spot colours')
- **Subjective accuracy**
  - Media-relative Colorimetric intent
  - Normalises white points so that source media white is matched to destination white
  - Often requires separate scaling of black point ('black point compensation')

# Using rendering intents

## Rendering intents support different goals:

- **Colorimetry + viewing condition + preference**
  - Perceptual intent
  - Colour adjusted to give a pleasing reproduction
  - Optimises use of destination colour gamut using Perceptual Reference Medium Gamut as exchange gamut
- **Arbitrary rendering**
  - Saturation intent
  - Can be used to map any arbitrary colour to a colour or grayscale range
  - Used in business graphics where accurate matching is not required but colour saturation is important
  - Can be used to achieve ‘false colouring’ of mono images

# Colour Management markets

## **Colour management was primarily developed for the graphic arts market**

- D50 colorimetry, primarily reflectance, measurements relative to a perfect diffuse reflector
- Default requirement to match relative to media white point
- Final output in hard copy
- Previews in soft or hard copy

## **Other markets have developed, adjustments made to the ICC architecture to accommodate**

- Digital photography (scene-referred data)
- Motion picture (floating point data, great transform functionality)

# Reference encodings

Profiling every device in an imaging chain is time-consuming and costly

In many workflows reference encodings are used instead. Output devices are calibrated so they match a suitable reference encoding. Similarly, image capture data is rendered to a suitable reference encoding

For RGB (and other 3-component colour space) data, standard encodings are defined in the ICC 3-Component Encoding Registry. These include sRGB and extended-gamut spaces such as Adobe RGB (1998)

Characterization data sets for standard printing conditions are also available in the ICC CMYK Characterization Data Registry

# Support for ICC profiles

## International Standards that use or reference the ICC profile specification (v2 or v4)

- EXIF 2** ISO12234-4: Photography - Electronic still-picture imaging – Part 4: Exchangeable image file format
- JPEG** ISO/IEC 10918-1: Coding of still pictures
- JPEG2000** ISO/IEC15444: Coding of still pictures -
- PDF/X** ISO 15930-1:2001 Graphic technology — Prepress digital data exchange.
- PNG** ISO/IEC 15948: Portable Network Graphics file format
- TIFF/IT** ISO 12639:2004 Graphic technology — Tag image file format for image technology
- DICOM** ISO 12052:2006 Health informatics -- Digital imaging and communication in medicine
- ISO 12647:** Graphic Technology - Process
- ISO 22028-1:2004** Photography and Graphic Technology – Extended colour encodings

## Other file formats that support ICC profiles

- CSS3** Cascading Style Sheets, W3C
- JDF** Job Definition Format, CIP4
- PDF** Portable Document Format, Adobe
- PICT** QuickDraw picture format, Apple
- SVG** Scalable Vector Graphics, W3C

# Support for ICC profiles

The ICC profile format is also supported in:

## Operating systems

- Windows, Mac OS

## Applications

- Imaging applications (e.g. Adobe CS)
- Office applications (e.g. Microsoft Office)
- ...

## Browsers

- Explorer, Firefox, Chrome, Safari, ...
- Different levels of support

## Programming languages

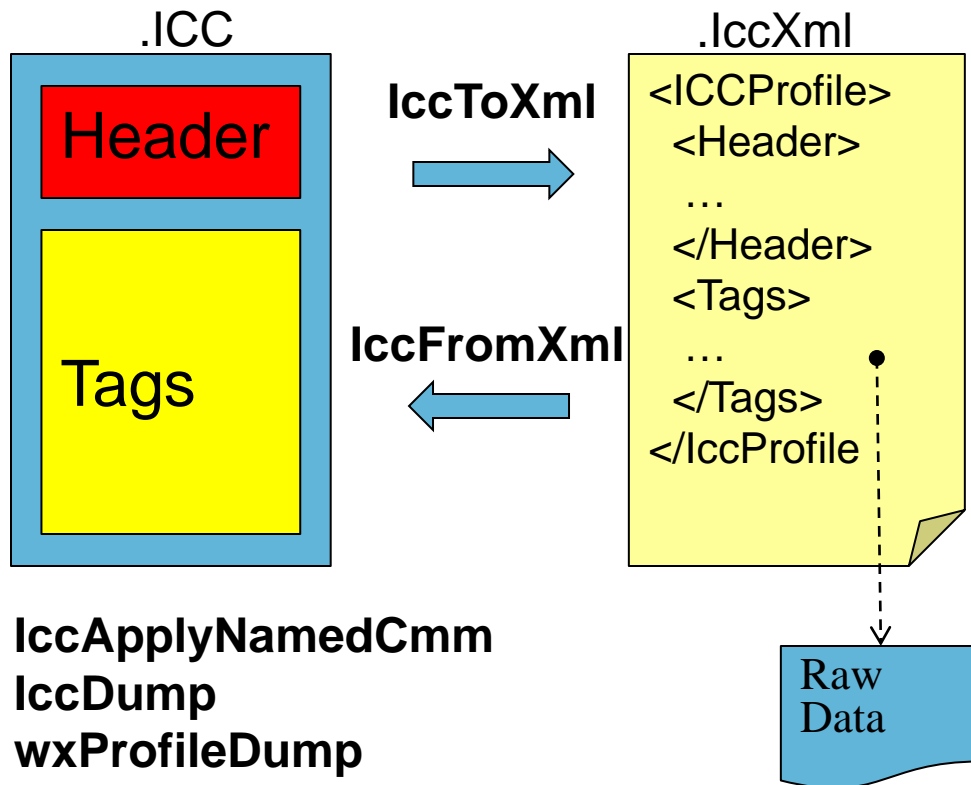
- E.g. Java, Javascript, C++, Matlab, PostScript ...



ICC test image to show what version of the profile specification is supported  
Available at <http://www.color.org>



# iccXml tools



- IccApplyNamedCmm
- IccDump
- wxProfileDump

- **Two types of colour profile**
  - Binary
    - Extensions of ICC profile specification
  - Xml
    - XML representation of ICC profile contents
    - May refer to outside data files
- **iccXml package contains libraries and tools**
  - IccProfLib (.ICC)
    - IccApplyNamedCMM
    - IccDump
    - wxProfileDump
  - IccLibXml (.iccXml)
    - IccFromXml
    - IccToXml

# Limitations of ICC approach

- **Fixed, print-centric PCS**
- **No support for spectral transforms**
- **No spatial or content-dependent transforms**
  - E.g. local appearance-based transforms
  - Depend on semantic content of original (e.g. image vs graphic or text)
- **Functionality limited**
  - More complex transforms cannot be encoded in existing profile classes
- **Verbose profile format**
  - In some applications it is desirable for the profile to define only the colour encoding, and leave the CMM to select the transform)

## Planned for ICC v5 (ICC-Labs)

- **Support for alternate illuminants and viewers for PCS connection**
- **Support spectral communication of colour 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
- **Extended MultiProcessing Elements for greater flexibility and simpler encoding of transforms**
- **Placeholder profiles**
- **Direct encoding of Gamut Boundary**

# Thank You!

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