Cross-media colour reproduction using ICC profiles

October 21, 2012

Beijing ICC meeting

Outline

- Key concepts
- Input and output media
- Image state
- Colour management components: characterization, gamuts, appearance and rendering
- Reference encodings for different media
- Cross media workflow

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, gamut 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

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.

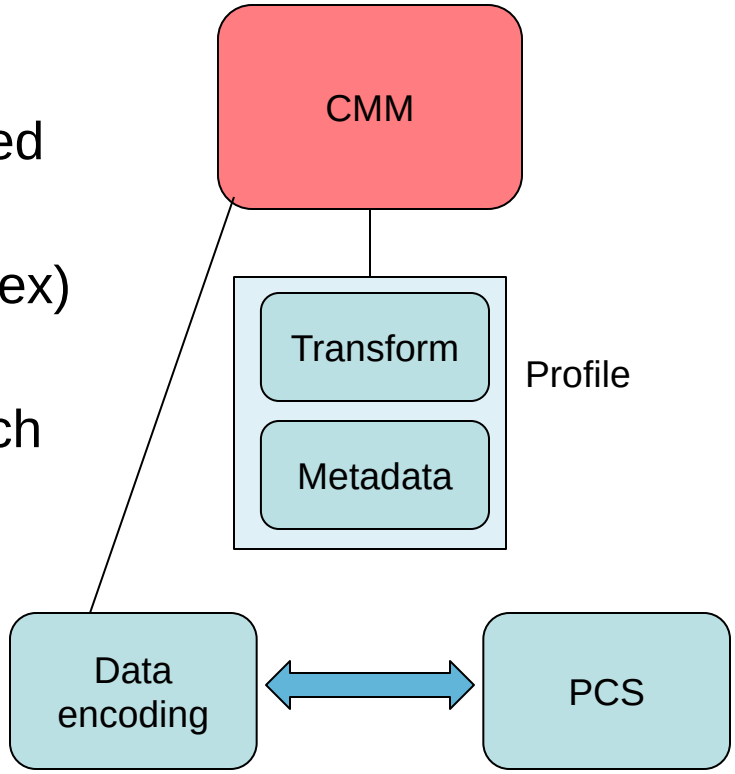
—Profile is in binary form (can be read as hex) and includes numeric and textual data

—Profile consists of header and ‘tags’ – each tag has a specified format

- **How is a profile used?**

—Profile contains transform between data encoding and Profile Connection Space

—CMM applies transform to source data encoding to compute output values



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 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

Colour reproduction input media

Input media are primarily cameras and scanners

In Graphic Arts workflows, most camera images are designed to produce RGB images rendered for display viewing

Many other types of cameras exist:

- Video
- Motion picture
- Multispectral
- Medical imaging
- Astronomy and space

All of these can be colour managed but have very different processing requirements and viewing conditions

Colour reproduction output media

Output media are primarily print, display and projection

Viewing conditions are critically important to the appearance of output media

Displays and projectors are usually optimal when viewed under dim conditions

Mobile devices pose special problems as they must be viewed in varied viewing conditions

Hard copy print may be viewed under reference conditions for approval, or under varied end use conditions

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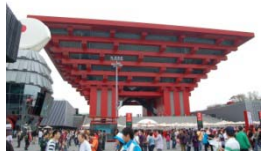


Image states

Image states can be: *

Scene-referred: spectral radiances of a view of the natural world, and the physical objects within it that are photographed

Original-referred: colorimetry of a hard copy photographic print or transparency

Output-referred: colorimetry and viewing conditions of a real or virtual output device

* Definitions from ISO 22028-1

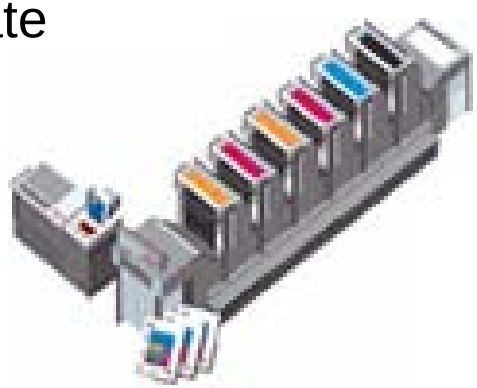
Image state conversion

Conversion from scene-referred to picture-referred state is **rendering**

Rendering operation

After initial rendering, image may be further re-rendered to a different output state

Re-rendering operation



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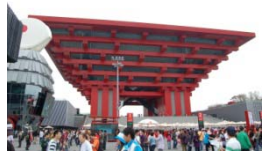
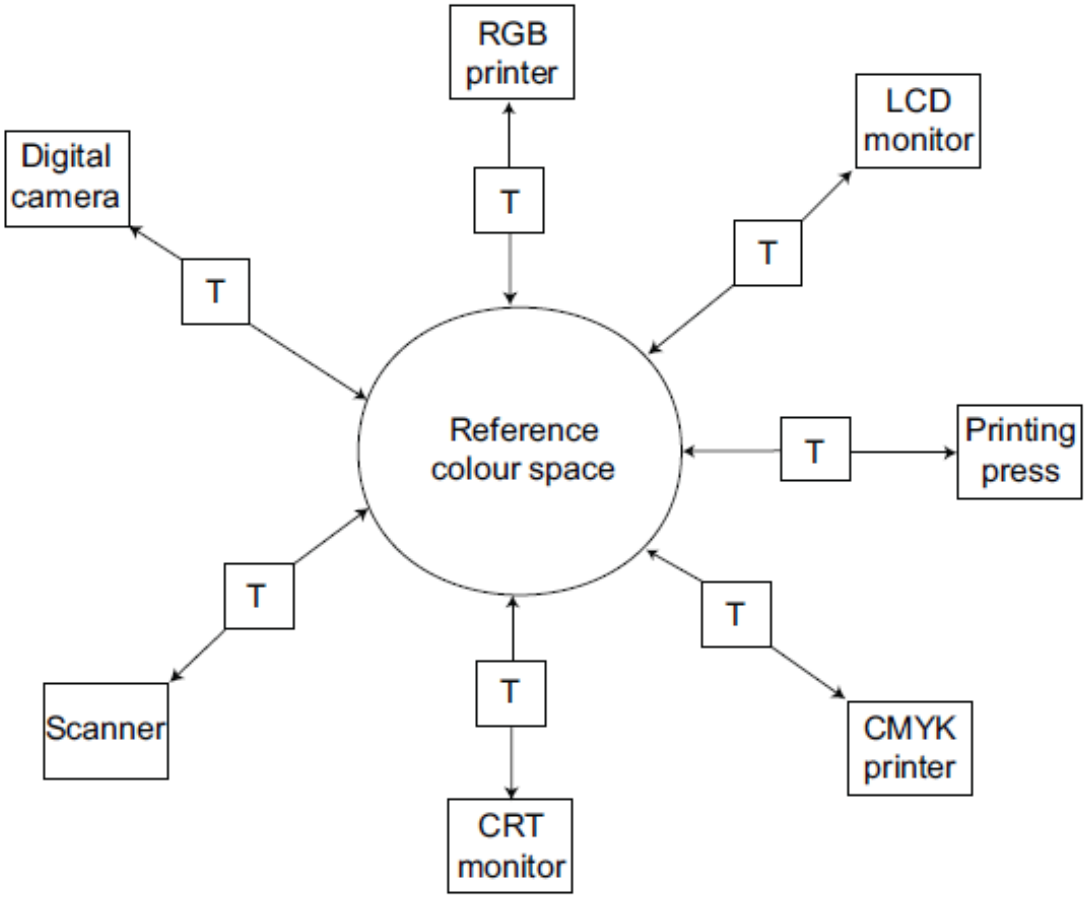


Cross-media reproduction using a reference colour space

One transform T (+ inverse) for each medium

Common reference colour space: D50 PCS CIELAB or XYZ

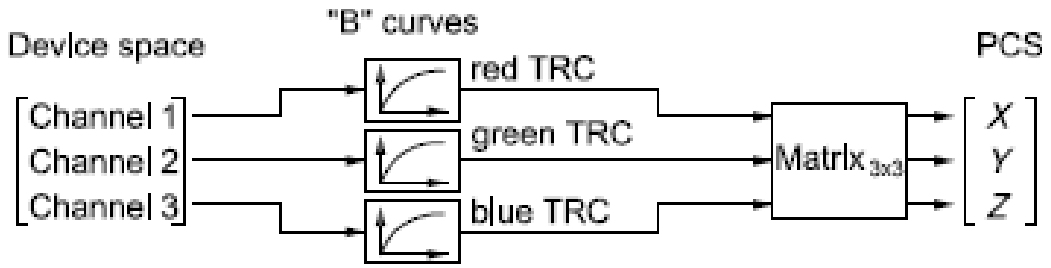
In v4, Perceptual PCS is also defined, limiting dynamic range and gamut to real media

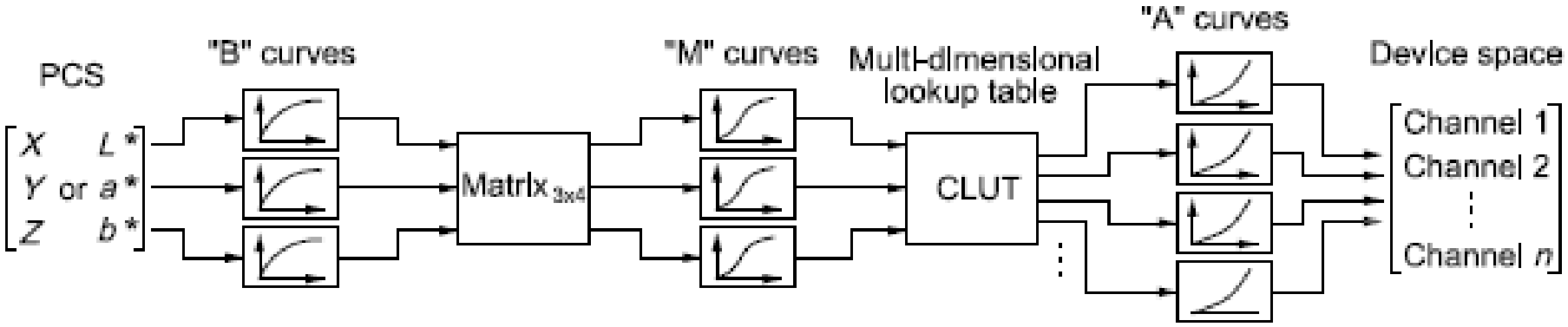


Encoding a colour transform

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

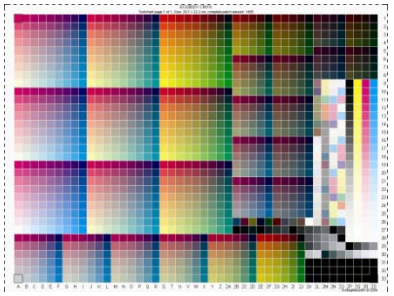
- **Device characterization** [device-to-CIE model]
- **Gamut mapping** [compensate for different gamuts]
- **Colour appearance** [compensate for different viewing conditions]
- **Colour rendering** [pleasing reproduction]

All of these can be handled in a ‘static’ ICC profile

In the future these may be programmable and handled at run-time by the CMM

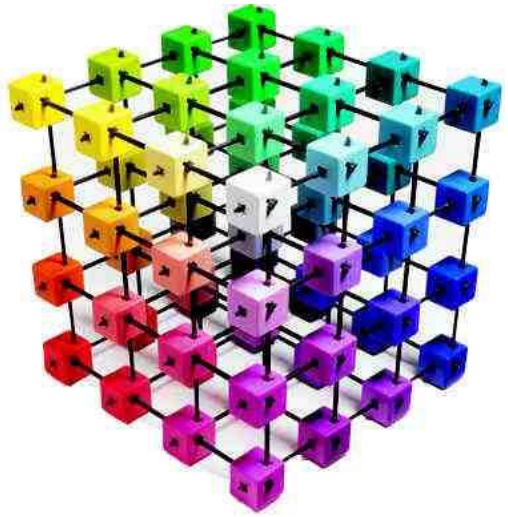
Device characterization

The key element in a transform is the device model, which converts device values to CIE colour space



To generate a model for an output device, sample device values are imaged on the device and measured

Characterization methods have been subject to much previous research to produce accurate results



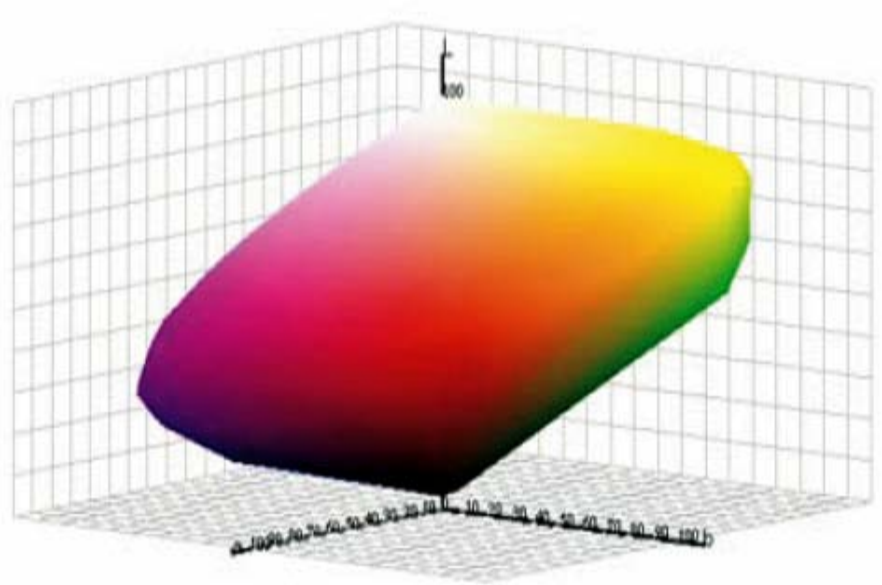
In most device profiles, the model is used to compute entries in a 3D colour look-up table (LUT)

Gamut mapping

In ICC v2, an output profile Perceptual intent has to make a guess about the source medium gamut

Often this guess is wrong, resulting in poor quality reproductions

In ICC v4, a reference gamut was introduced: now input profiles render to the PRMG and output profiles render from the PRMG



ICC has provided v4 sRGB profiles which render to PRMG: sRGB v4 preference and sRGB v4 appearance

Colour appearance

The appearance of a colour depends on the viewing conditions, including:

- Luminance and chromaticity of viewing light
- Luminance and chromaticity of background and surround

Most aspects of colour appearance change can be predicted with a colour appearance model such as CIECAM02

When rendering to or from a medium with a different viewing condition to the ICC PCS, appearance adjustments should be made to the transform

Chromatic adaptation

One component of a colour appearance model is 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

Rendering for preferred images

Converting from one image state or medium to another requires more than colorimetric accuracy

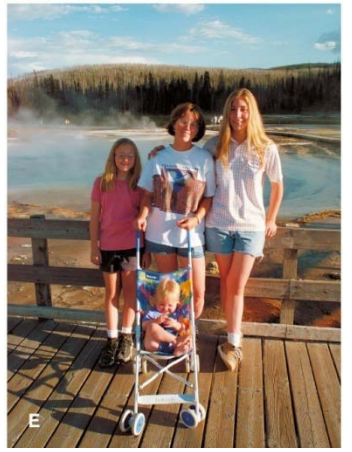
Successful rendering produces images which are optimal for the target medium

Such images will be preferred by users over alternative renderings, and will perform well on image quality metrics

This often involves ensuring that images look bright, colourful and natural

In consumer photography, camera RAW images are rendered to an output encoding and preference adjustments are made at this stage in the camera

Further re-rendering may be needed if the output medium changes



J. Holm

Reference encodings

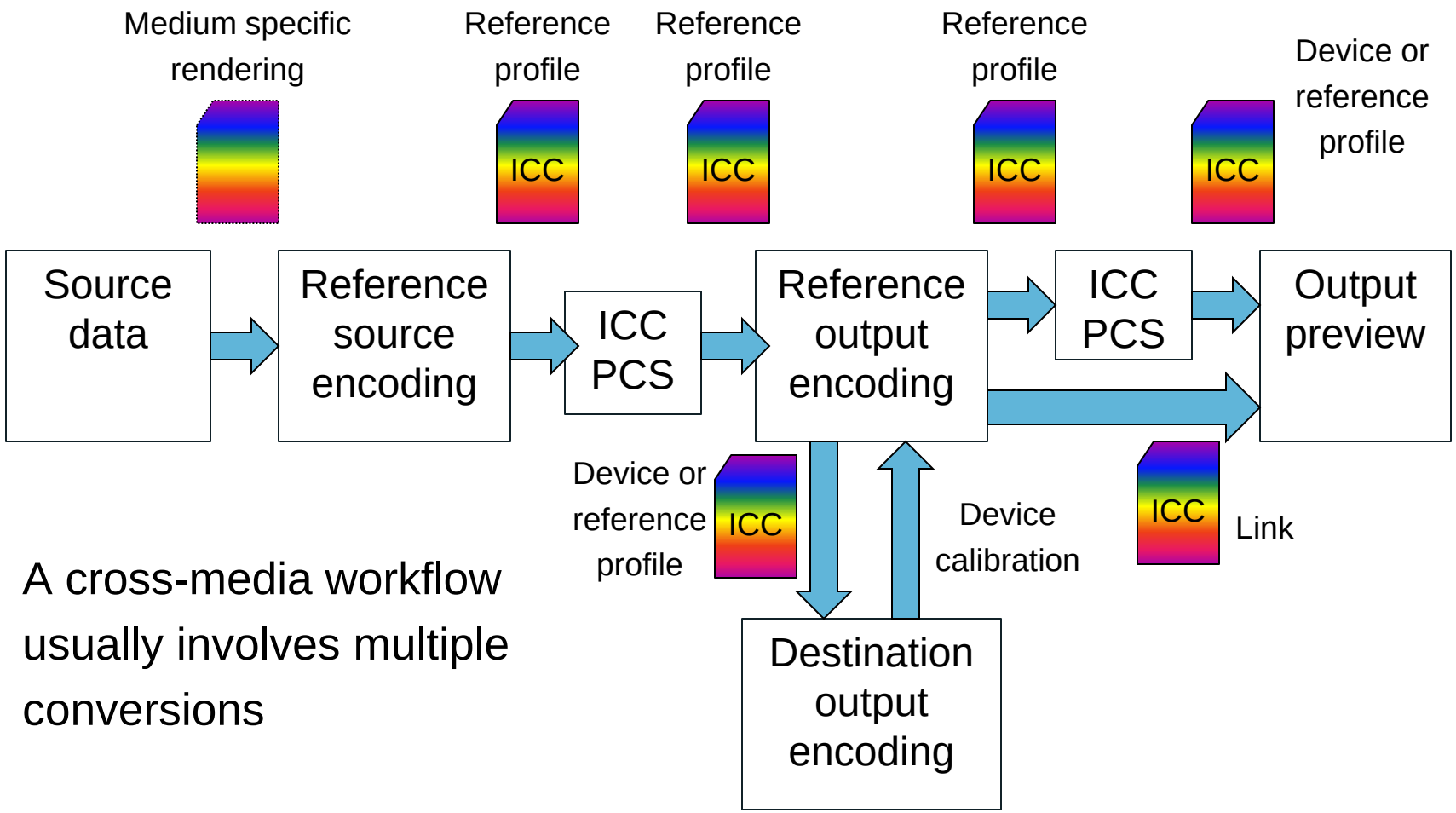
Profiling every device in an imaging chain is time-consuming and costly

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 data, standard encodings are defined in the ICC 3-component encoding registry. These include sRGB and extended-gamut spaces such as Adobe RGB (1998)

For CMYK output data, characterization data sets provided by FOGRA, CGATS and others are listed in the ICC CMYK Characterization Data Registry

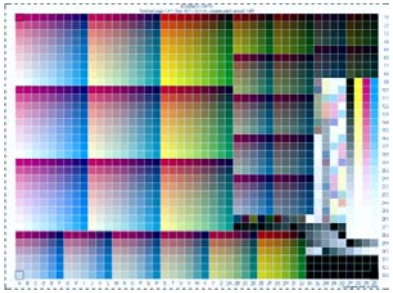
Cross-media workflow



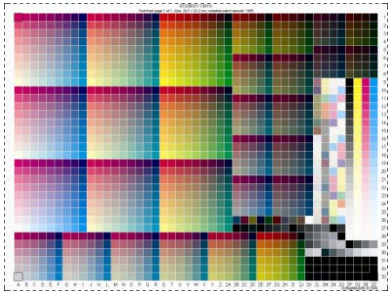
A cross-media workflow usually involves multiple conversions

White point adjustment

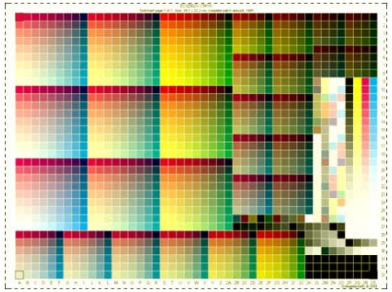
If the actual paper white is different from that in the target characterization data, the target data can be adjusted using a media-relative transform



Characterization data target



ICC PCS

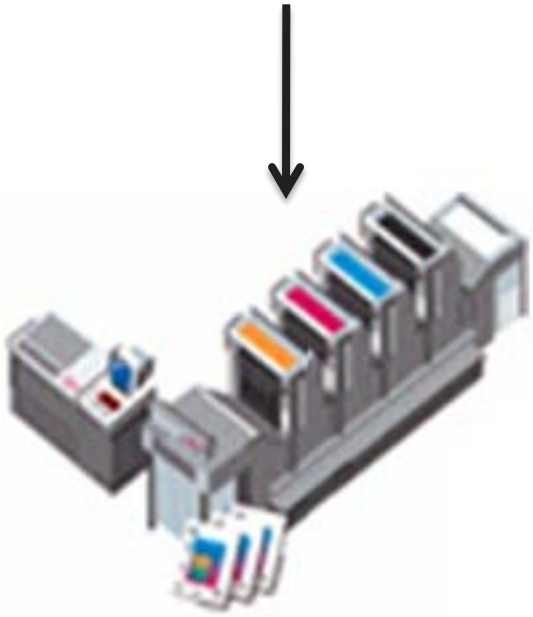


Adjusted characterization data

Traditional cross-media workflow

Traditional print production workflow based on:

- Single target output (sheet-fed offset on coated paper)
    - Variants usually created by modifying tonal value increase
- Early binding workflow – document converted from source RGB to final CMYK early in workflow
- Printer receives CMYK data, needs no additional information
- Final colour previewed by mechanical or photomechanical process closely emulating printing process



Current cross-media workflow

- Multiple target outputs, usually unknown at early stage in workflow
- Late binding workflow – document prepared in a colour encoding different from final outputs
- Printer receives any colour encoding, interprets the file using colour transform metadata (ICC profile)
- Final colour determined by data processing + printing condition
- Final colour previewed by any process, colour matching provided by processing

PCS

Conversion between other transform data formats and ICC

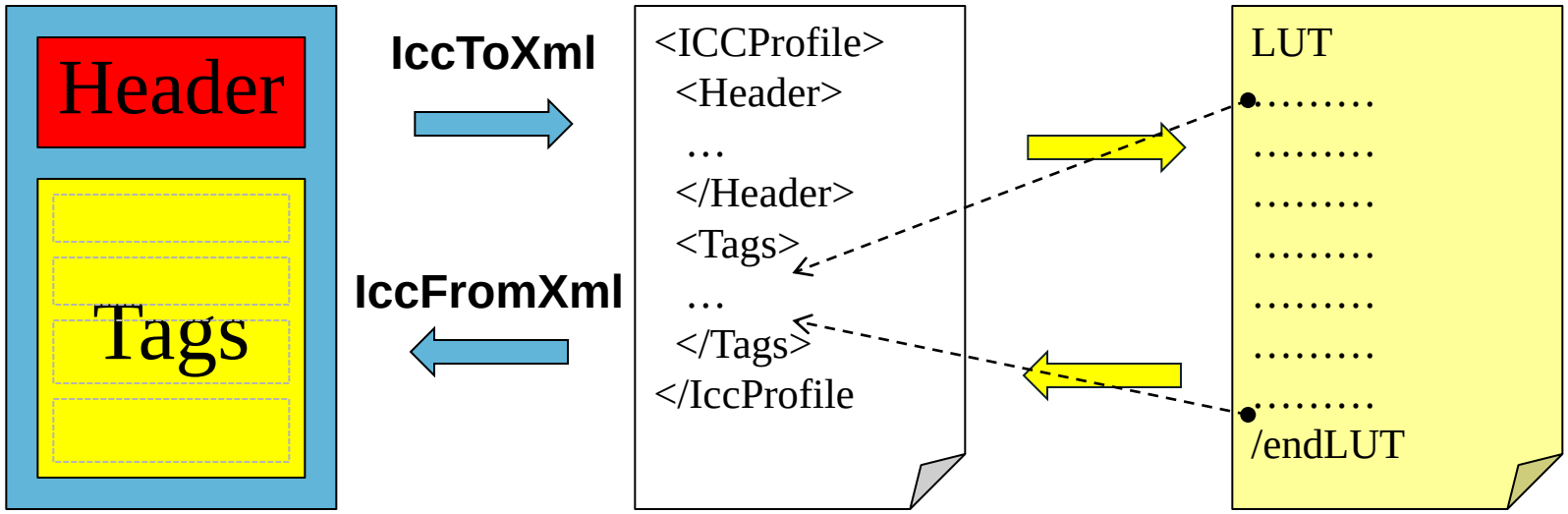
- Some industries (e.g. motion picture) use alternative formats to encode transforms
- These transforms are often based on the same transform types as used in ICC profiles (matrices, curves, LUTs)
- ICC profiles are more complex (binary format, data typing, multiple transform components etc.) but can carry more metadata and are more flexible, robust and powerful
- Alternative transform encodings are often text-based can readily be converted to ICC profiles
- This can be done using IccLibXml, with XML as an intermediate encoding

Transform conversion

.ICC

.IccXml

Text-based LUT



Thank you!