Revealing ICC Color Management: Version 4, Rendering Intents, Profile Connection Space

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(excerpted from the CIC10 tutorial)

Color Fidelity

The term “color fidelity” refers to the successful interoperability of color data, from image creation to output across multiple targets, such that color reproduction quality consistent with the user’s intent can be achieved

Note: Interoperability among system color components, necessary for color fidelity, is both color-workflow and market-segment dependent

Version 4 is motivated primarily by interoperability improvements – leading to enhanced color fidelity

Version 4...

Specification ICC.1:2001-12

File Format for Color Profiles (Version 4.0.0)

Interoperability improvements are the key...

Revision Overview

- Balanced approach to tightening the profile interface
  - When a particular pair or sequence of profiles is used - consistency is improved regardless of CMM
  - Differing interpolation procedures may still result in small interpretation differences
- ICC does not constrain workflow or usage, although certain configurations "make more sense"
- Workflow usability still depends on the profile exchange infrastructure - file format, etc., related standards
- Areas of change
  - PCS
  - Rendering Intents
  - Chromatic adaptation
  - LUT structures
  - N-colorant tags
  - Unicode

ICC Version 4 Changes - Profile Connection Space 5

- Perceptual PCS distinct from Colorimetric PCS
  - See Annex D
  - Perceptual PCS provides a defined “color-rendering target” for perceptual Rendering Intents, with specified neutral bounds
  - Media-relative Colorimetric PCS is the “measurement” path
- PCS CIELAB equations are *clarified* (not changed) and NEW PCS CIELAB value encoding range is defined
  - See 6.5.9, 6.5.15, Annex A.1, A.2, Annex D
  - L* = 100 is encoded as FFFFh (L* = 100 was encoded as FF00h)
  - a*, b* = 127 is encoded as FFFFh (was encoded as FF00h)
  - Note 6.5.15 namedColor2Type exception
- PCS viewing conditions are clarified, defined
  - Colorimetric PCS default - illuminant level is 500 lux, Annex A.1
  - Perceptual PCS viewing condition - Annex D.1.4 - ISO 3664 P2
- Handling of PCS encoding bounds is defined
  - Clipping is specified between XYZ PCS and LAB PCS - Annex A.3

ICC Version 4 Changes - Profile Connection Space

- Normative Annex D.1
  - Reference Viewing Environment *and* Reference Medium specified for Perceptual PCS
    - Reference medium linear dynamic range = 287.9:1
  - PCS white point value specified for media-relative colorimetric, perceptual and saturation Rendering Intent transforms
    - Annex D.1.3 - Table 96 ***(L*a*b* = 100, 0, 0)***
    - White point of the actual medium and the white point of the reference medium (Perceptual PCS)
  - PCS zero reflectance specified for media-relative colorimetric Rendering Intent transforms
    - Annex D.1.3 Table 97 ***(L*a*b* = 0, 0, 0)***
  - PCS perceptual black point specified for perceptual and saturation Rendering Intent transforms
    - Annex D.1.3 Table 98 ***(L*a*b* = 3.1373, 0, 0)***
- Informative Annex D.2
  - Explanatory discussion and computation examples

ICC Version 4 Rendering Intents - Definitions

- Rendering Intent definitions A.4
- Media-relative colorimetric
  - Colors are represented with respect to a combination of the illuminant and the media's white point
  - In-gamut chromatically adapted tristimulus values are scaled such that the white point of the actual medium is mapped to the PCS white point, and the relationships between in-gamut colors are preserved
  - Media-relative colorimetric intent procedural guide D.2.6.2
- ICC-absolute colorimetric
  - Colors are represented with respect to the illuminant and a perfect diffuser
  - In-gamut chromatically adapted tristimulus values are normalized relative to the perfect diffuser viewed under the same illumination source (PCS illuminant D50), in-gamut color relationships are preserved
  - Equations A.1

ICC Version 4 Rendering Intents - Definitions

- Perceptual
  - The exact mapping of the perceptual intent to the reference medium is vendor specific and involves compromises such as trading off preservation of contrast in order to preserve detail throughout the tonal range
  - Intended for general reproduction of natural imagery
- Saturation
  - The exact mapping of the saturation intent to the reference medium is vendor specific and involves compromises such as trading off preservation of hue in order to preserve the vividness of pure colors
  - Intended for computer generated imagery such as business graphics
- Reference medium is specified in Annex D.1.5
  - Neutral reflectance WP= 89%, BP= 0.30911%, density range 2.4593, linear dynamic range 287.9:1

Note the profile builder options for these intents

...this is what we mean by encoding a “color aim” in a profile

ICC Version 4 Rendering Intents - Definitions

- After Color-Rendering to the Reference Medium → Perceptual and Saturation renderings are scaled to PCS
  - From the perceptual reference medium, the color-rendered in-gamut tristimulus values are scaled such that the white point of the reference medium is mapped to the PCS white point, and the relationships between in-gamut colors are preserved
  - I.e, conceptually - the desired reference medium image is transformed to the colorimetric PCS using a media-relative colorimetric intent
  - Procedural guide - D.2.7.8
- White Point (WP) and Black Point (BP)
  - The white point (used for normalization) and black point are fixed for Perceptual PCS and are not fixed for Colorimetric PCS
- 6.3 and Table 20 define the supported combinations of Rendering Intents and profile types
  - Input, output, display, colorspace, monochrome all bi-directional
- 0.8 defines Rendering Intent fall-back strategy

Note N-Component LUT Display Exception - Rev Passed

ICC Version 4 Rendering Intents - Usage

- Viewing and Medium Conditions
  - Each profile is created for one viewing environment
    - Viewing illuminant, illumination level, stray light, surround effects, ...
  - ... And one imaging medium
    - White point chromaticity and percent reflectance
    - Maximum density - media black point
  - The particular conditions pertain to the DEV side of each Rendering Intent transform in the profile
  - Those conditions are inherent in the colorimetry delivered to the Colorimetric PCS through the media-relative colorimetric Rendering Intent transform in the profile
  - The perceptual intent transforms color-render to and from those conditions
- Perceptual and Colorimetric PCS use the same color spaces
  - The difference is that the perceptual intent color-renders to a fixed reference medium color-rendering target --- and
  - The medium for the colorimetric intent is variable $\Rightarrow$ the medium for which the profile is created (transformed to the D50 colorimetry)

ICC Version 4 Rendering Intents - Usage

- In a capture (scene-referred input) profile, for the DEV to PCS direction
  - The me… …-relative colori…etric inte… …elivers a scene in PCS color enco…
  - The perceptu… …t c… …an image displayed on the…
- In a cap… …r the DEV to PCS direc…
  - The media-rel… …riginal in PCS color enco…
  - The perceptual int… …inal to an image displayed on the R… …en… …dium.

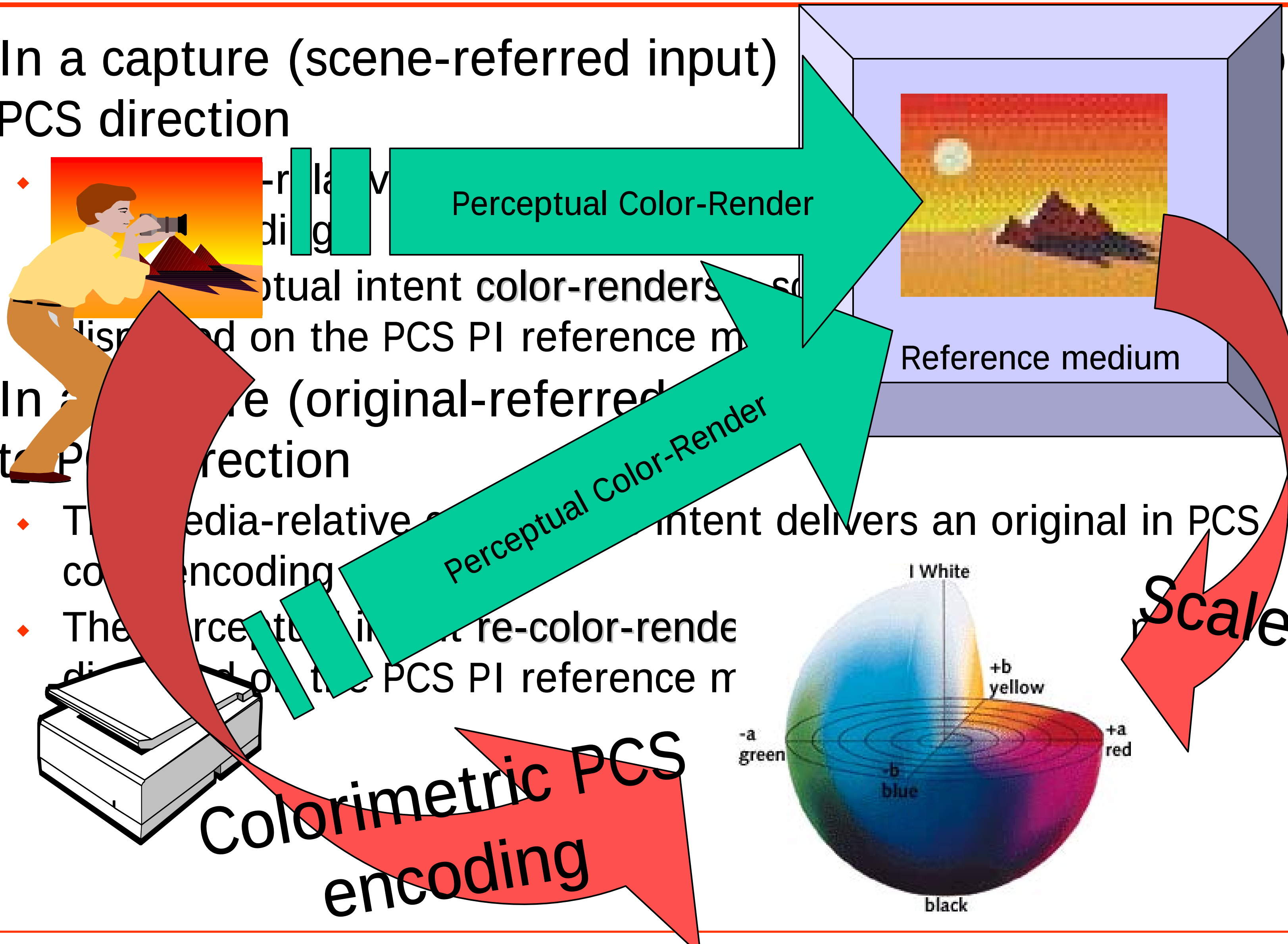
Pick your capture rendering intent based on how you will use the image

ICC Version 4 Rendering Intents - Usage

- In a capture (scene-referred input) profile, for the DEV to PCS direction
  - The media-relative colorimetric intent delivers a scene in PCS color encoding
  - The perceptual intent color-renders a scene to an image displayed on the PCS PI reference medium
- In a capture (original-referred input) profile, for the DEV to PCS direction
  - The media-relative colorimetric intent delivers an original in PCS color encoding
  - The perceptual intent re-color-renders an original to an image displayed on the PCS PI reference medium.

ICC Version 4 Rendering Intents - Usage

- In a capture (scene-referred input) … PCS direction
  - …-r… la… v…
    …di… g…
  - …ptual intent color-renders … sc…
    …disp… …d on the PCS PI reference m…
- In a… …e (original-referred…
  t… P… …rection
  - T… …edia-relative … intent delivers an original in PCS
    co… …encoding
  - The … …rce… …t… …i… …t re-color-rende…
    di… …d o… t… PCS PI reference m…



ICC Version 4 Rendering Intents - Usage

- In capture (scene-referred input) pro... le, for the PCS to DEV direction
  - The med... lative colori... ic inte... vers a PCS encoded scene re-encoded ... captu... di...
  - The perceptua... tual DEV to PCS PI color-rendering ... minus any clippi... PCS PI transfor...
- In capture (o... he PCS to DEV directi...
  - The m... relative ... CS encoded original re-encode... ing
  - The perceptual in... inv... he a... ed perce... ual DEV to PCS PI re-color-rendering, resto... the cap... ed original encoding, minus any clipping that may hav... occurred t... rough the prior DEV to PCS PI transform

In Version 4 input profiles the new PCS to Device transforms are UNDOs that invert the assumed transform that was used into PCS
e.g., Perceptual ⇔ Perceptual

ICC Version 4 Rendering Intents - Usage

- In capture (scene-referred input) profile, for the PCS to DEV direction
  - The media-relative colorimetric intent delivers a PCS encoded scene re-encoded in the capture encoding
  - The perceptual intent inverts the assumed perceptual DEV to PCS PI color-rendering, restoring the captured scene encoding, minus any clipping that may have occurred through the prior DEV to PCS PI transform
- In capture (original-referred input) profile, for the PCS to DEV direction
  - The media-relative colorimetric intent delivers a PCS encoded original re-encoded in the capture encoding
  - The perceptual intent inverts the assumed perceptual DEV to PCS PI re-color-rendering, restoring the captured original encoding, minus any clipping that may have occurred through the prior DEV to PCS PI transform

ICC Version 4 Rendering Intents - Usage

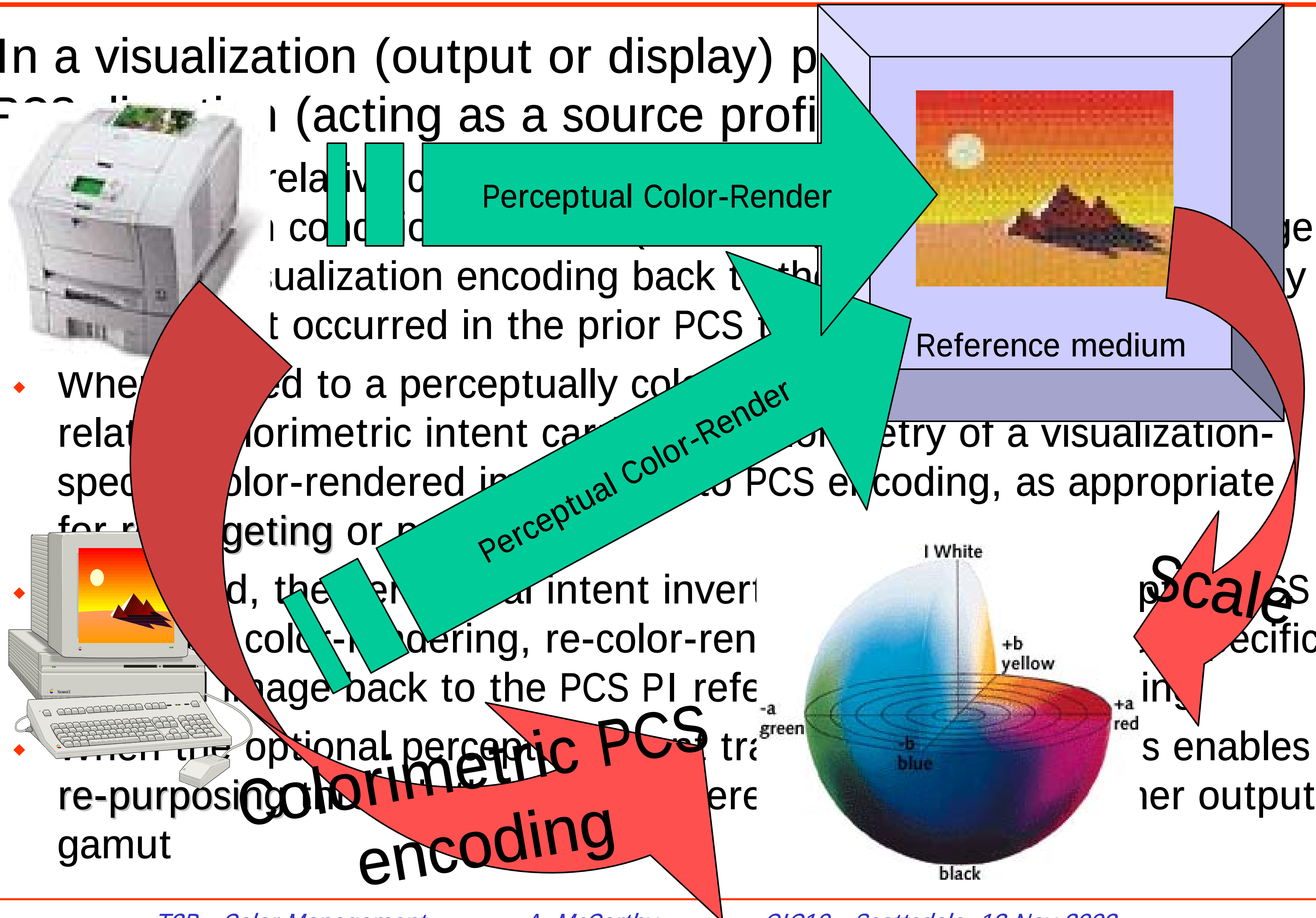
- In a visualization (output or display) profile, for the DEV to PCS direction (acting as a source profile)
  - The media-relative colorimetric intent d[illegible]vers the colorimetry of a visualiza[illegible]on condition enc[illegible]ded (scen[illegible]iginal/color-rendered) image, from the vi[illegible]ization enc[illegible] bac[illegible]he PCS encoding (minus any clipping that o[illegible]d in[illegible]nsform)
  - When applied to [illegible]mage, the media-relative [illegible]visualization-specific co[illegible]g, as appropriate for re-targetinc[illegible]
  - If included[illegible]sumed perceptual PCS PI to DEV color-ren[illegible]e visualization-specific encoded image ba[illegible]o th[illegible]S P[illegible]ence m[illegible]ium encoding
  - When the optional percep[illegible] intent [illegible]nsform is present this enables re-purposing through the [illegible]S PI reference medium to another output gamut

When re-rendering, pick your source rendering intent based on how you will re-use the image

ICC Version 4 Rendering Intents - Usage

- In a visualization (output or display) profile, for the DEV to PCS direction (acting as a source profile)
  - The media-relative colorimetric intent delivers the colorimetry of a visualization condition encoded (scene/original/color-rendered) image, from the visualization encoding back to the PCS encoding (minus any clipping that occurred in the prior PCS to DEV transform)
  - When applied to a perceptually color-rendered image, the media-relative colorimetric intent carries the colorimetry of a visualization-specific color-rendered image back to PCS encoding, as appropriate for re-targeting or proofing
  - If included, the perceptual intent inverts the assumed perceptual PCS PI to DEV color-rendering, re-color-rendering the visualization-specific encoded image back to the PCS PI reference medium encoding
  - When the optional perceptual intent transform is present this enables re-purposing through the PCS PI reference medium to another output gamut

- In a visualization (output or display) p... PCS direction (acting as a source profi... relative c... n condition... visualization encoding back t... the... t occurred in the prior PCS t...
  - When ...ed to a perceptually col... relative colorimetric intent can ...etry of a visualization-spec... color-rendered i... to PCS encoding, as appropriate for re-targeting or r...
  - ...d, the ...al intent invert... ...ge, ...y color-rendering, re-color-ren... image back to the PCS PI refe... ...cs ...ecific ...in...
  - When the optional percep... tr... ...s enables re-purposing the ...ere... ...her output gamut



ICC Version 4 Rendering Intents - Usage

- In a visualization (output or display) profile, in the PCS to DEV direction (acting as a destination)
  - The media-relative colorimetric intent delivers the colorimetry of a PCS encoded (scene/original/color-rendered) image from the PCS encoding to the profile's target visualization condition encoding (actual or reference device/medium), constrained by any data clipping required to fit the PCS encoded colorimetry into the target output gamut
    - Note that the Colorimetric PCS does not constrain either viewing environment or medium - the color coordinates are known, but the color appearance is carried through from device to device
    - A media-relative colorimetric intent transform (PCS to DEV) *following* a capture perceptual intent transform (DEV to PCS) - effectively “proofs” the image from the PCS Reference Medium to the output visualization condition
  - The perceptual intent re-color-renders from the PCS PI reference medium encoding (a reference output device) to the profile's target visualization condition encoding (actual or reference device/medium)

ICC Version 4 PCS and Rendering Intent Usage

- For LUT-based profiles
  - Perceptual PCS holds media-relative colorimetric values for an idealized visualization condition
  - Colorimetric PCS holds media-relative colorimetric values for a real or standard visualization condition, or for a capture condition
  - Connecting the two different PCSs together is the same as delivering media-relative colorimetric values to another device
- For Matrix/TRC profiles
  - These profiles may have a false black point of 0
  - Interact poorly with LUT-based profiles of either intent
  - Apply an XYZ PCS scaling to or from PCS PI as shown on page 93 Eqn. D.1.3.0.0
- Cautionary note
  - Differing capture or visualization conditions inherent in specific media-relative colorimetric intent transforms can affect results when two profiles with such differing transforms are sequenced

ICC Version 4 Changes - Chromatic Adaptation

- If the chromaticity of the illuminant (light source of the measurement environment) is different from that of D50, corrections for chromatic adaptation must be incorporated into the media-relative colorimetric and perceptual transforms by the profile builder
  - For example, if an Alexandrite stone appears to be a purple color when viewed under tungsten illumination, and appears to be sea-green when viewed under daylight - then if an image of the stone is captured under tungsten illumination, its PCS colorimetry (as produced by the input profile) should correspond to the purple color ...Annex D.2.3
  - Colorimetric Rendering Intent transforms - see D.2.4 & D.2.6.1
  - Perceptual Rendering Intent transforms - see D.2.4 & D.2.7.8
- For media intended for the graphic arts, it is recommended that the color measurements conform to ISO 13655 (this includes specification of D50)

ICC Version 4 Changes - Chromatic Adaptation

- Chromatic Adaptation Matrix (CAM) tag is required when the actual illumination is other than D50 - Annex E
- The chromatic adaptation matrix transforms real measured medium values - under the measuring illumination - to D50 relative values
  - The D50 adapted values are then scaled for encoding as media relative PCS values - Annex D.2.6.2 step 6

All profile types except DeviceLink and Named Color

- mediaWhitePointTag contains the CIE 1931 XYZ colorimetry of the white point of the actual medium, adapted to the PCS illuminant (D50)
  - The chromatic adaptation matrix is applied to the colorimetry of the white point of the actual medium
  - In a DISPLAY profile - the mediaWhitePointTag must equal D50
- mediaBlackPointTag contains the CIE 1931 XYZ colorimetry of the black point of the actual medium
  - To be adapted to the PCS illuminant (D50) as needed

ICC Version 4 Changes - Chromatic Adaptation

- Consideration of an ICC Recommended Chromatic Adaptation Transform (CAT)
  - The use of different chromatic adaptation transforms is allowed in creating ICC profiles
  - Profiles based on different chromatic adaptation transforms will produce different colorimetric values in the PCS
  - In order to avoid unintentional variation in profiles and resulting PCS values, it is desirable to recommend a chromatic adaptation transform - to be used when there is no explicit reason to use another method
- Linear Bradford CAT will be recommended for consistent use in the next revision of the ICC specification

ICC Version 4 Changes - Chromatic Adaptation

- With Colorimetric PCS - example Annex E.2
  - Color-Rendering sequentially through a capture profile that uses one chromatic adaptation matrix method - and a display profile that uses a different chromatic adaptation matrix method

    - or -

  - Displaying two color-renderings of a source image that have each been color-rendered through different display profiles that differ in the chromatic adaptation matrix method used

⇒ Can result in visible hue shifts such as blue appearing purple

- With Perceptual PCS - undoing the profile's CAM to then apply a uniform chromatic adaptation method (in a sequence of profiles) may not deliver uniform results due to the proprietary renderings in the perceptual intent transforms

ICC Version 4 Changes - LUT Structures

- lutAtoB and lutBtoA
  - Shortcomings in the previous version t… form tag types
    - AToBn and BToAn t…s used lut8Ty… …t16Type structures
    - …ToBn structures … …t be th… of the BToAn structures
    - …atrix v…e…
    - Th… …ries in 8-bit
    - A si…
    - … each
    - T…
  - … …rrect these problems
  - Provide a … s… for … …play, an… …ut profiles
    - New L…-based di… …ofile - 6…
  - Improve interchange … PostScript
  - Note new parametric…rveType - 6.5.16
    - Describes a one-dimensional curve by specifying a predefined function

New lut structures correct deficiencies
in the lut8 and lut16 structures
and
provide a common lut structure for
input, display, and output profiles

ICC Version 4 Changes - LUT Structures

- lutAtoB and lutBtoA
  - Shortcomings in the previous version transform tag types
    - AToBn and BToAn Tags used lut8Type or lut16Type structures
    - AToBn structures could not be the reverse of the BToAn structures
      - The matrix was always performed first
    - The 1-D input and output tables were fixed to 256 entries in 8-bit
    - A single “gamma” value could not be used
    - The CLUT required that the number of grid points be the same in each dimension
    - There was no provision for a ‘placeholder’ element
    - The matrix had no provision for offset terms
  - The new lutAtoBType and lutBtoAType structures correct these problems
  - Provide a uniform structure for input, display, and output profiles
    - New LUT-based display profile - 6.3.2.3
  - Improve interchange with PostScript
  - Note new parametricCurveType - 6.5.16
    - Describes a one-dimensional curve by specifying a predefined function

ICC Version 4 Changes - LUT Structures

- lutAtoBType - 6.5.11
  - Either XYZ or LAB PCS encoding may be used with this tag type
  - Data are processed through the following computational elements:
    - ('A' curves)→ (multi-D CLUT)→ ('M' curves)→ (matrix)→('B' curves)
    - Curves are curveType or parametricCurveType
    - CLUT can have a variable number of grid points in each dimension
      - Number of dimensions is the number of input channels
      - Channel response may require fewer or greater # of grid points
    - CLUT can be 8-bit or 16-bit ⇒ improved with new uniform LAB values
      - Simple lossless 8-bit ⇔ 16-bit conversions using fixed point math
  - The following sequence combinations are allowed
    - B
    - M → matrix → B
    - A → CLUT → B
    - A → CLUT → M → matrix → B
    - Other sequence combinations can be achieved by setting processing element values to identity transforms
  - Improves compatibility for reformatting as a PostScript CSA

ICC Version 4 Changes - LUT Structures

- lutBtoAType - 6.5.12
  - Either XYZ or LAB PCS encoding may be used with this tag type
  - Data are processed through the following computational elements:
    - (‘B’ curves)→ (matrix)→ (‘M’ curves)→ (multi-D CLUT)→(‘A’ curves)
    - Curves are curveType or parametricCurveType
    - CLUT can have a variable number of grid points in each dimension
      - Number of dimensions is the number of input channels
      - Channel response may require fewer or greater # of grid points
    - CLUT can be 8-bit or 16-bit ⇒ improved with new uniform LAB values
      - Simple lossless 8-bit ⇔ 16-bit conversions using fixed point math
  - The following sequence combinations are allowed
    - B
    - B → matrix → M
    - B → CLUT → A
    - B → matrix → M → CLUT → B
    - Other sequence combinations can be achieved by setting processing element values to identity transforms
  - Improves compatibility for reformatting as a PostScript CRD

- Enhanced support for N-color profiles
  - Current N-colorant specification pertains to o utput profiles and named color profiles
  - Conside tion of future exp sion to in ofiles
- Addition of c ntTable 6.4 d colorantTableTy
  - This tag is re files when the pro paces
  - Count of co profile header
  - Specifies the nd an XYZ or L
    - Colorant coordinat e
  - The PCS value can used appl orithms derive the visual density of the colora d dete e overlay va ues
  - Colorant PCS values are pop ated by pro essing each colorant through the A2B1 (DEV to C lorimetric PCS) tag of the profile
- Does not replace namedColor2Tag for Named Color profiles

New colorantTableTag
specifies the colorants used in an output or
named color profile
by a unique name and
an XYZ or Lab PCS value

ICC Version 4 Changes - N-colorant tags

- Enhanced support for N-color profiles
  - Current N-colorant specification pertains to output profiles and named color profiles
  - Consideration of future expansion to input profiles
- Addition of colorantTableTag - 6.4.14 and colorantTableType - 6.5.3
  - This tag is required for output profiles and named color profiles when the profile color space signature is one of the xCLR color spaces
  - Count of colorants must match color space signature in profile header
  - Specifies the colorants used in the profile by a unique name and an XYZ or Lab PCS value
    - Colorant coordinates in the PCS color space of the profile
  - The PCS value can be used by trapping algorithms - to derive the visual density of the colorant and determine overlay values
  - Colorant PCS values are populated by processing each colorant through the A2B1 (DEV to Colorimetric PCS) tag of the profile
- Does not replace namedColor2Tag for Named Color profiles

ICC Version 4 Changes - N-colorant tags

- Addition of colorantOrderTag - 6.4.13 and colorantOrderType - 6.5.2
  - Provides control of colorant laydown order - N-color or CMYK
  - Count of colorants must match color space signature in profile header
  - When colorant laydown order is the same as the channel generation order listed in the colorantTableTag or the channel order of a color space such as CMYK this tag is not needed
- Clarification of colorant tags - changing specification from ‘Colorant’ to ‘MatrixColumn’ - affecting 6.3.1.2, 6.3.2.2, 6.4.4, 6.4.22, 6.4.41
  - Matrix-based input and display profiles are affected
  - redMatrixColumnTag replaces redColorantTag, green & blue...
    - Matrix values rather than XYZ values of colorants
- Deleted namedColorTag, namedColorType redColorantTag, greenColorantTag, blueColorantTag

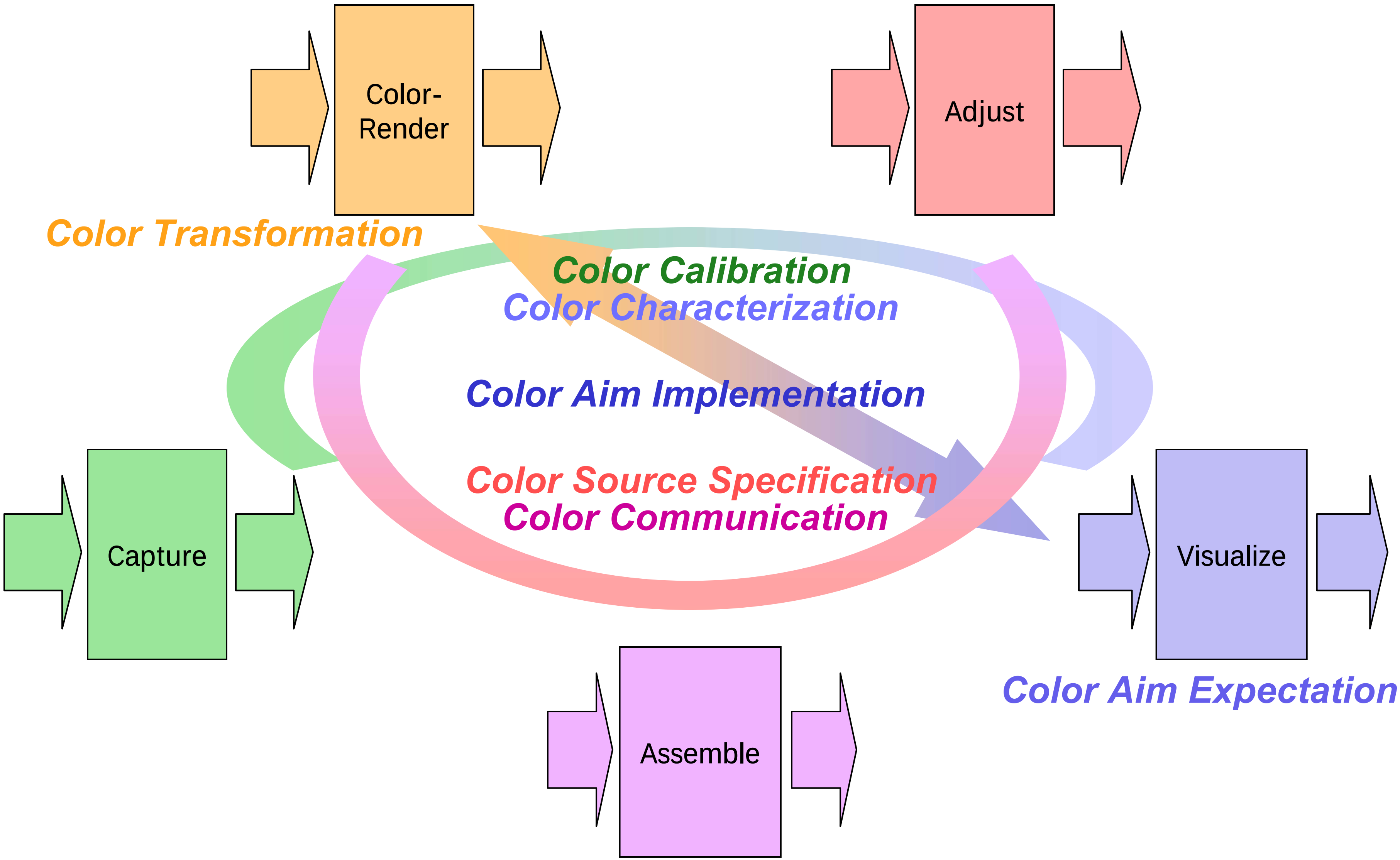
ICC Version 4 Changes - Unicode

- **All text fields formerly typed with textDescriptionType are now Unicode**
  - Deleted textDescriptionType
  - Replaced with multiLocalizedUnicodeType
  - Some uses of textType also converted
  - Multi-lingual Unicode strings supercede
    - textDescriptionType: ASCII, Unicode and ScriptCode alternatives
- Affected tags
  - copyrightTag, deviceMfgDescTag, deviceModelDescTag, profileDescriptionTag, screeningDescTag, viewingCondDescTag
- charTargetTag still uses textType
  - Contains the name of the registered characterization data set, or the measurement data for a characterization target
  - Enables identification of the underlying characterization data used to build a profile
  - ‘ICCHDAT’ value links to characterization data set on ICC website

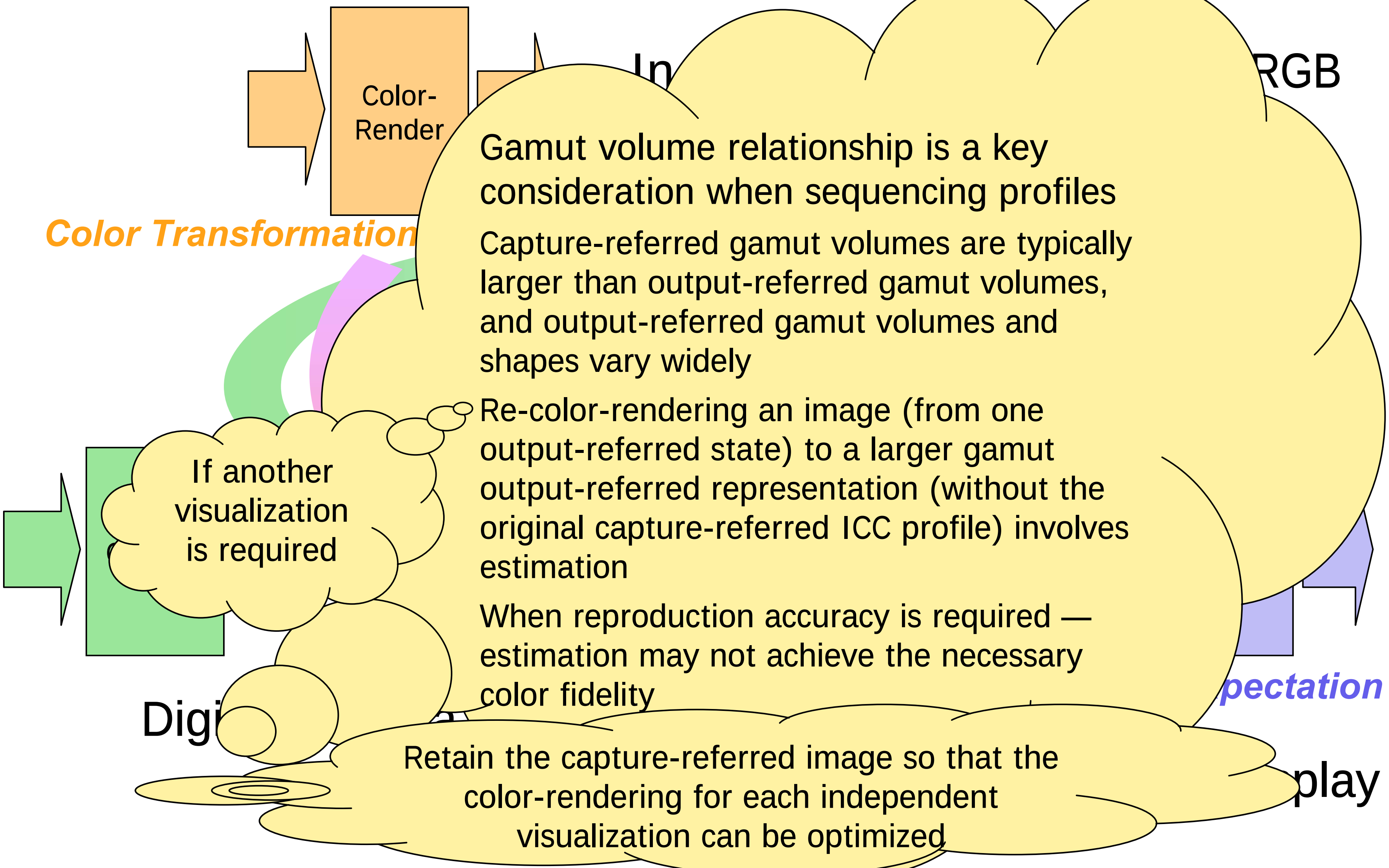
ICC Version 4 Changes ...and finer points...

- Profile ID field in header
  - Persistent profile identification in profile header
    - MD5 fingerprinting method - reference available on ICC website
  - Profile structure requirements
    - Allows each tag no more than three following NULL pad bytes to reach a long word boundary
    - All profiles are reduced to minimum size
- Change the definition of the gray profile
  - grayTRCTag
    - First element is black and last element is white in all cases
    - Additive interpretation for input, display, and output profiles
  - Values defined: 0 represents black and 1.0 represents white
    - Consistent for input, display and output profiles
    - Consistent with PostScript
- Consistent date/time values
  - All date/time values shall be in Coordinated Universal Time (UTC, also known as GMT or ZULU Time)

Version 4 Considerations in a Workflow



Sequencing ICC Profiles



If another visualization is required

Gamut volume relationship is a key consideration when sequencing profiles

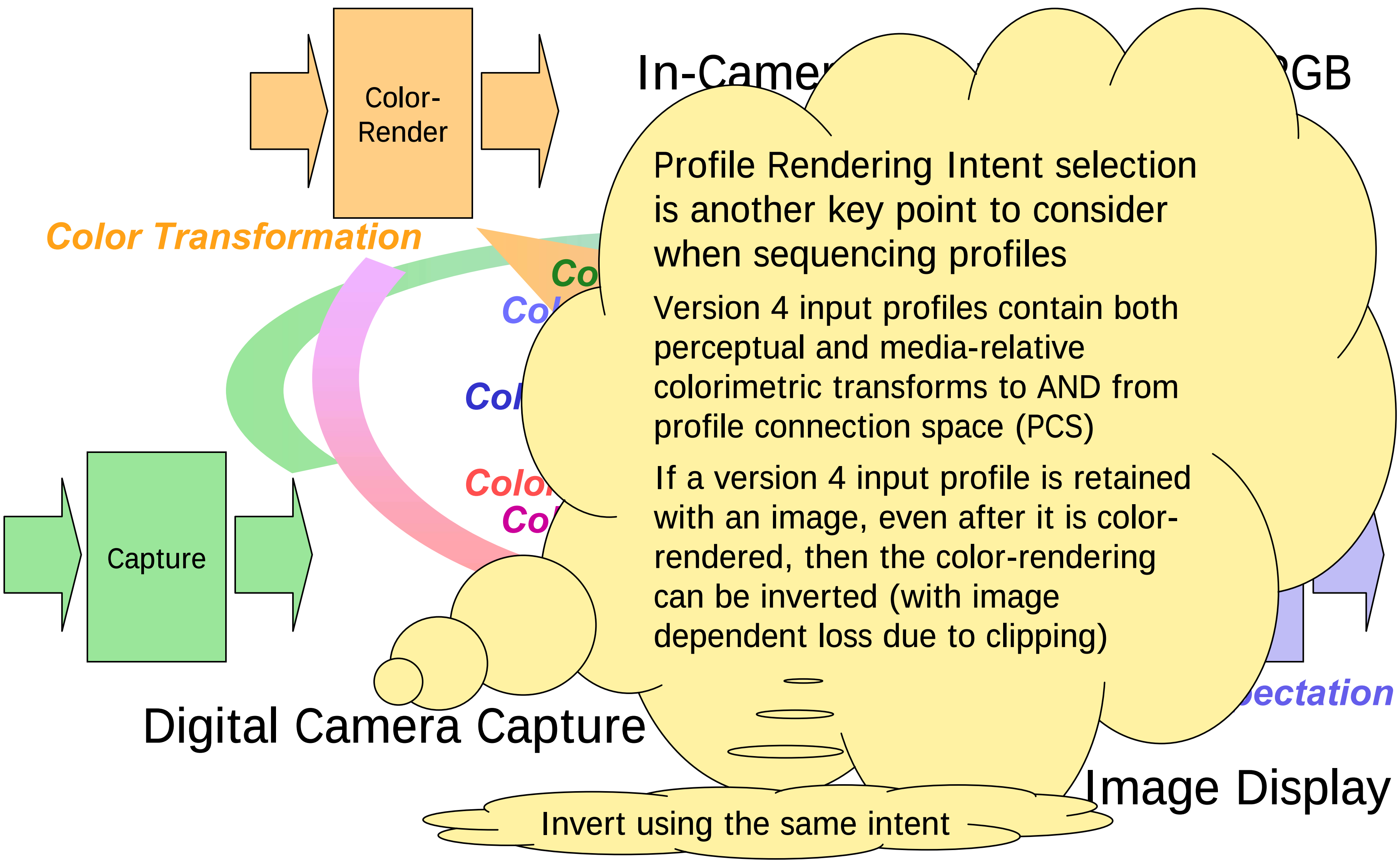
Capture-referred gamut volumes are typically larger than output-referred gamut volumes, and output-referred gamut volumes and shapes vary widely

Re-color-rendering an image (from one output-referred state) to a larger gamut output-referred representation (without the original capture-referred ICC profile) involves estimation

When reproduction accuracy is required — estimation may not achieve the necessary color fidelity

Retain the capture-referred image so that the color-rendering for each independent visualization can be optimized

Sequencing ICC Profiles



Sequencing ICC Profiles

Rendering Intent usage for general purpose pictorial reproduction:

perceptual from capture to PCS ⇒ perceptual to visualization

Perceptual PCS holds media-relative colorimetric values for an idealized visualization —which are then color-rendered to an actual visualization

When the capture goal is to accurately retain a limited gamut source image:

media-relative colorimetric from capture to PCS ⇒ perceptual or media-relative colorimetric to visualization

Recall: In this case PCS holds capture-referred media-relative colorimetric values - output conditions must be handled through the output profile

Perceptual transforms from PCS to DEV must handle the full range of PCS code values to enable connect *from* media-relative colorimetric DEV to PCS

Is the source image gamut well matched to the PCS? E.g., ~288:1 linear dynamic range?

Note that ICC profiles are capture condition or visualization condition specific, rather than image specific

Customizing the choice of Rendering Intent is one way to manage this

Colo

Color-rendering of scenes to reproductions typically includes a chroma and contrast boost

⇒ This boost must only be done once — in the DEV to PCS perceptual transform of the input profile

⇒ This boost is by nature a non-convergent operation, and if it is applied repeatedly produces unacceptable results

⇒ Perceptual PCS serves as a target for this scene to reproduction perceptual color-rendering

⇒ Subsequent reproductions through destination profile PCS to DEV perceptual or media-relative colorimetric transforms should not implement this boost

⇒ Any Version 4 destination profile DEV to PCS perceptual transform should only invert that profile's own PCS to DEV perceptual color-rendering

Expectation

oftcopy Image Display

Color Tra

Expectation

Digital

tcopy Image Display

Notes on Perceptual Color-Rendering:

The problem of color-rendering scenes to media includes compressing the scene gamut and dynamic range to that of the medium. However, while it is true that some scenes have colors out to the spectral locus and have very high dynamic ranges, many scenes do not. In fact, most scenes have dynamic ranges (and gamuts) smaller than the 288:1 of the PI reference medium.

The **essential problem** dealt with in a scene to reproduction perceptual transform — is to map low, medium, and high scene dynamic ranges to the fixed range of a reproduction in pleasing ways. The single most consistent part of this mapping is a boost of the scene gamut and mid-tone contrast.

> E.g, film reproduction systems have a mid-tone gamma greater than unity (~ 1.2 to 1.6). Video systems have a system gamma of ~1.2 to 1.4 and some highlight compression (at least in high-end systems).

Optimal mappings can differ for scenes of low, medium, and high dynamic range

Sequencing ICC Profiles

Colo

Additional Rendering Intent sequence examples:

Colorimetric (within gamut intersection) proof of original on output (media relative): Use media-relative colorimetric to and from PCS

NOTE: Appropriate for reproductions on similar media

Colorimetric (within gamut intersection) proof of reflection hardcopy original on reflection hardcopy (absolute): Use absolute colorimetric to and from PCS

Proof of PCS reference medium image: Use perceptual into PCS and media-relative colorimetric from PCS

NOTE: Appropriate for slide scans and scene capture, where a colorimetric proof of the scene is not appropriate, but the objective is to proof the PI reference medium image on a similar real (i.e., photo quality) medium (black point scaling may be a CMM option)

Black Point note: In the perceptual PCS, colors with an L* less than 3 are not defined. Colorimetric PCS, however, does have a defined meaning for colors with an L* less than 3. The Colorimetric PCS black point is the real capture black point.

The relationships between the capture condition gamut, the visualization condition gamut, the specific image gamut, and the color fidelity requirements, determine the best choice of Rendering Intents

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Image Specific Profiles for Color-Rendering

Color Tra

An image specific (or image type) profile can be used to apply an optimal color-rendering from a capture-referred state to the output-referred PCS

Consider the dynamic range difference between the source **image** and PCS Reference Medium and then determine how much black clipping to do, and how to shape the tone curve to rescale the values

A combination of shadow and highlight compression coupled with lightening can be used when transforming from a higher range medium to a lower range medium

Mid-tone gamma, chroma boost, gamut expansion or compression, can be balanced for the particular image or image type

Optimal mappings can differ for scenes of low, medium, and high dynamic range

Expectation

Digital

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Image Specific Profiles - Adjusting

Color

Also, an image specific (or image type) profile might be used to encode global preference adjustments for an image, avoiding actually modifying the image code values until the image is transformed for visualization

Preference edits can be captured by modifying the perceptual intent transforms (both DEV to PCS and PCS to DEV) in either a source or destination profile

When a source profile associated with a capture-referred image is adjusted to deliver a specific preference, that preference will be carried to all succeeding perceptually color-rendered visualizations

When a destination profile associated with a capture-referred or reference-output-referred image is adjusted to deliver a specific preference, that preference will be realized in the specific destination visualization — if the perceptual color-rendering transform in the destination profile is used

An abstract profile is another option.

Adjusting a source profile associated with a reference-output-referred image can be problematic — The edits will not be applied when the colorimetric DEV to PCS transform is used (as in the retargeting case) — and may not be optimal for an unknown re-purposing case

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ICC Version 4 Impact on Color Control Architecture Elements

- Device calibration
- Capture and visualization characterization
- Profile creation
- Image color encoding
- Profile selection and exchange
- Profile use
- Visualization – the human element