Features of iccMAX

ICC DevCon 2020 - The Future of Color Management

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Resources for iccMAX

- The specification document
  - ICC.2 specification on ICC web site
  - ISO 20677 from ISO
- Demonstration implementation
  - https://github.com/InternationalColorConsortium/RefIccMAX
    - iccFromXML useful for creating iccMAX profiles from XML representation
- Example iccMAX Profiles
  - http://www.color.org/iccmax/profiles/index.xalter
  - http://www.color.org/iccmax/download/RefIccMAX-Testing-2.1.17.zip
- ICC White Papers and other information on www.color.org

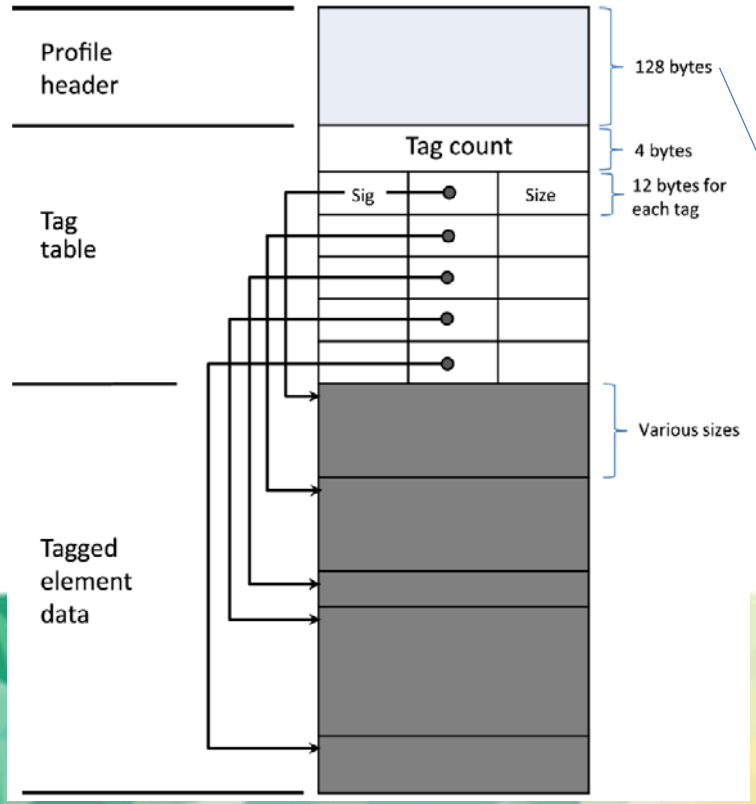
Overview of iccMAX Specification?

1. Scope, references, terms, definitions and abbreviated terms
2. Basic types
3. Conformance guidance
4. Expanded PCS discussion
5. Profile requirements
6. Minimally required tags for profile classes and tag precedence
7. Tag definitions (Section 9)
8. Tag type definitions (Section 10)
9. multiProcessingElementType definitions (Section 11)
10. Struct tag type definitions (Section 12)
11. Tag array type definitions (Section 13)
12. Annexes providing profile creation specifics and CMM implementation guidance
    - Annex A – Elemental calculations and inter-PCS operations
    - Annex K – Workflow scenarios and CMM processing control options

What are the main use cases for iccMAX?

- Expanded PCS functionality
  - Spectral processing
  - Alternate PCS colorimetry
  - Alternate illuminants and observers
- Extended color metrology
  - Support for bi-spectral and multi-angle measurement and processing
- Extended nameColor profiles
  - Encoding of tints, spectral processing, unsupported transforms, non-0:45 measurements, alternative illuminants and observers
- Multiplex Connection
  - Ability to have flexibility in connection beyond appearance
- Extended transform functionality
  - Programmable transforms
- Alternative to embedding transforms in profile
  - Pointers to reference encodings

iccMAX Profile Format Overview



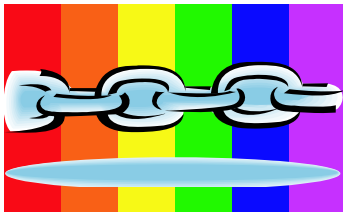
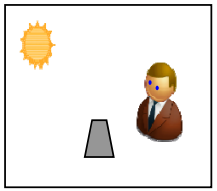
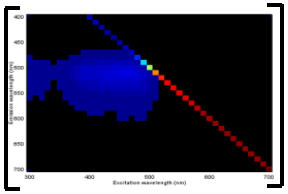
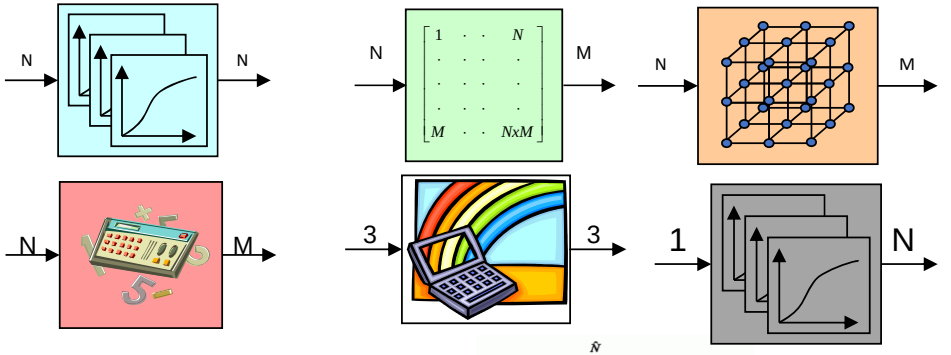
Byte Position	Field length (bytes)	Field contents	Encoded as
0 to 3	4	Profile size	UInt32Number
4 to 7	4	Preferred CMM type	See 7.2.5
8 to 11	4	Profile version and sub-version number	See 7.2.6
12 to 15	4	Profile/Device class	See 7.2.7
16 to 19	4	Colour space of data (possibly a derived space)	See 7.2.8
20 to 23	4	PCS	See 7.2.9
24 to 35	12	Date and time this profile was first created	dateTimeNumber
36 to 39	4	'acsp' (61637370h) profile file signature	See 7.2.11
40 to 43	4	Primary platform signature	See 7.2.12
44 to 47	4	Profile flags to indicate various options for the CMM such as distributed processing and caching options and MCS connection requirements	See 7.2.13
48 to 51	4	Device manufacturer of the device for which this profile is created	See 7.2.14
52 to 55	4	Device model of the device for which this profile is created	See 7.2.15
56 to 63	8	Device attributes unique to the particular device setup such as media type	See 7.2.16
64 to 67	4	Rendering Intent	See 7.2.17
68 to 79	12	The nCIEXYZ values of the illuminant of the PCS.	XYZNumber
80 to 83	4	Profile creator signature	See 7.2.19
84 to 99	16	Profile ID	See 7.2.20
100 to 103	4	Spectral colour space signature	See 7.2.21
104 to 109	6	Spectral PCS wavelength range	spectralRange
110 to 115	6	Bi-spectral PCS wavelength range	spectralRange
116 to 119	4	MCS signature	See 7.2.24
120 to 123	4	Profile/Device sub-class	See 7.2.25
124 to 127	4	Reserved bytes shall be set to zero (00h)	See 7.2.26

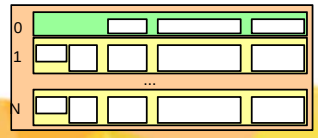
iccMAX High Level Features

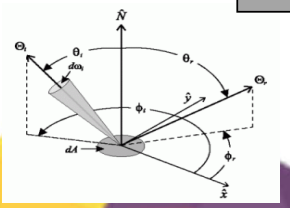
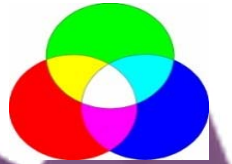
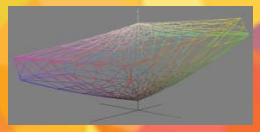
- Spectral PCS to enable spectral communication of color information
  - Illuminant and observer can be defined
- Extended CMM functionality
  - Support for spectral data
  - New Gamut Boundary Description
  - Encoding of BRDF parameters
  - New encoding of Named Colors to support tints
- Hierarchical data encoding
- multiProcessElements with programmable transforms
  - Functional operators, conditional evaluation and vectorized operations
- Color appearance processing
  - Facility to store appearance attributes in a profile processing elements
- Abbreviated profiles
  - References to color encoding standard or to existing profile

iccMAX – High Level Overview

- Connection Space Extensions
  - Spectral profile header extensions
  - Profile Connection Condition (PCC) tags
  - PCS Transforms
  - Sparse matrix encoding
  - Material Connection Spaces
- multiProcessingElements
  - 1-D Look Up Tables (LUTs)
  - Matrices
  - N-dimensional LUTs
  - Calculator element
  - ICC Color Appearance Model element
  - Tint Array element
- Hierarchical tag types
  - Named Color Tag Array
  - Support for angular dependencies via Bidirectional Reflectance Distribution Functions (BRDF)
  - *Profile Sequence Information*
- Other Extensions
  - Color Space Encoding profiles
  - Gamut Boundary Description encoding
  - *Color Measurement (CxF) tag encoding*
  - *UTF8 text & UTF16 encoding*
  - *Additional Numeric Array Types*

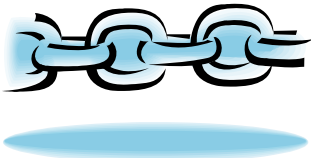


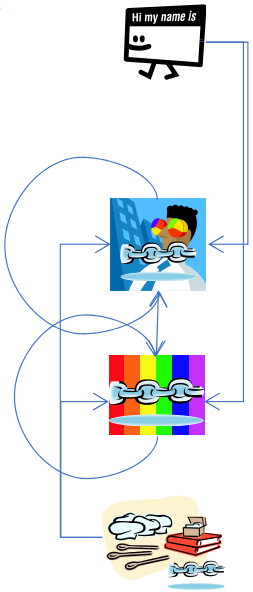
iccMAX Color Spaces

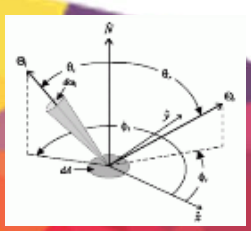
- Colorimetric Profile Connection Spaces
  - Same as defined in ICC.1 (XYZ and L*a*b*)
  - Observer and Illuminant can vary as defined by spectral viewing conditions tag
- New Extended Color Space Signatures Types
  - Allow from 1 to 65535 channels to be defined
- Device color spaces and color encodings
  - Color space signatures as defined in ICC.1
  - Profiles can point to registered color space encodings and associated transform
  - Additional extended N-channel color space signatures defined
    - “ncxxxx” multi-channel color space with XXXX channels defined in header
- Multiplex Connection Spaces
  - Additional tags define multiplex connection channel names and default values
    - “mcXXXX” “multiplex” values with XXXX channels defined in header

iccMAX Connections

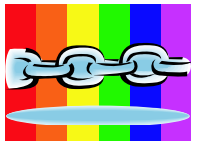


- iccMAX supports five types of inter-profile connections
- Colorimetric Connections (How does an observer see it?)
  - Connection provided by B in A2Bx/B2Ax transform tags
  - Can be linked with both Colorimetric and Spectral connection tags
- Spectral Connections (What is its relationship to light?)
  - Connection provided by B in D2Bx/B2Dx transform tags
  - Can be linked with both Colorimetric and Spectral connection tags
- Named Color connections
  - Provides relationship between named colors and colorimetric, spectral as defined by header PCS fields as well as optional BRDF information
  - Can be linked with colorimetric and spectral connection tags
- Multiples Connections (What is it?)
  - Connection provided by M in A2M0, M2A0, M2B0, and M2A0 transform tags
  - M2B0 tags can be connected to B2Ax Colorimetric connection tags
  - M2S0 tags can be connected to B2Dx Spectral connection tags
- BRDF Connections (How color change at different angles?)
  - Profile transforms provided in BRDF tags





iccMAX PCS Support



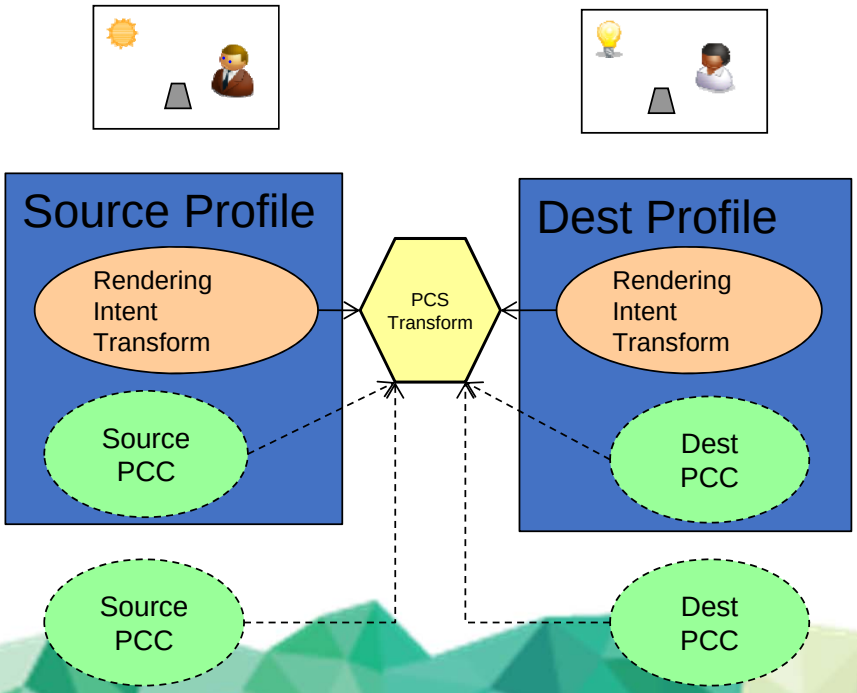
ICC.1 PCS Support

	From Lab	*From XYZ*	*From Reflectance*	*From Transmittance/ Transmissive*	*From Radiant/ Emission*	*From Fluorescence*
To Lab	Yes	Yes	Using PCC	Using PCC	Using PCC	Using PCC
To XYZ	Yes	Yes	Using PCC	Using PCC	Using PCC	Using PCC
To Reflectance	No	No	Yes	Yes	Extract PCC illuminant	Apply then extract PCC illuminant
To Transmittance/ Transmissive	No	No	Yes	Yes	Extract PCC illuminant	Apply then extract PCC illuminant
To Radiant / Emission	No	No	Apply PCC Illuminant	Apply PCC illuminant	Yes	Apply PCC illuminant
To Fluorescence	No	No	No	No	No	Exact match required

Operations to perform conversions are outlined in Appendix A of iccMAX Specification

PCC = Profile Connection Conditions

iccMAX Profile Connection Conditions

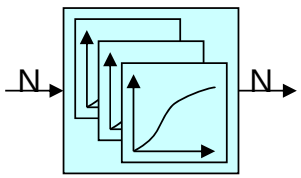


Allows PCS data in profiles to use actual viewing conditions
PCC is required in profile if D50 PCS is not used

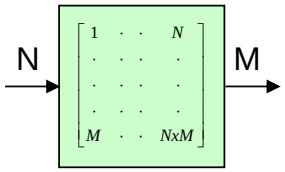
- Source and destination profiles can have different Connection Spaces
- Profile Connection Conditions provide additional information for the CMM to perform spectral and custom colorimetric PCS processing (e.g. illuminant, observer, viewing conditions, and conversion transforms)
- PCC information can come from either the profile or externally provided to the CMM

Processing with multiProcessElements

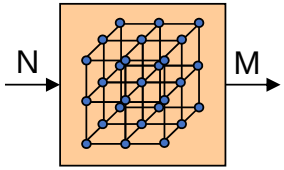
- Allows processing workflows to be defined using an arbitrary order of flexible processing elements with 32bit floating point processing
- Completely defines transformations from input to output



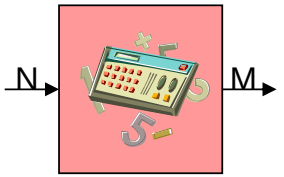
1-D LUTs



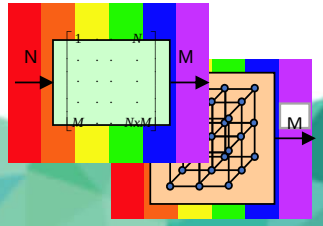
NxM Matrix



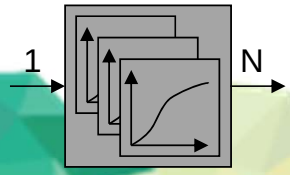
Multi-Dimensional LUT



Programmable Calculator



Spectrally Defined Colorimetric



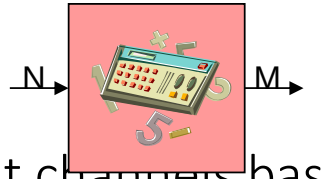
Tint Curves

Colour Appearance Model

Placeholder

Programmable Calculator Element

- Provides mechanism for encoding more complex (non-linear) device models
  - Avoids limitations of Color Look-Up Table(CLUT) accuracy and massive storage requirements when many input channels are used
  - Possible to embed and use other processing elements
  - Results in smaller and potentially more accurate profiles



- Defines a script based expression calculator to determine output channels based upon input channels
  - Uses a sequence of operations that apply to a Reverse Polish Notation (RPN) argument stack
  - Finite memory storage for temporary results
  - Nearly all operations are vector based (operating on multiple channels at same time)
  - Secure deterministic behavior

iccMAX Workflows

- iccMAX defines a platform for defining domain specific color management workflows
- iccMAX workflows are defined by iccMAX Interoperability Conformance Specification (ICS) documents separate from iccMAX specification
  - ICS documents define workflow specific requirements utilizing features of iccMAX specification
  - ICS documents will be registered with the ICC for defining various domain specific workflows
- Not every feature of iccMAX specification needs to be implemented to support an iccMAX based workflow
- Allows for future iccMAX extensions

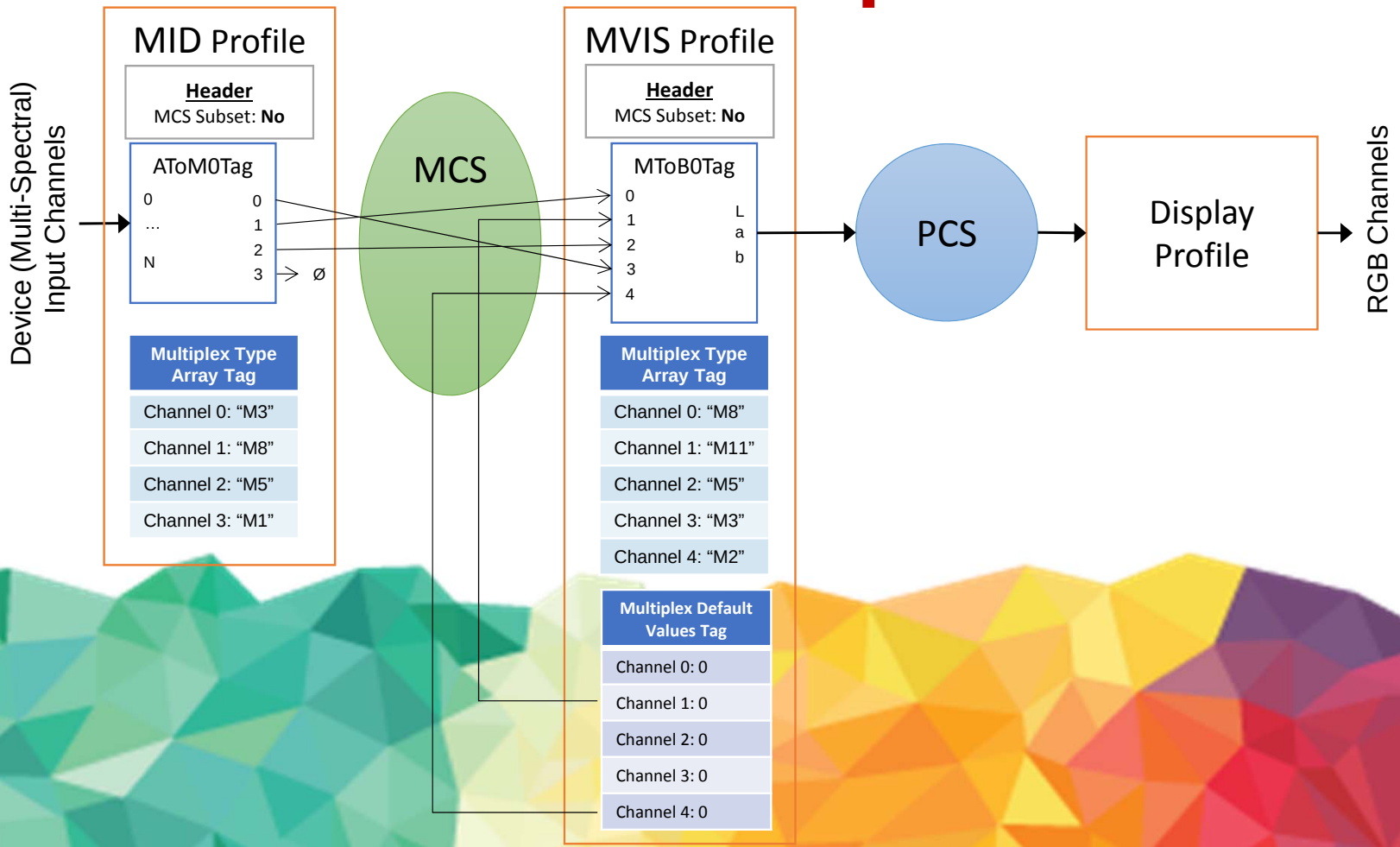
Color Appearance Model MPE extensions

- ICC defines a Color Appearance Model (IccCAM) with a modification of CIECAM02 to avoid problems found with CIECAM02
- Color appearance parameters to apply are stored as part of each IccCAM based processing element
  - *XYZtoJab element*
    - Uses IccCAM model to convert from colorimetry to cartesian based color appearance correlates
  - *JabtoXYZ element*
    - Uses IccCAM model to convert from cartesian based color appearance correlates to colorimetry
- Uses:
  - XYZtoJab and JabtoXYZ processing elements can be used to define standardToCustomPCS and customToStandardPCS tags
  - CLUT's can be addressed using Jab

Multiplex Connection Workflows

- Some workflows require a connection based upon a description that defines what the color channels are rather that how they look or are related to light (PCS's)
- Examples include:
  - Pigment Identification
    - Going from Multi-spectral capture to Pigment identification to Visualization of pigments
  - Medical imaging
    - Scanning to RGB + channels that provide bio-marker information to visualization of scan with bio-markers
  - Ink Visualization
    - Going from printed ink channels to visualization of different ink orders or use of spot inks
  - Satelite imaging
    - Going from Hyper-spectral capture to feature identification to Visualization of features
- Could be implemented as Device Link Profile – but number of channels and channel order are fixed

MCS Connection Example

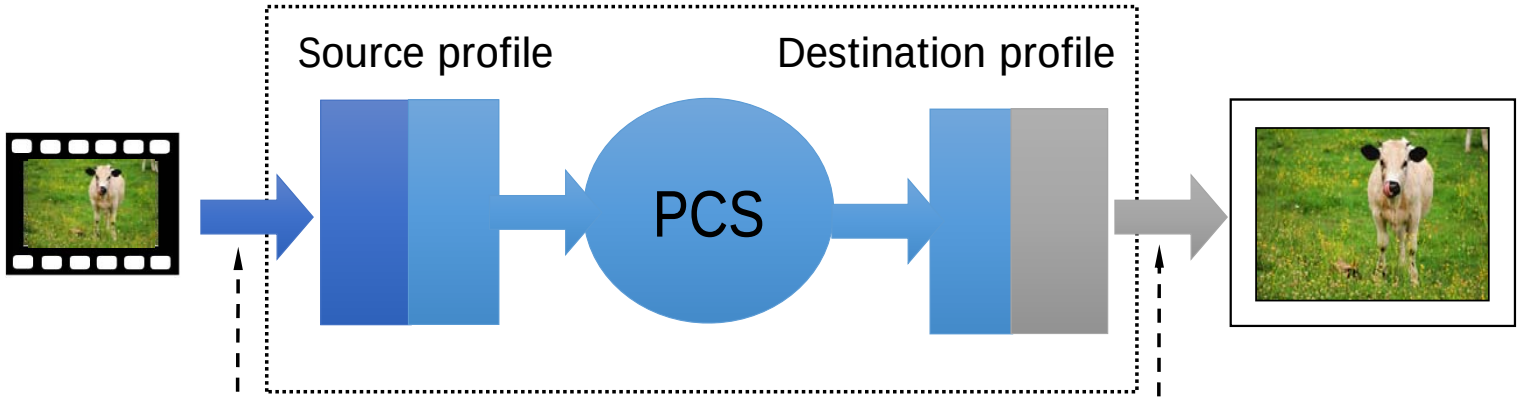


Configuring Profile Connection

Introduction to Resource on ICC web site

ICC Color Management Basics

- In an ICC color managed workflow, profiles are typically used to transform between a source and destination color encoding (sometimes inexactly called a color space).



Making Connections with iccMAX

- Useful information about “Making Connections with iccMAX” can be found on ICC web site
  - http://www.color.org/iccmax/connecting_with_iccMAX.xalter
- Intended for people who want to have a rudimentary understanding about what it means to connect and work with ICC profiles and especially iccMAX profiles
- Main focus is about how one configures profile connection and profile usage
  - Uses fairly high-level description of basically what the CMM is doing when profiles are connected
  - Contrasts and expands upon profile connection using version 2 and version 4 ICC profiles

Questions that are answered

- What options are needed to have/use for configuring the connection?
- What parts of the profiles are used, and how are they used (on a high level)?
- What is the CMM doing (on a high level) to make the connection work?
- What kinds of things can one accomplish using different profile connection parameters?

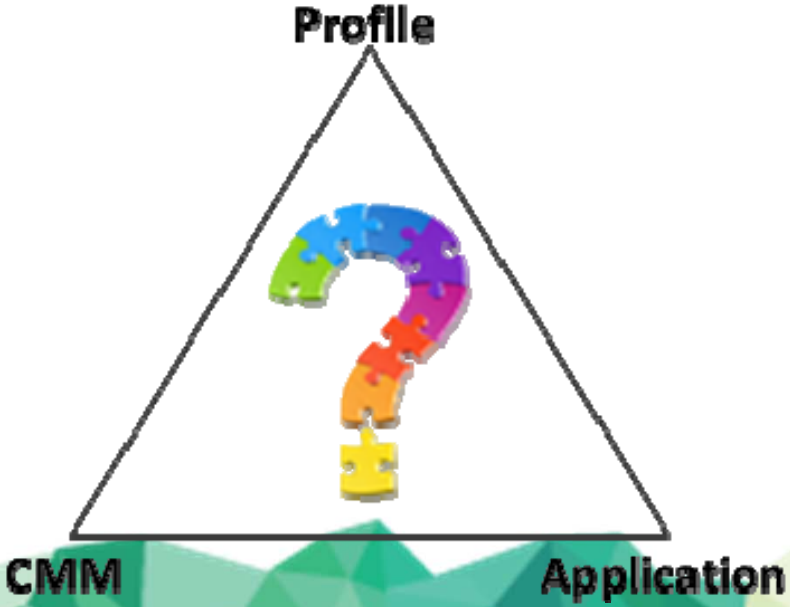
Two key concepts related to profile connection

- Transform Selection
  - Based on:
    - Profile Class
    - Position (in transform chain)
    - Rendering Intent
    - Transform Type
      - V2/V4 transform types:
        - Color transformation (matrix/TRC or N-D LUT)
        - Named Color
        - Preview
        - Gamut
        - MPE (in V4.3)
- PCS conversion/adjustment
  - Performed by CMM and may involve:
    - Pass Through (no change)
    - Colour Space Conversion
    - Rendering intent adjustment
    - CMM controlled adjustment

More on Transform Type

- Defines how the profile is used, and is associated with the workflow “scenario” that is involved
- Transform type options are dependent on the profile class/sub-class
- Transforms for different transform types may have different connection endpoints
- Transform type may either be explicitly selected as a CMM control option (in addition to rendering intent) or transform type may simply involve the use of different interfaces of the CMM
- Transform type is often overlooked in V2/V4 because it is explicitly assumed (usually colour transformation with tag precedence applied) or only one transform type is supported/implemented by the CMM

Where are decisions made?

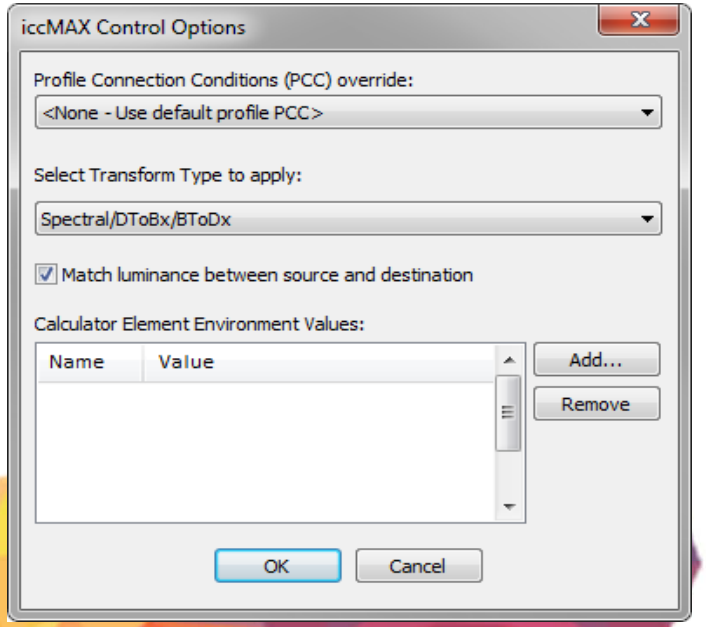


- Most decisions are made by the profile maker when creating the Profile
- Results in “smart” profiles encoded in transforms
- Profiles applied by a “dumb” CMM that only knows how to apply the transforms
- Variability is encoded as separate transforms that the Application can select from

- Approach used by v2/v4/iccMAX

Extending the “Dumb CMM” for iccMAX

- Though limitations have been overcome and capabilities have increased with iccMAX, the fundamental approach of having limited CMM decision-making has remained for the same reasons as for V2/V4 profiles
- More information is required in iccMAX profiles and more selections are presented to or by calling applications
  - Transform Type
  - Profile Connection Conditions (PCC) override
  - Calculator Element Environment Values
  - Option to match luminance between source and destination profiles



Connecting profiles with iccMAX

- Transform selection and PCS Conversion / Adjustment are still the two key aspects of connecting with iccMAX profiles
- However, significant extensions of these concepts are introduced to allow for a wider variety of colour management scenarios to be accomplished

iccMAX Transform Type Selection

- Extended transform types
  - Color (colorimetric / spectral)
  - BRDF parametric (colorimetric / spectral)
  - BRDF sampled (colorimetric / spectral)
- Multiple transform types in same profile
- The use of transform type becomes critically important to differentiate and select between workflow scenarios
- Establishes both the transform tag as well as the associated PCS configuration used for the profile connection within the CMM
  - PCS configuration is associated with colour space encoding, illuminant, observer, and spectral ranges as they apply

iccMAX PCS Conversion/Adjustment

- From high level the PCS operations are generally the same as PCS operation with V2/V4 profiles (though with more options and details involved)
  - Pass through (when PCS configurations are the same)
  - Colour configuration conversion
    - Involving Profile Connection Conditions as needed
  - Rendering intent adjustment
  - CMM controlled adjustment

Profile Connection Parameters

Various parameters are used by the CMM when connecting profiles to determine what tags to use from the profiles and how to make PCS connection conversions

- V2/V4 parameters
  - Profile file and its profile class
  - Position of profile in transform sequence
  - Rendering Intent
  - Transform Type
    - Usually assumed to be colorimetric
  - CMM controlled adjustments
    - Black point compensation is an example
- Additional iccMAX parameters
  - *Note: Transform Type selection is required*
  - PCC override option
  - CMM environment values
  - Other CMM controlled adjustments
    - Mapping lightness

Example Connection Scenario

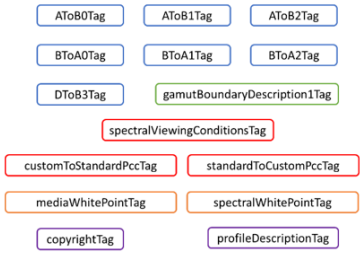
Simulating to the standard observer on an RGB display how a CMYK print generated for one observing condition is seen for a different observing condition

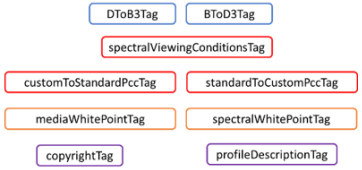
V2.1 RGB profiles

ID	Description	Tag Content Overview	Details
A	RGB Profile	redMatrixColumnTag, redTRCTag, greenColumnMatrixTag, greenTRCTag, blueMatrixColumnTag, blueTRCTag, mediaWhitePointTag, copyrightTag, profileDescriptionTag	Version: 2.1 Class: ColorSpace Sub-Class: - Colour Space: RGB Colorimetric PCS: XYZ Spectral PCS: - Illuminant: D50 Observer: Std. 2 degree

ID	Description	Tag Content Overview	Details
B	RGB Display Profile	redMatrixColumnTag, redTRCTag, greenColumnMatrixTag, greenTRCTag, blueMatrixColumnTag, blueTRCTag, mediaWhitePointTag, copyrightTag, profileDescriptionTag	Version: 2.1 Class: Display Sub-Class: - Colour Space: RGB Colorimetric PCS: XYZ Spectral PCS: - Illuminant: D50 Observer: Std. 2 degree

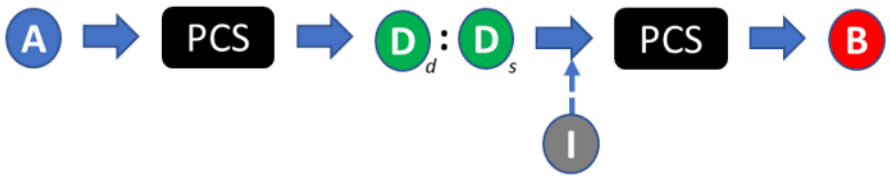
iccMAX Profiles

ID	Description	Tag Content Overview	Details
D	iccMAX CMYK Printer Profile		Version: 5.0 Class: Output Sub-Class: ExtendedOutput Colour Space: CMYK Colorimetric PCS: Lab Spectral PCS: Reflectance Illuminant: Illum. A Observer: Std. 2 degree PCC Conversion: Wpt MAT ICS: TBD

ID	Description	Tag Content Overview	Details
I	iccMAX Spectral PCC Profile		Version: 5.0 Class: ColorSpace Sub-Class: TBD Colour Space: 6-Channel Colorimetric PCS: None Spectral PCS: Reflectance Illuminant: F5 Observer: Custom PCC Conversion: Wpt MAT ICS: TBD

Example iccMAX Connection Scenario

Simulating to the standard observer on an RGB display how a CMYK print generated for one observing condition is seen for a different observing condition

Profile Sequence	Profile Setup		
	A	Rendering Intent:	Perceptual
		Transform Type:	Colorimetric
		PCC Override:	Ignored
	D_d	Rendering Intent:	Perceptual
		Transform Type:	Colorimetric
		PCC Override:	None
	D_s	Rendering Intent:	Absolute
		Transform Type:	Spectral
		PCC Override:	I
	B	Rendering Intent:	Absolute
		Transform Type:	Colorimetric
		PCC Override:	Ignored

Thank You!