Using ICC Profiles for Motion Picture Production

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Agenda

- Industry-specific requirements
- Using ICC profiles in motion picture workflow
- Camera Negative Profile - Creation and Challenges
- ICC's new Floating Point Device Encoding Range

Hollywood drives Color

- **Color-Managed Capture, Editing, Distribution, and Projection**
  - Preserve the director's artistic intent throughout the workflow
    - Set color at capture; confirm in editing; expect in theater

- **Real-time processing needs extreme data rates**
  - 24 fps, 4k Wide x 2k High, 12x3 bits/pixel, uncompressed
  - Data rate = 7 Gbits/second
  - Pixel rate = 200 Mpixels/second
  - Conversion rates achievable with GPUs

Hollywood drives High Dynamic Range

- **Large-scale digital rendering of High-Dynamic Range images**
  - (Some video games already use HDR for synthetic images)
- **Digital movie production and release**
  - Mass-delivery of digitally HDR-rendered images
    - 178,000 HDR-rendered images for the price of a movie ticket

What are High-Dynamic Range images?

- The dynamic range (black to white) of the image exceeds the dynamic range available from a normal display
- The entire image cannot be displayed well on a normal display

- For more info: http://en.wikipedia.org/wiki/Hdr

– View shadows

View highlights

Source: Stu Maschwitz, The Orphanage

Drives application development

- **Vertical applications need to support “Cinematic Color”**
  - Support evolving standards for movie production
    - Color, compression, file formats, workflows
  - Support emerging digital movie cameras and formats
  - Photo-realistic High-Dynamic-Range image editing
  - Fully color-managed pipeline and media conversions
  - GPU for real-time performance

- **Expect these requirements to trickle down to HD video and some multi-media applications**

Movies and Graphic Arts need Common Color Foundation

- **Media have converging needs**
  - Same contents are published for a range of devices
    - Movies are shown in cinema theater, on TV, PC, video player
  - Contents from different vendors go to same device
    - User views Flickr and Google web pages on same display
  - Multiple media types are shown on same device
    - User's display shows text, pictures, video, movies, games
  - Same media file can hold line-art, pictures, animation, video/film
    - Examples: Web pages, Flash, PDF, games
- **Threat of inconsistent color appearance**
  - Multiple, conflicting standards for content creation
  - Multiple, conflicting standards for device calibration
- **Can ICC provide a common foundation?**
  - Source metadata and single target calibration

Q. Can ICC profiles be used in Color Management for Motion Picture Production ?

A. Yes, but read more …

From LUTs to ICC profiles

- **Look Up Tables (LUTs) common in movie industry**
  - Many proprietary 3D LUT formats
    - We found over 25, some encrypted
  - Few structural options: three 1D LUTs or one 3D LUT
  - Simple to build
  - Limited accuracy (3D)
  - Poor round-tripping precision (3D)

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

From LUTs to ICC profiles

- **ICC profile model supports many conversion stages**
  - Up to 5 stages per profile enable improved device modeling
  - Profiles created per device, then connected
  - Profiles connected by colorimetry
  - More complex to build, enables high accuracy, modularity

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

A Color Management Architecture for Digital Motion Picture

- **Color management goals**
  - Consistent appearance on any display
  - Preview of theater appearance
  - Convert between scanned camera film and linear-light working space

Profile Architecture in DMP workflow

- **Connecting film in -> scene space -> film out**
- **Theater preview is possible in all stages of editing**

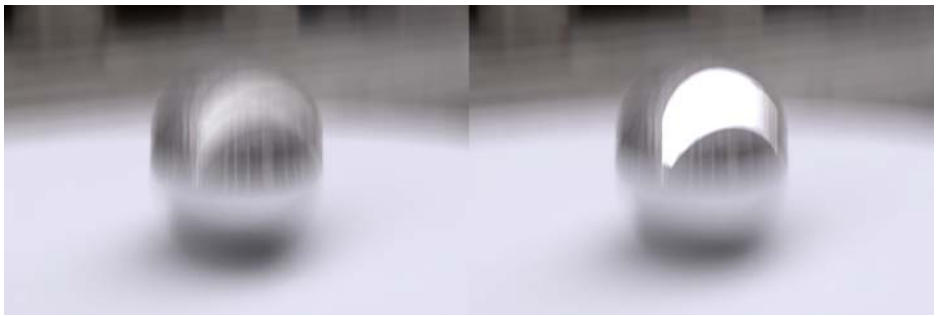
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Four profiles needed in DMP

- **Camera negative profile ← NEW**
  - Calculating scene colorimetry from film density (DPX)
- **Working space profiles**
  - Converting to RGB color space for compositing
- **Theater preview profiles ← NEW**
  - Calculating a preview of how the film would appear in an actual cinema theater
- **Display profile**
  - Converting to your preview (computer) display

Camera Negative Profile - Creation and Challenges

Purpose of Camera Negative Profile

- **Scanned film must be edited for Visual Effects or compositing**
- **Some editing is best done in a linear-light Scene Space**
  - Effects (such as motion blur or adding shadows) are more photo-realistic when made in scene colorimetry
    - Example from http://en.wikipedia.org/wiki/Hdr
- **Rendered**  **Linear Scene**
- **For editing: Convert film density to Scene Colorimetry**
- **When saving: Convert Scene Colorimetry back to film density**
  - Requires perfect round-trip

Model for Camera Negative Profile

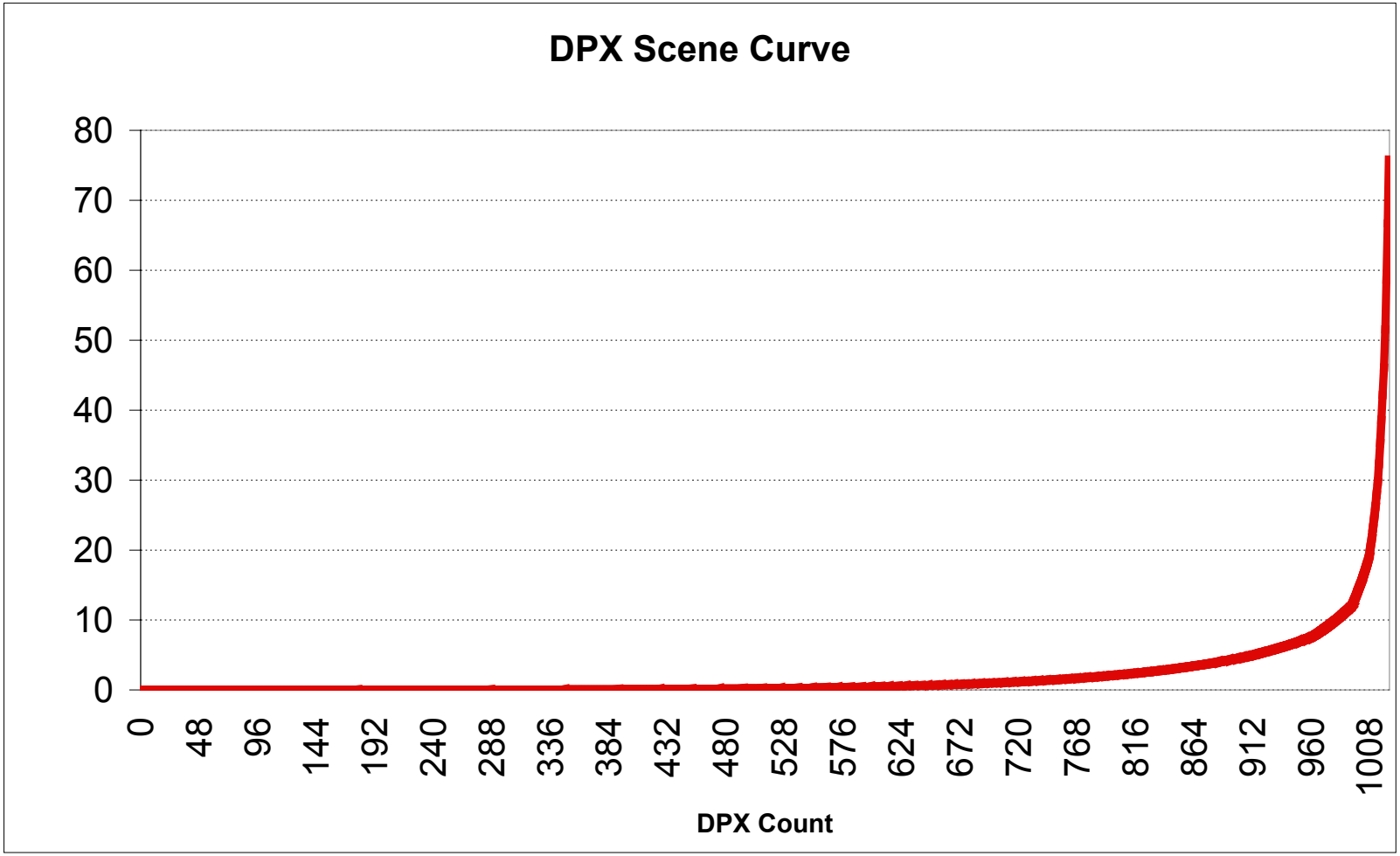
- **Use the ICC Curve-and-Matrix model:**

  Film density → Three 1-D LUTs → 3x3 Matrix → Scene XYZ

  - This Curve-and-Matrix model can be inverted exactly for converting Scene XYZ to Film density
  - NOTE: 3D LUTs cannot be inverted exactly

- **Determine the three 1-D LUTs and the 3x3 Matrix parameters**
  - From published data for KODAK VISION2 500T Color Negative Film 5218 / 7218

Determining the three 1-D LUTs



Challenges

- **The output Y range = [0, 76] exceeds White = 1**
  - The ICC Profile can only encode values in the range [0, 2]

- **The curve has a long, flat section**
  - Input values 0-40 map to same output value 2 in 16-bit
  - 16-bit integer encoding causes severe quantization in shadows

ICC's new Floating Point Encoding for Digital Motion Picture

Floating-point Requirements

- **Extend ICC Profiles to support:**
  - Floating-point precision in transform elements
    - No quantization in shadows
  - PCS Encoding Range beyond [0,1]
  - Device Encoding Range beyond [0,1]
- **Ease creation of film-to-scene profiles**
- **Make extension backwards-compatible with ICC 4.2 Profiles**

ICC extends profile format with "Floating Point Device Encoding Range"

- **Floating-Point extension approved in 2006**
  - Floating-point encoding and overranged connection space
  - New tag type multiProcessElementsType
  - New series of tags BToDx, DToBx
- **Specification published on ICC Web site**
  - http://www.color.org/ICCSpecRevision_02_11_06_Float.pdf
- **Sample implementation available to ICC Members**

Flexible Data Representation

- **Supports Arbitrary Un-building and Rendering Models**
  - Building blocks: Curves, Matrices, and Multi-Dimensional LUTs
  - Any number of building blocks - in any order
    - Up to 4 Gbyte total profile size, 65535 channels
  - Curves can be sampled, or use Log, Exp, Gamma functions
  - Can mix sampled and analytical segments in any curve
  - Optional tags for Absolute Colorimetry
- **Parallel integer tags AToBx,BToAx, provide compatibility with Version 4.2**

Benefits of New Floating-Point Extension

- **Easier to create ICC Profiles for complex devices**
  - Curves, LUTs and Matrices encoded directly in floating point
  - No need to recode into fixed-point format
  - No need to fit to a curve-LUT-curve-matrix-curve format
- **Potentially unlimited transform accuracy**
  - The transform encoding format does not limit accuracy
  - Practically limited by model size and conversion speed
- **Huge dynamic range**
  - Limited only by floating-point representation = 10^{39}

Uses of ICC Floating-Point Extension

- **Meets Digital Motion Picture editing requirements**
  - Edit HDR and film files in scene-referred space
  - Perfect round-trip for film -> Editing -> film
- **Provides a standards-based open architecture for HDR and film**
- **Lays groundwork for future enhancements**
  - Architecture Working Group proposals

ICC - Promoting open, cross-platform color management