



Advanced Color Management for Digital Photography

and possibilities for using ICC profiles

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Demo capture color processing

- Camera raw processing steps

Color processing issues

- White balancing & scene analysis
- Digital scene relighting
- Adopted white luminance determination
- Color rendering
- Color encoding

Options for image data saving

- Image states

Demo camera raw profile example

Conclusions and recommendations

Demo capture color processing



- See “Camera raw – the basics” backup slide set

All slide sets will be posted at:

<http://www.color.org/tokyomeeting2006.html>

- If a scene analysis matrix is applied, white balancing must be followed by clipping to produce neutral saturation ceiling.
 - Non-neutral saturation ceiling visually unacceptable, and produces artifacts if matrixed
 - Clipping is quite lossy if channel multipliers are not close to unity
- Scene analysis transforms are typically illuminant dependent
 - Need to know adopted white to transform to scene-referred
- Many demosaicing algorithms perform best after white balancing

Saving camera raw image data has significant advantages over saving scene-referred image data

- CFA data losslessly compressed by a factor of 3

Scene dynamic ranges

- Statistically average scene dynamic range = 160:1
 - Depends on measurement method
 - Most valid to use sampling angle on the order of 1/4 degree
 - Must average many pixels to reduce noise
- Approximately normal distribution of log dynamic range
 - Standard deviation = $0.6 \log_{10}$ units
 - One-sixth of scenes are less than 40:1
 - One-sixth of scenes are greater than 640:1

Scene adopted white to mean luminance ratios

- White/arithmic mean (126 outdoor scenes)
Average = 5.43 SD = 3.11 Minimum = 1.89 Maximum = 18.6

Dependence of exposure on processing



- The best option would be if cameras created output-referred images color rendered exactly as the photographer or client desires every time
 - The photographer only has to select the most appropriate output-referred color image encoding for the expected end-use
 - Unfortunately, color rendering contains artistic elements
 - Algorithmic success cannot be guaranteed
 - Specific scene content and personal choice are factors
- Camera raw is an excellent backup
 - allows the photographer to direct redoing of the processing when the camera processing does not produce the desired result
 - Some cameras can simultaneously save camera raw and output-referred files
- Unfortunately, camera exposure & gain are often set so that typical exposures are excessively clipped for raw processing
 - If exposure is set optimally for raw processing, in-camera processed files are often too dark
 - In-camera processing needs to be improved to allow exposure & gain to be set to avoid excessive clipping

Adopted white luminance determination



- Low contrast scene (24:1)



**scene white = media white
colorimetric reproduction**

**scene mean = media midtone
colorimetric reproduction**



**image specific tone curve
color rendering applied**



Medium Contrast Scene



- Medium contrast scene (157:1)



scene white = media white
colorimetric reproduction



scene mean = media midtone
colorimetric reproduction



image specific tone curve
color rendering applied

High Contrast Scene

- Medium high contrast scene (335:1)



scene mean = media midtone
colorimetric reproduction

scene white = media white
colorimetric reproduction



image specific tone curve
color rendering applied



Problems with Video Reproduction



- Scene contrast 158:1



simple system gamma = 1.2



image specific tone curve
color rendering applied

Problems with fixed photo reproduction



- Scene contrast 74:1

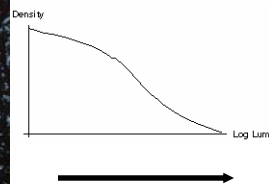
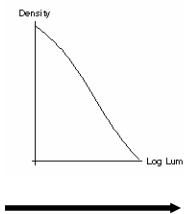


typical default photo reproduction of high key scene



image specific tone curve color rendering applied

Adaptive tone curves



Digital scene relighting



- Reduces unevenness of illumination in scene
- Eases job of color rendering



scene colorimetry

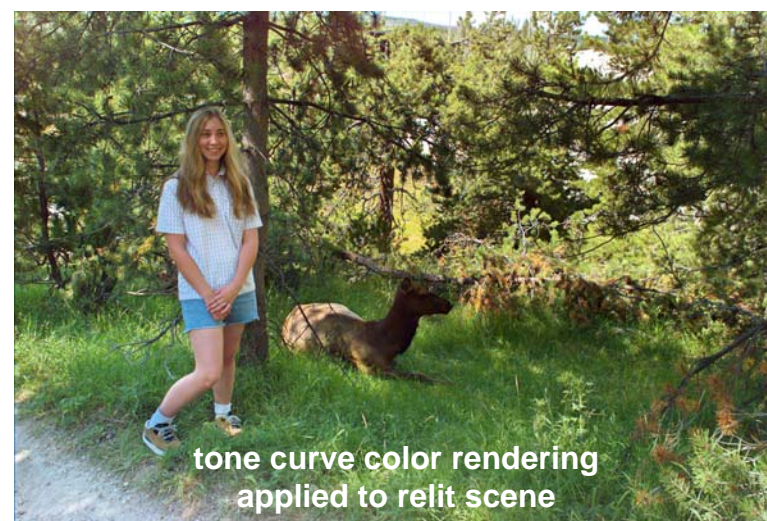


Image specific tone curve



digitally relit scene

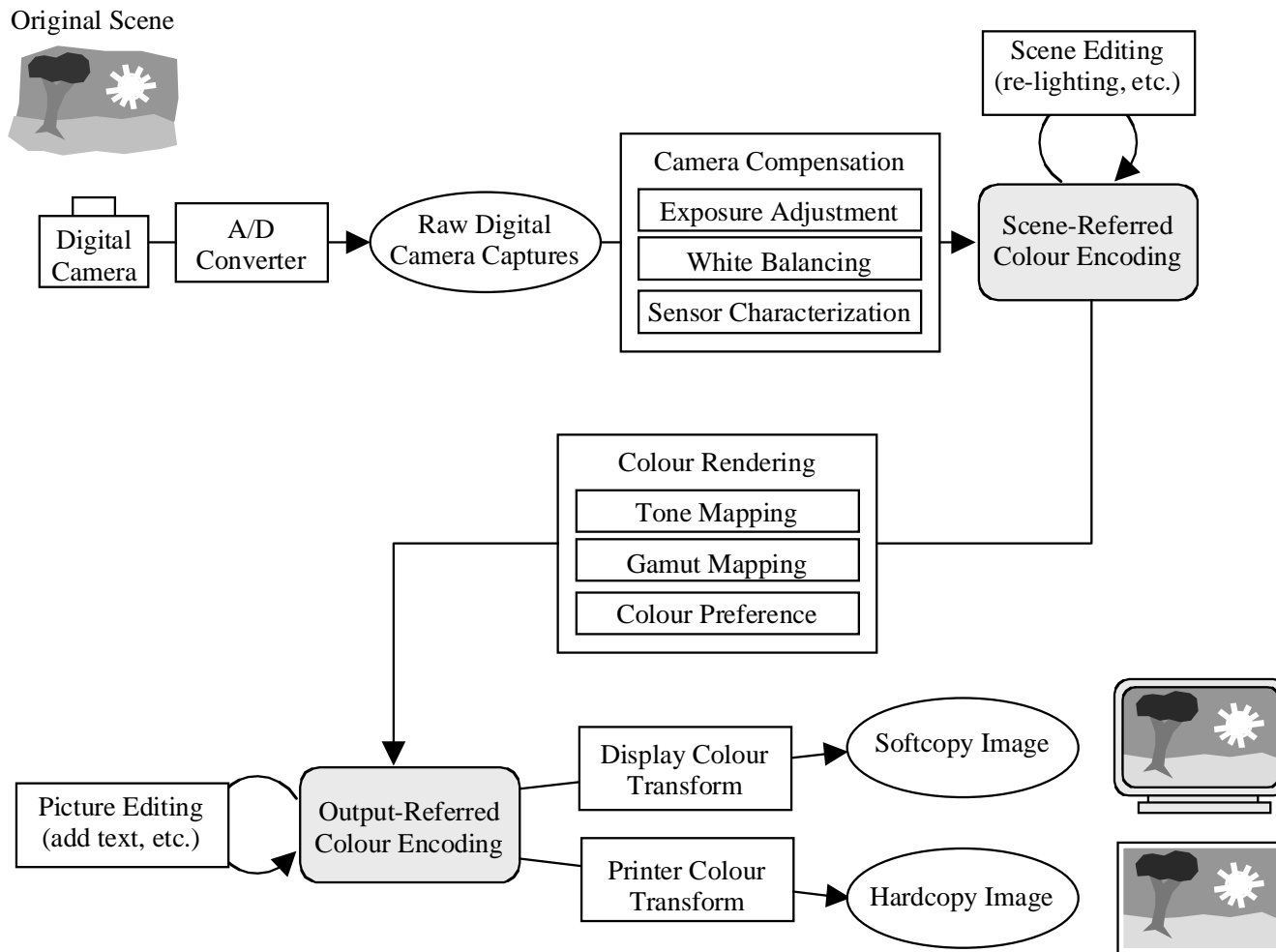
Limitations of adaptive tone curves and scene relighting



Digital photography color processing



- From ISO 22028-1



Camera raw

- But exactly how raw?
- ICC CMM's don't generally demosaic

Camera RGB (after demosaicing)

- Large file size, but can attach ICC profile

Scene RGB

- Large file size, but can use a standard scene-referred color encoding and attach ICC profile
- potential loss from white balance error

Standard output-referred color encoding

- ICC profile perceptual rendering intent applied to camera or scene RGB
- Apply appropriate color rendering and encode in output-referred encoding (e.g. sRGB, Adobe RGB, ProPhoto RGB), and attach ICC profile for that encoding
 - sRGB profile needs perceptual intent color re-rendering to ICC PCS

What color rendering does ICC support?



- Reproduction of scene colorimetry
 - Colorimetric intent applied to scene-referred image data encoding
 - Camera/illuminant specific profile colorimetric intent applied to camera RGB
- Camera specific preferred reproduction
 - Camera specific perceptual intent applied to camera RGB or scene-referred image data encoding
- Image specific preferred reproduction
 - Image specific perceptual intent applied to camera RGB or scene-referred image data encoding
 - Only global operations supported
- CMM color rendering
 - Using scene colorimetry and output profile colorimetric intent
 - May need to re-estimate adopted white luminance (ignore nominal PCS adopted white)

Demo camera raw profile example



- See “Camera raw profile example” backup slide set

Copy work

- Known illuminant & adopted white luminance

Studio photography

- Known illuminant & adopted white luminance
- Need for image specific color rendering minimized by careful lighting

Field photography

- Camera/illuminant-specific profiles to obtain scene-referred image data from camera RGB for manual color rendering
 - PCS media white luminance is camera clipping ceiling
- Image specific profiles to obtain ICC v4 PI RM colorimetry
 - No known implementations

Conclusions & Recommendations



- ICC profiles can provide a variety of advantages for digital photography
 - Backward-compatible support for existing & new color encodings
 - demosaiced camera raw
 - scene-referred & output-referred
 - There are some limitations
 - Can't use much more compact CFA files with ICC profiles
 - Scene-specific color rendering requires image specific profiles
 - Spatially varying color rendering must be performed by the CMM
 - User understanding of how all this should work is almost nonexistent
- Image state tracking is necessary
 - Color processing goals are different at different locations in the processing pipeline
 - A good color rendering algorithm will be different from a good color re-rendering algorithm
- Camera exposure & gain settings, and in-camera color rendering need to be improved so that photographers can take better advantage of in-camera processing while avoiding excessive clipping
 - so the camera raw file retains adequate headroom
- Advanced color management techniques for digital photography are currently not widely understood or implemented



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