Computer Graphics

Virtual objects, lights and textures

Rendered to produce image

Topics

- ❑ Simulation vs. design
- ❑ Color representations
- ❑ Color in graphics systems

Principles of Digital Image Synthesis
Andrew Glassner

Illumination and Color in Computer Generated Imagery
Roy Hall

Simulation vs. Design

Simulation

- ❑ Model reality
- ❑ Physically correct models
- ❑ Typically spectral representations

Design

- ❑ Create an effect
- ❑ User-adjustable models
- ❑ Typically RGB representations

Simulation

Model reality: Good enough to measure

Physical models

- Materials and lights
- Shading: How light interacts with surface
- Illumination

Perceptual model for viewer

Design

Design an effect

- Goal is appearance
- Unreal may be good

All models have knobs

- Phong shading and its varients
- Strauss model (SGI Inventor format)
- “Gooch shading” (SIGGRAPH ‘98)

Artistic Rendering

Pen and ink, watercolor, etc.

Model the medium

- "Fractel Design Painter" (now Metagraphics)
- Many recent U of W. SIGGRAPH papers

Kubelka-Monk for paint mixture

- Thin, uniform layers of color
- Model scattering and absorption of light

Color Representation

Spectral models

- Issue is efficient representation
- Uniform samples: 36-180 samples

RGB models

- Independently shade R, G and B
- Linear combination of display primaries
- Works amazingly well

Spectral Models

Adaptive sampling

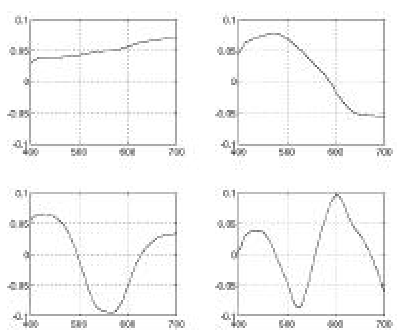
- Meyers, Hall, Glassner
- 4 carefully chosen samples/spectrum

Linear models

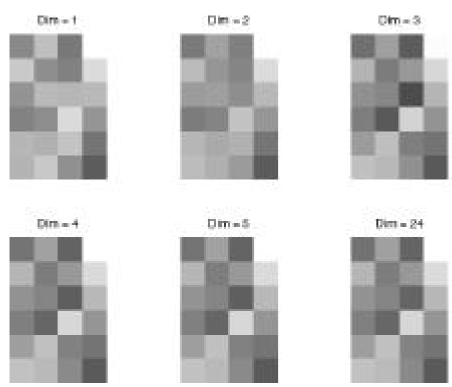
- Peercy, Maloney & Wandell
- 3-4 basis functions/spectrum

Roy Hall (CG&A, May 1999)

Linear Model Example



First 4 basis functions
For the Macbeth ColorChecker



Example renderings of the
ColorChecker from basis functions

RGB Models

Simple extension of grayscale shading

- ❑ Red, green and blue intensity
- ❑ Typically display primaries
- ❑ Change primaries with a linear transform

Not physically accurate

Product of Tristimulus values	≠	Tristimulus values of Product of spectra

Psychophysics of RGB

Primary-specific additive model

- ❑ RGB are the tristimulus values
- ❑ All spectra are sums of primary spectra

Only “correct” for simple cases

- ❑ Flat, white lights
- ❑ Local illumination
- ❑ Borges (SIGGRAPH ‘91)

Demo

Java applets from Brown

- RGB products vs. spectral products
- Difficult to see problem for simple light+surface calculation
- Errors appear on cumulative products (ie, as rays bounce around)

Color in Graphics Systems

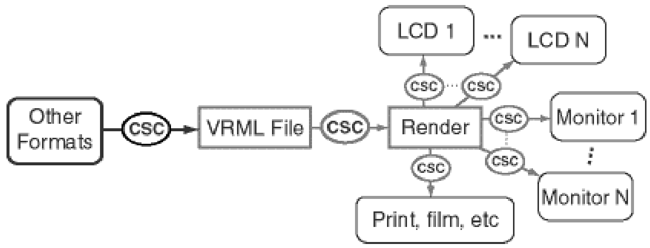
“Classic 3D” is a dedicated application

Must integrate with desktop and web

VRML example

- Virtual Reality Modeling Language
- 3D for the WWW
- All renderings should “look the same”
- Must run fast

The Problem



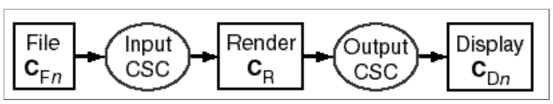
CSC is color space conversion

Multiple browsers and platforms
Calibrate to external standards
Workstation/web environment

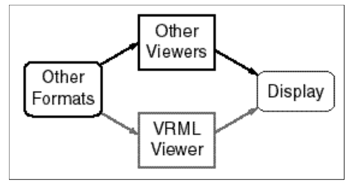
Color in VRML

Basically "SGI Open Inventor" model
- Face and vertex colors
- Material properties
- Light source properties
- Image and video textures

Uncalibrated RGB triples



Workstation Color



Shared Desktop
- Multiple windows
- Multiple applications

Shared Display System
- Controlled by the OS
- The "gamma" problem

The Gamma Problem

Device gamma
- Monitor: $I=A(k_1D+k_2V)^{\gamma}$
- LCD: Nearly linear

Typical monitor γ**=2.5**

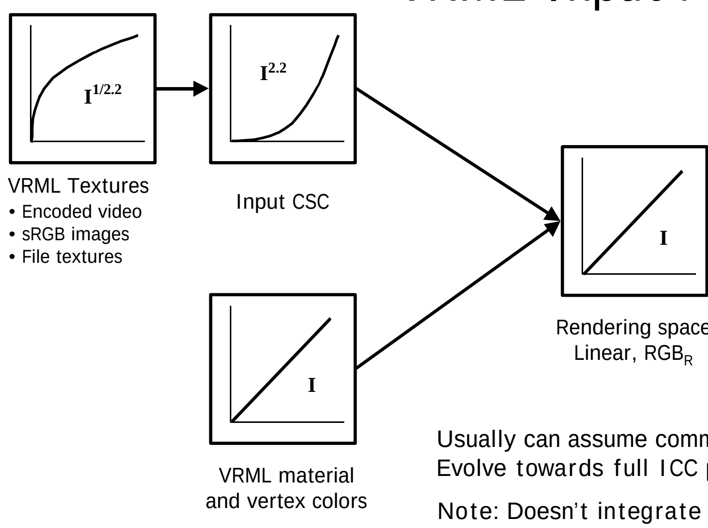
OS Gamma
- Defined by operating system
- Inverse gamma curve
- Framebuffer to voltage LUT

PC	Mac	SGI
1.0	1.4	1.7

Display system gamma
- Framebuffer to viewer
- Include viewing conditions

PC	Mac	SGI
2.2	1.6	1.3

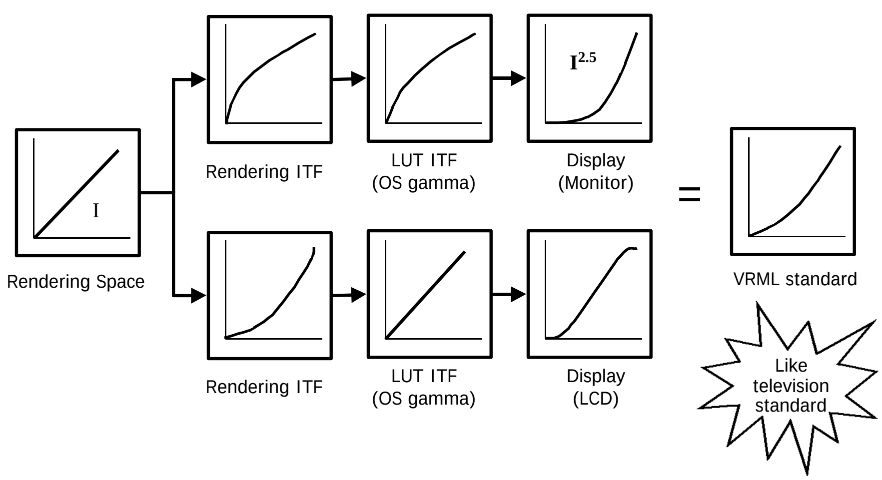
VRML Input Pipeline



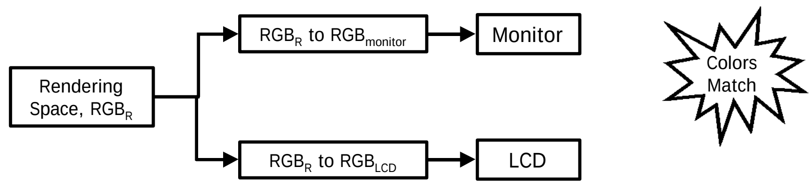
Usually can assume common RGB
Evolve towards full ICC profiles

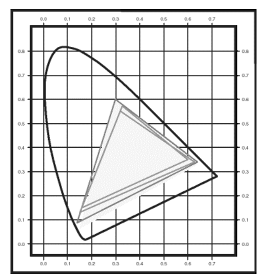
Note: Doesn't integrate well with desktop RGB "color picker."

VRML Output Pipeline



RGB Output Pipeline





$RGB_{monitor} \neq RGB_{LCD}$

Need 3x3 matrix transformation

Summary

VRML project is on hold

- Agreed to amend spec
- Too expensive to implement now

Modeling and representation

- Ongoing research
- Not just color, but perception too
- Workshop on Rendering, Perception, and Measurement, Cornell, April 1999