Gaffer to Game Engine:
Cinematic Effects

Kevin Bjorke

Game Developer's Conference, 2003

Cinematic Effects – Technical

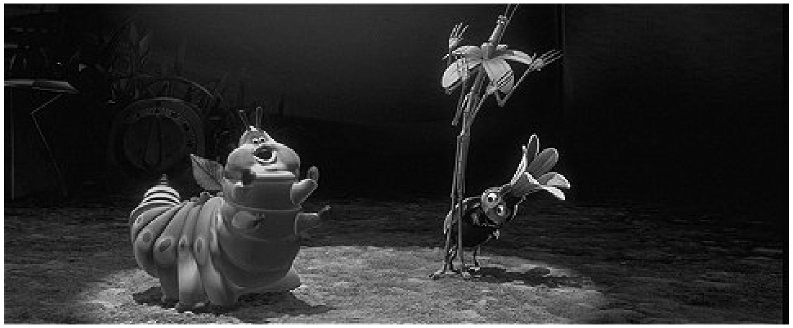
- What makes movie rendering different?
    - Heavy-duty software rendering, <0.001fps
    - Zero tolerance for obvious errors
        - BUT, we can paint-out the bad frames in an emergency – can’t do that in a game!
    - Massive scale
        - Complex Models, Complex Surfaces
        - Complex Compositing – may have hundreds of passes per frame
        - Motion blur, shadows used everywhere
    - Basis in Live-Action Traditions
    - Techniques now approachable in real time

Cinematic Effects – Artistic

- What makes movie making different?
  - Tightly-controlled camera
    - Movie photography is as much about lighting as it is about camerawork
  - Controlled timing – animation, voice, music cues
  - Passive Audience
    - Viewer identification with characters and events comes through indirect means – not through experience in “being” or controlling the action
    - Framing, staging, camera motion, lighting, and sound are all tuned to that very purpose – drawing the viewer into the scene

My Perspective

- California Institute of the Arts in cinematography
- Digital Productions, Abel, Omnibus, Kroyer Films, R/Greenberg NYC, dWi, AAA Paris, Lightmotive, Pixar, Square
- Wide variations in “Realism”: *Toy Story, A Bug’s Life, Final Fantasy, Flintstones, Jetsons, AniMatrix;* live, cel, theme parks, TV, games



Toy Story/A Bugs Life © Disney/Pixar
Time Machine of Dreams© Sanrio

Dick Dastardley
© Hanna-Barbera

Dr. Sid © FFFP

Style

- Home movies are “real,” but boring
- Realism (“authenticity”) helps w/ suspension of disbelief, but just so we can get on with the main business
- Style and a unified look are ultimately more important
- Emphasis on illustration over simulation

The Sixth Sense © Disney, Spyglass Entertainment

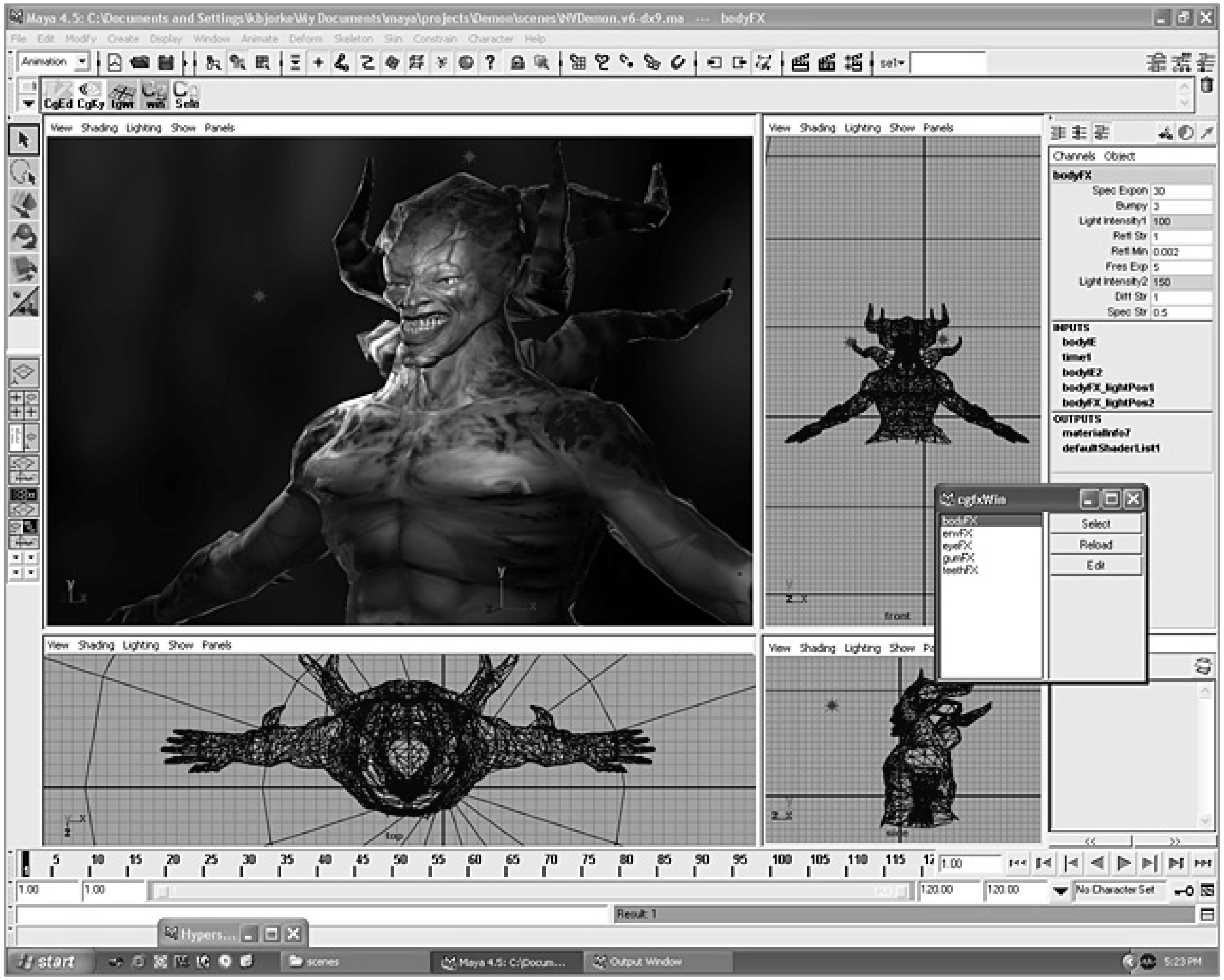
Real Production Issues

- It's All About Control
  - Directing the Eye
  - Setting the Mood
  - Saving Time & Money
- We Want a Big Toolbox!

Big Toolbox, 2002 – Design Chips

Big Toolbox, 2001 – Render Pictures

Big Toolbox, 2003



Maya 4.5: C:\Documents and Settings\kbjorke\My Documents\maya\projects\Demon\scenes\HVDemon.v6-dx9.ma --- bodyFX

bodyFX

Spec Expon	30
Bumpy	3
Light Intensity1	100
Refl Str	1
Refl Min	0.002
Fres Exp	5
Light Intensity2	150
Diff Str	1
Spec Str	0.5

INPUTS
bodyE
time1
bodyE2
bodyFX_lightPos1
bodyFX_lightPos2

OUTPUTS
materialInfo7
defaultShaderList1

bodyFX
envFX
eyeFX
gumFX
teethFX

1.00 1.00 120.00 120.00 No Character Set

Result: 1

CgFX puts the big toolbox on your desktop.

Real-World Lighting – Big Tool #1

- Live-action DPs/Photogs use lots of controls to manipulate the light and how it records
  - Barndoors
  - Scrims & Gobos
  - Silks & Gels
  - Reflectors
  - Fog & Smoke
  - Lab Effects
  - Focusing Sources & Parabolics
  - Lens Diffusion & Filtration
- We want just as much control in games

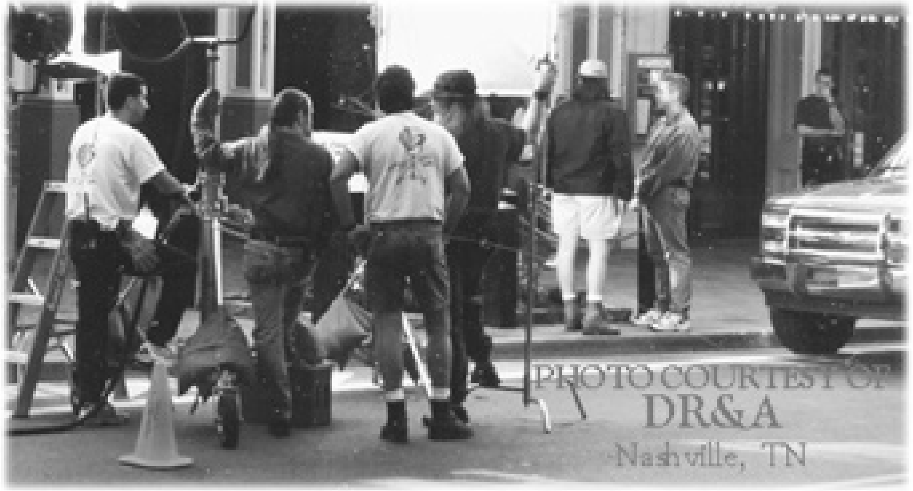
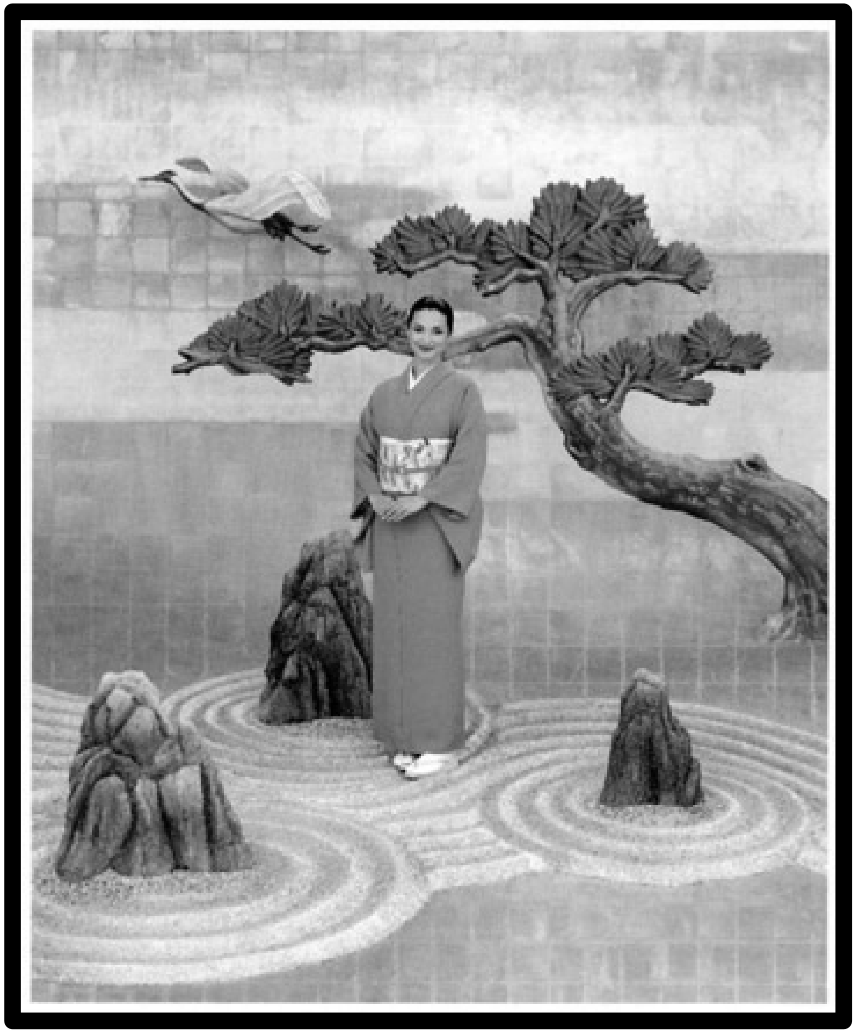


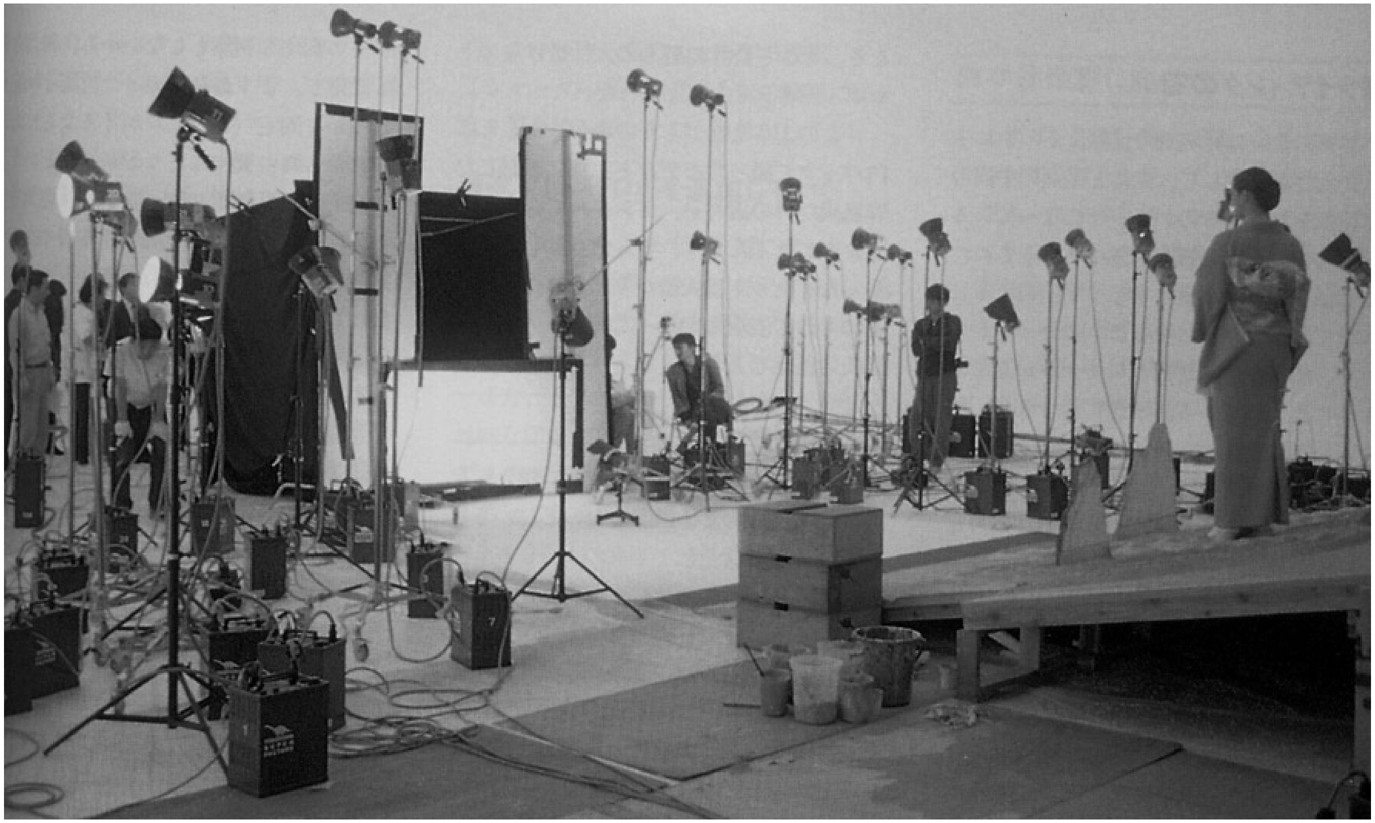
PHOTO COURTESY OF
DR&A
Nashville, TN

A Simple Example



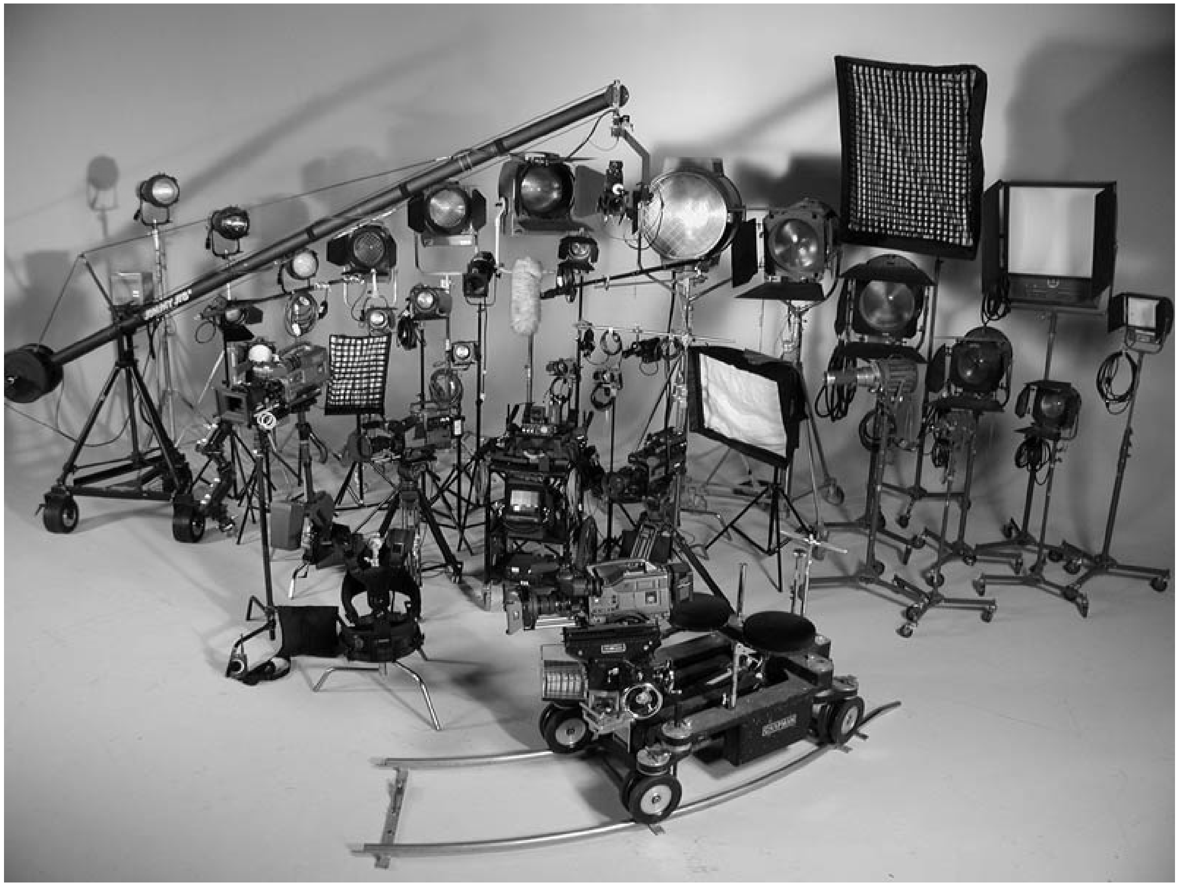
- Simplicity Itself, Right?

What Was Really Happening



- Over 50 lamps!
- And that’s *with* real-time global transport, diffusion, and anisotropic BRDF algorithms already solved....

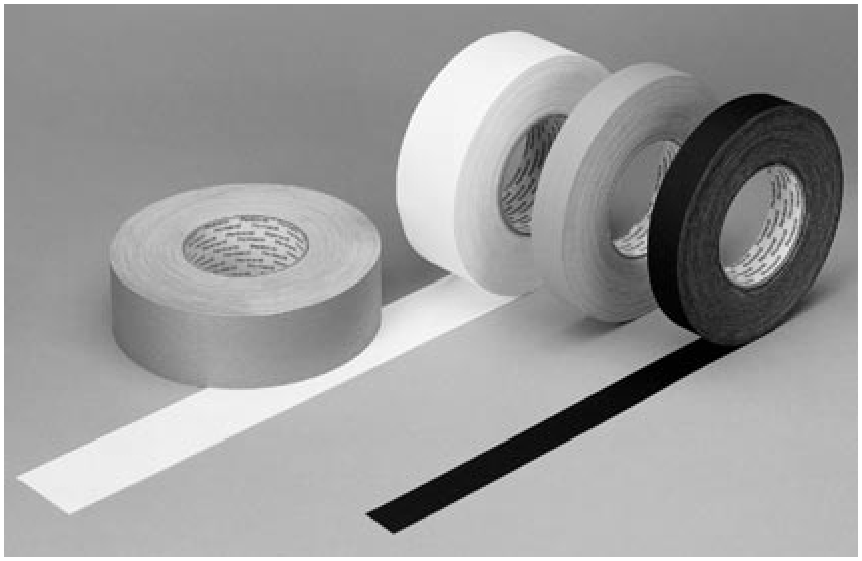
Tools for Any Kind of Lighting Job



- Which are most-important?

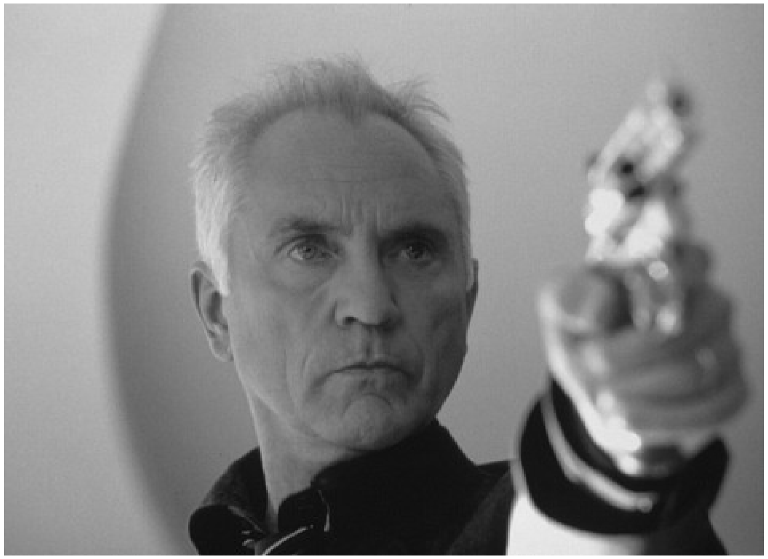
The Most Important Lighting Tool of All

- Programmable Shaders Hold the Universe Together
  - Simple Tools versus Compound Tools
  - Gaffer's Tape: Like duct tape, but with a key added feature: *choice*



Shape

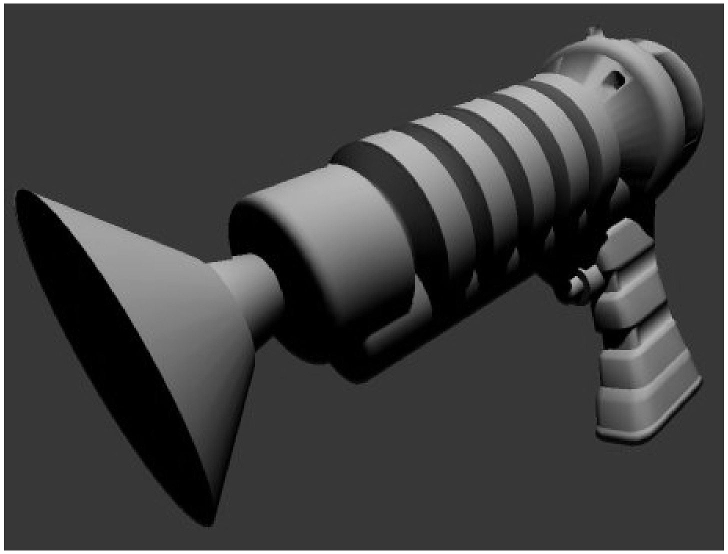
- Light Shape is a volume, possibly with infinite bounds
- Can be any volume we specify
  - Pointlight = sphere
  - Spotlight = cone
  - What about a cube?
  - How about an L-shaped prism?
- Shaping volume lets us direct the eye



The Limey © Artisan

Color Variation

- Cg lets us choose any criterion:
  - Variation according to surface orientation
    - “Complementary Lighting” a la *Shrek*
    - Diffuse GI Mapping
  - World-coords 3d location
    - Light Maps
  - Slide Projectors
  - Negative Lights
- Variation helps us lend solidity to the scene



“Complementary” Light Color

```
float ldn = dot(Ln,Nn);
  ldn = max(0.0,ldn);
Cl = lerp(Color1,Color2,ldn);
```

Shadows

- **Shadows also define a volume. We can mix volume functions in Cg – depth maps, polygonal stencil volumes, others**
- **Shadows don't have to be black**

```
lerp(shadowColor,lightColor,shadowfunc());
```

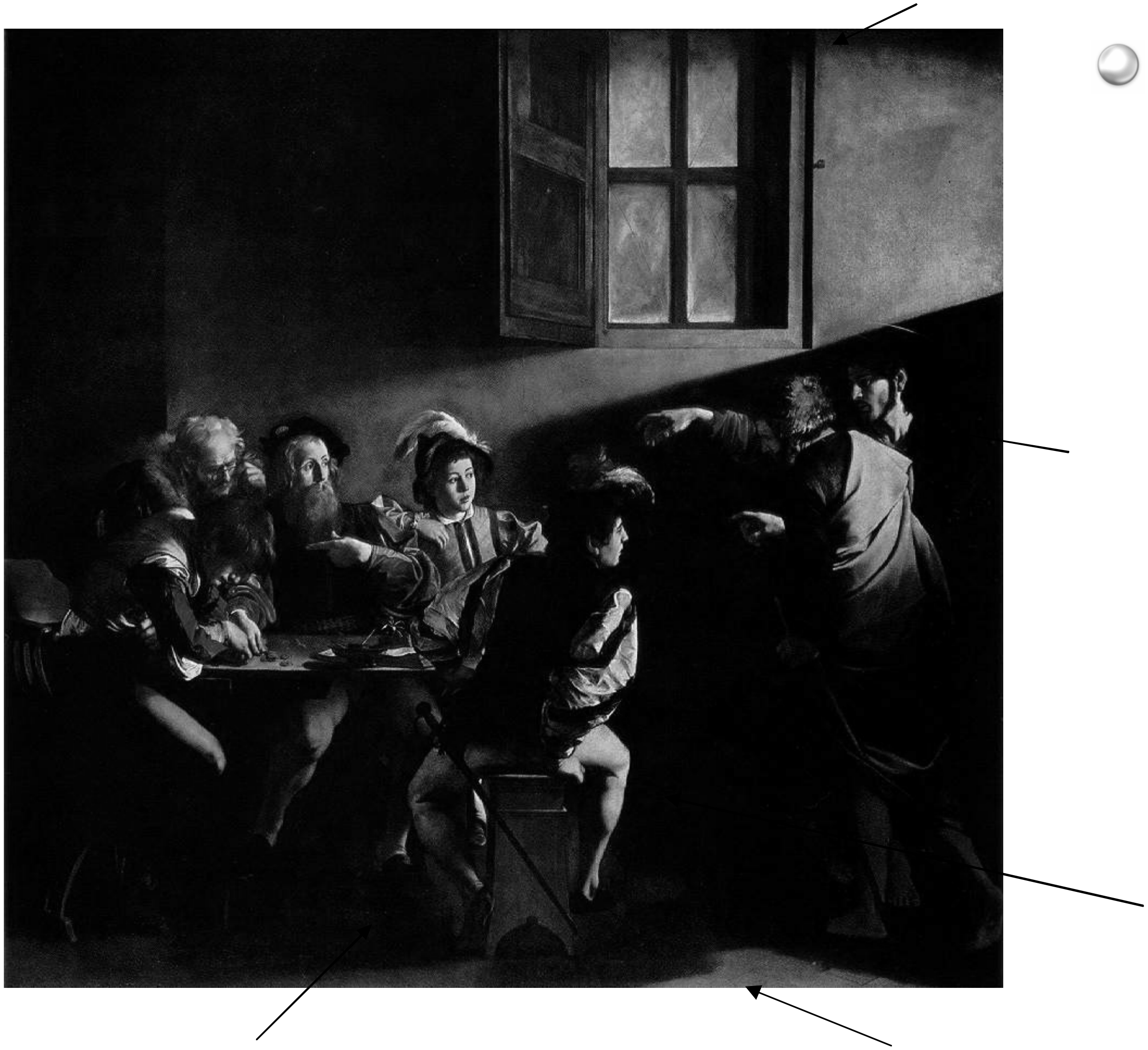
- **Shadows can be misdirected**
  - **Light direction doesn't always have to be shadow direction – the viewer's eye will accept the *shadow* direction more than the light!**
  - **Multiple sources can share the same shadow**
  - **One source may have multiple shadows**

Shadows Where They Don't Belong?

Animatrix: Final Flight of the Osiris © 2003 Warner Bros
http://www.whatisthematrix.com/

- Shadow as a Graphic Element – Instantly Readable
  - Jue's contact shadow is posed for visual effect and to connect her firmly to the rooftop – it's *not* driven by the lightsources themselves.

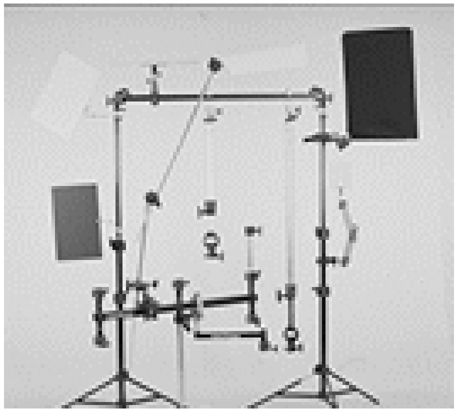
An Historical Example of Tweaking

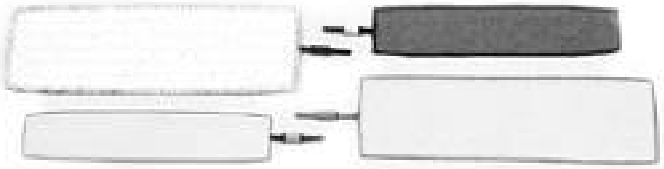


- Carravaggio's *The Calling of St. Matthew,* 1599
  - Missing shadows?
  - Where *are* the light sources, really?

Fake Shadows with Gobos/Scrims

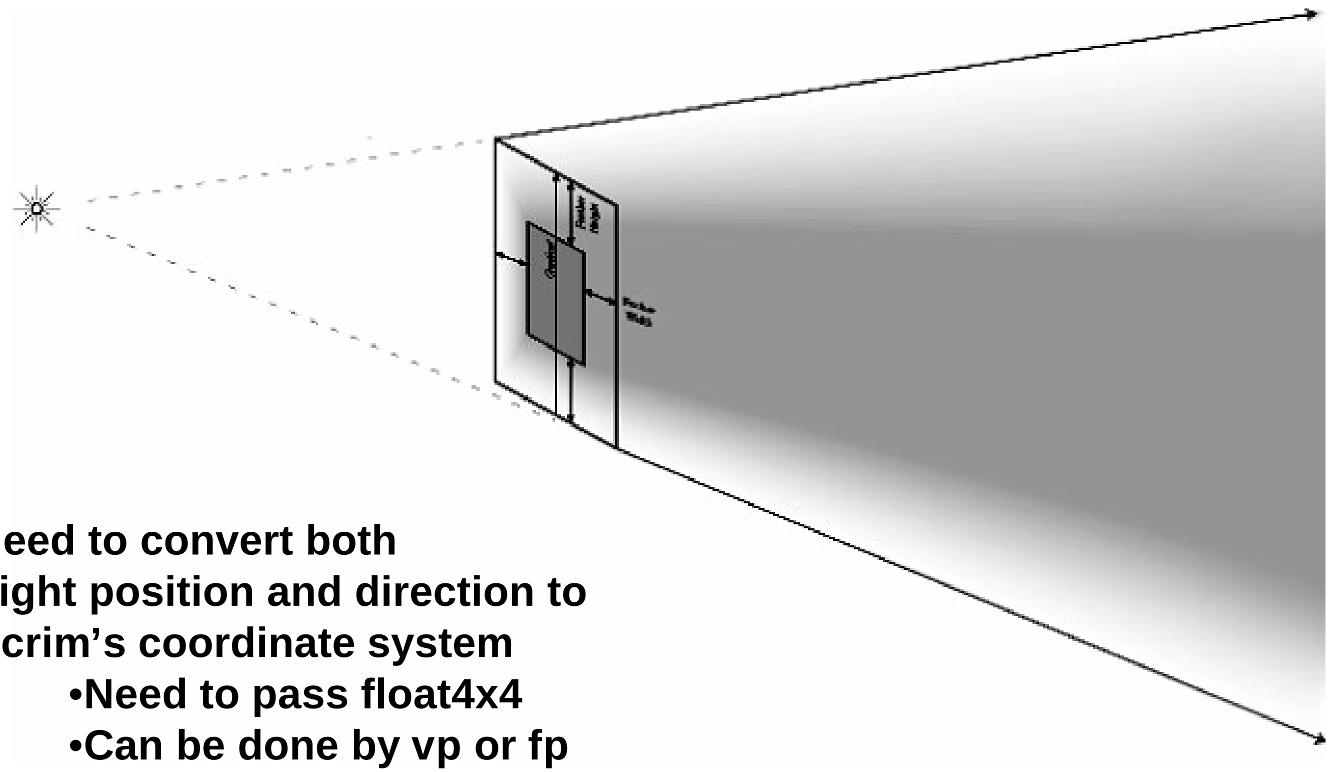
- "Fake" objects can be resolved mathematically
  - Save on # of render passes
  - Can stand-in for nonexistent models
  - Can be texture-mapped
  - May consume shader parameter space, so be aware of the costs





Scrims in Action

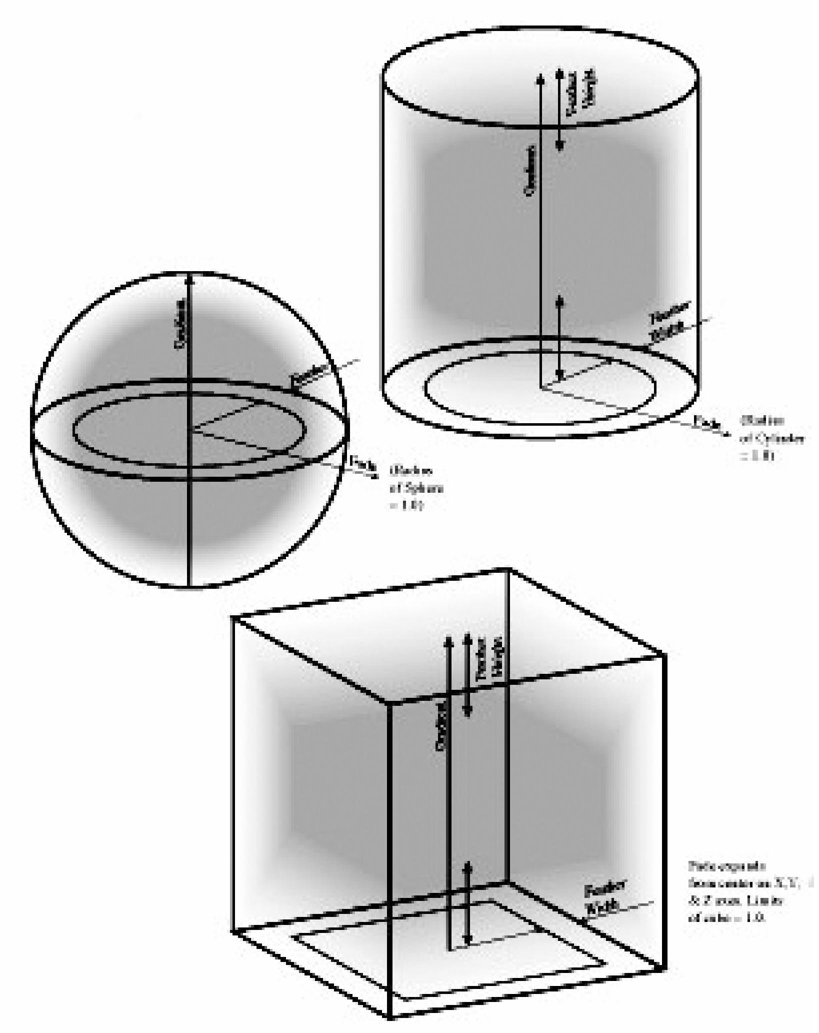
- Cast shadow based on scrim-coordinate “z=0”



Need to convert both Light position and direction to Scrim’s coordinate system

- **Need to pass float4x4**
- **Can be done by vp or fp**
- **Static positions can be precalculated by CPU**
- **Optional `smoothstep()`’d edges**
- **X,Y at Z=0 can be used for tex2D() lookups**

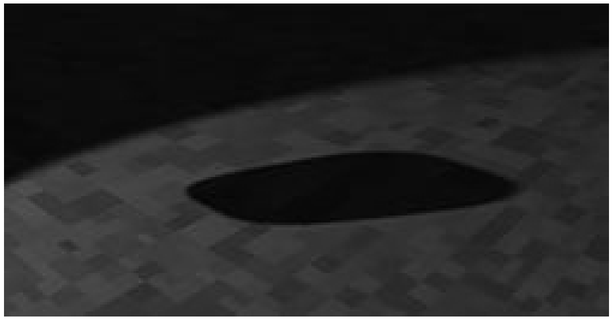
Scrims Can Have Arbitrary Volumes

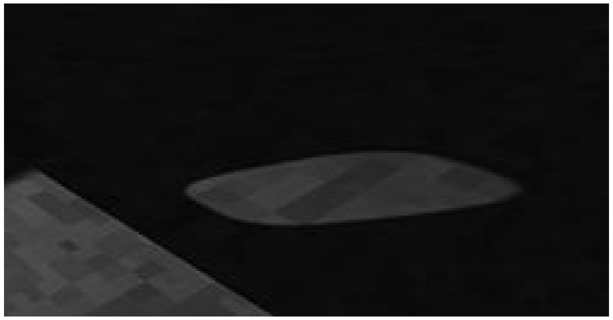


- We can use cubes, spheres, or any other simple easy-to-evaluate function, projected from the light or not
- Can incorporate 2D, 3D, or Cube textures
- Can apply to ambient or light maps too

Varying Scrim Opacity

- Cg scrims can also be inverted
  - Useful feature for controlling attention: doorways, keyholes, etc





The Sixth Sense @ Disney , Spyglass Entertainment

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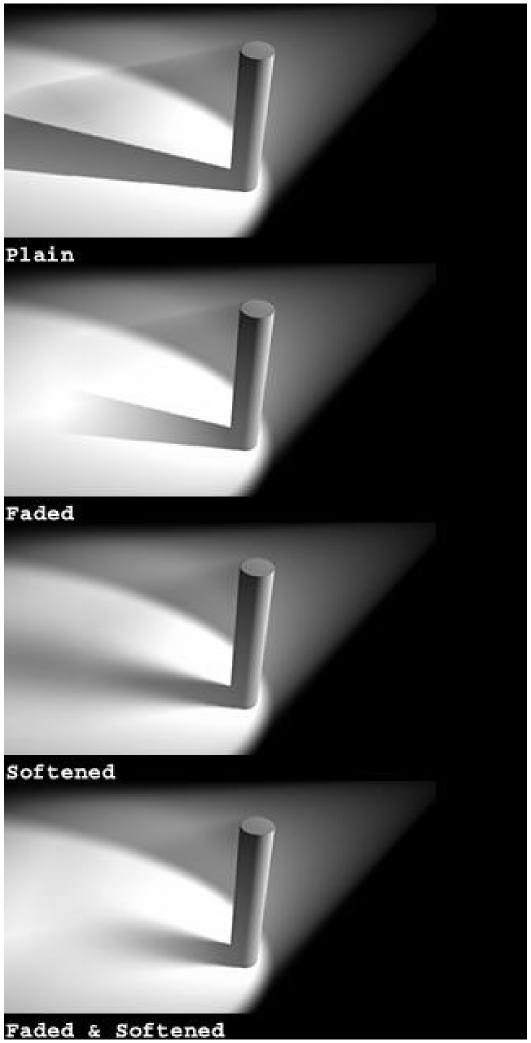
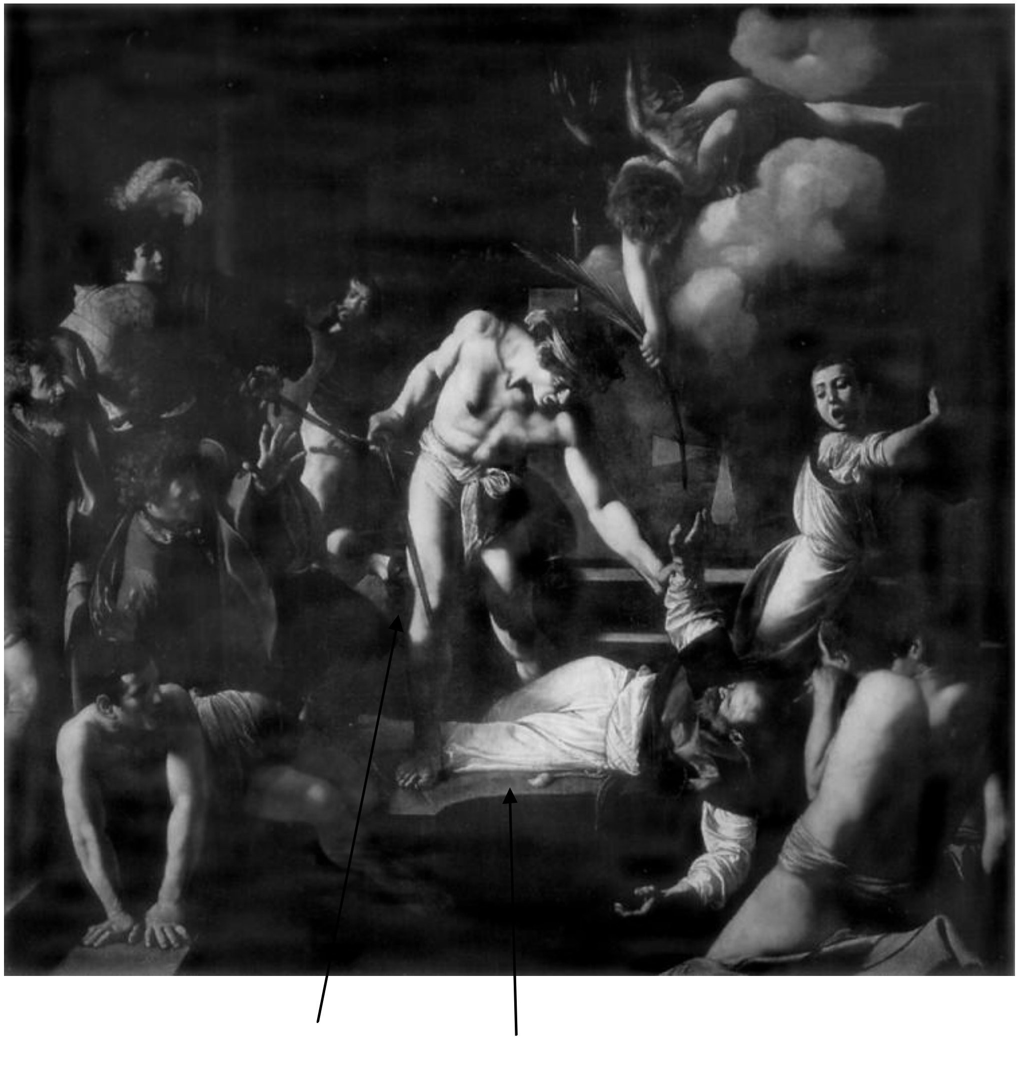
Scrim + Shadow Map = Fader/Softener



- Mix shadow-map evaluation with deep scrim to create soft-shadowing effects
  - Can apply to stencil shadows too
  - We can selectively create shadows, shape shadows, or selectively-suppress shadows

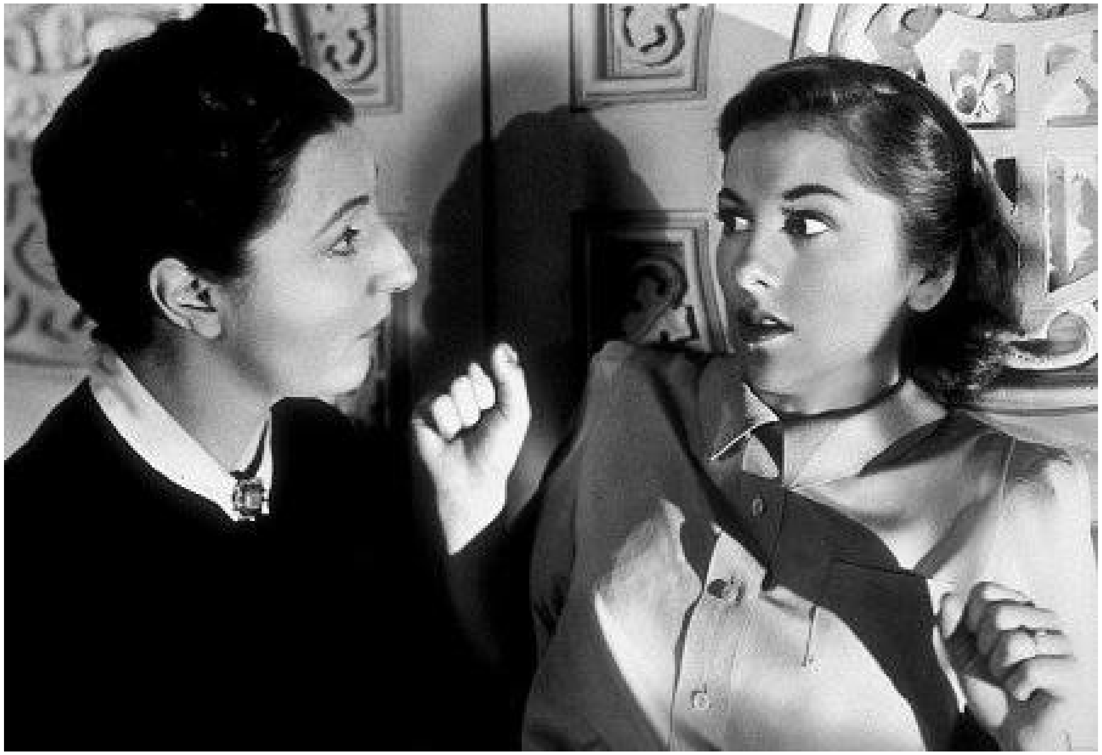
Another Historical Example



- Caravaggio's *Martyrdom of St Matthew*, 1599/1600
  - Hard shadows, or soft?
    - Soldier: hard
    - Saint: soft

Creating Mood with Shadows

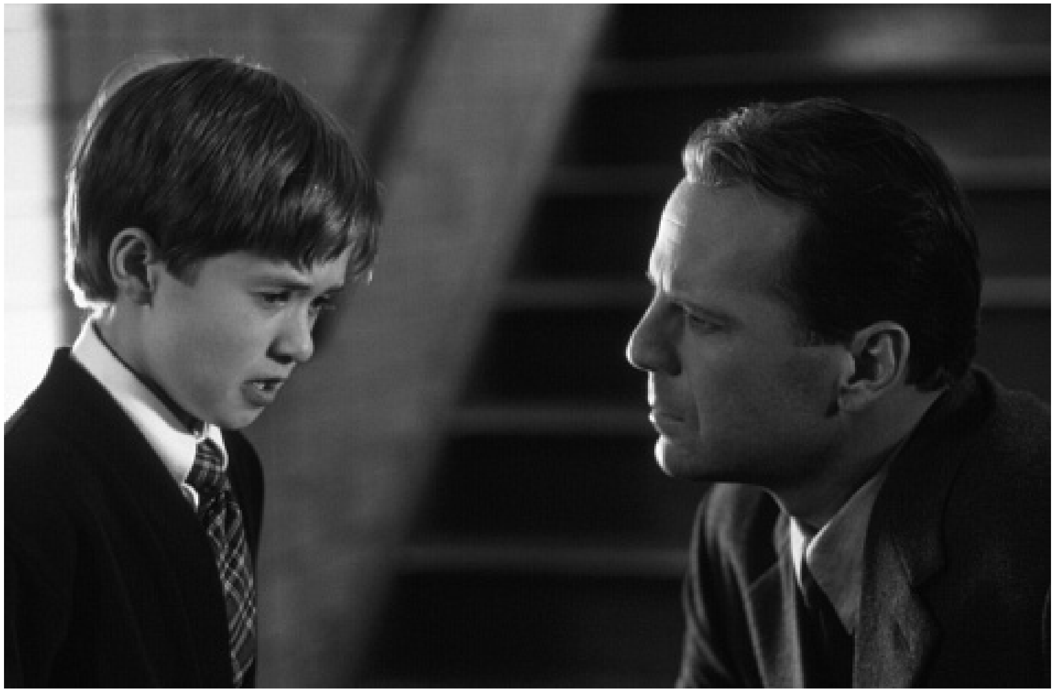
- **Hard shadows reflect Mrs. De Winters’s agitation, contrasted with the smooth calm light on Mrs. Danvers**



Rebecca © 1940 United Artists. Courtesy MPTV Archives

Modern Example: SPOILER ALERT!

- Is it the light, or is it Bruce?
- Good lighting isn’t just technical showmanship – the goal is to support the story



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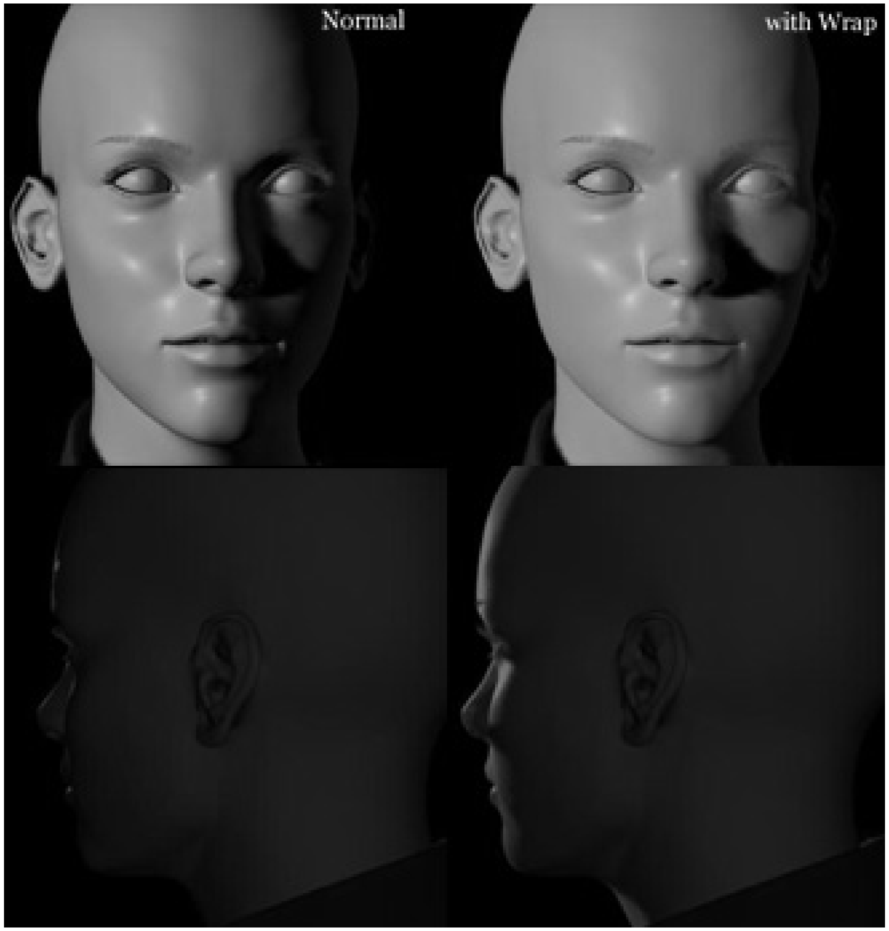
Rim and Wrap Lighting



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- Bypassing physics makes lights more useful for games, allows us to use fewer lamps
- Contre-jour effects help to define shape
- Special surface and/or special light

Wrap Lighting

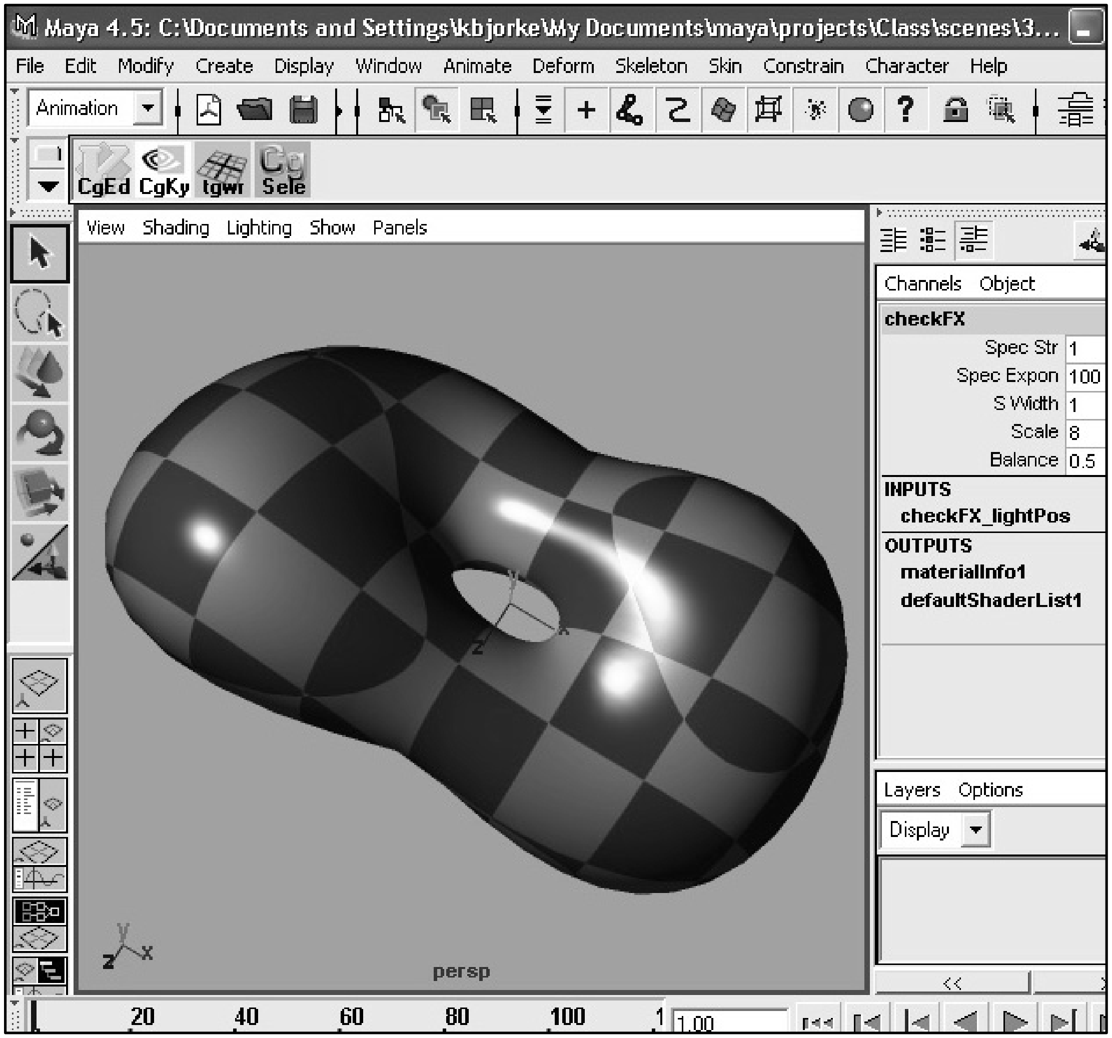
- Simple method: angle “L” slightly toward the surface tangent

```
float4 wrapAxis = cross(-L,N);
float rotAmt = acos(dot(N,-L))/(wrapAmount+(PI/2.0));
float4x4 theRotM = rotate_xform(rotAmt*wrapAmount,wrapAxis); // function
L = mul(theRotM,L);
/* … and calculate diffuse and specular normally with this new “L” */
```

- Even Simpler method: renormalize dot(L,N)

```
float LdN = dot(L,N); /* normal lambertian would be = max(0,LdN) */
float adjVal = cos(wrapAngle); /* can be a precalculated constant */
float newLdN = (LdN+adjVal)/(1.0+adjVal);
float diffuse = max(0,newLdN);
// alternative: float diffuse = smoothstep(-adjVal,1.0,LdN);
```

Alternative Diffuse Lights: CgFX Demo


Maya 4.5: C:\Documents and Settings\kbjorke\My Documents\maya\projects\Class\scenes\3...
File Edit Modify Create Display Window Animate Deform Skeleton Skin Constrain Character Help
Animation
CgEd CgKy tgwr Sele
View Shading Lighting Show Panels
persp
Channels Object
Layers Options
Display
20 40 60 80 100 1 1.00

checkFX

Spec Str	1
Spec Expon	100
S Width	1
Scale	8
Balance	0.5

INPUTS
checkFX_lightPos

OUTPUTS
materialInfo1
defaultShaderList1

- Standard
- Wrap
- Combined

Shadow-Inset Objects

- Use a slightly-smaller version of the geometry when making the shadow map/volume
  - Can use the *same* geometry data and alter the vertex program to create a slightly-inset surface during the shadow-render pass

```
float4 insetP = IN.Pos – inset*IN.Normal;
OUT.HPosition = mul(WorldViewProjXf,insetP);
```

- The technique can be used to solve a variety of shadowing and shadow-aliasing (“Z-fighting”) problems

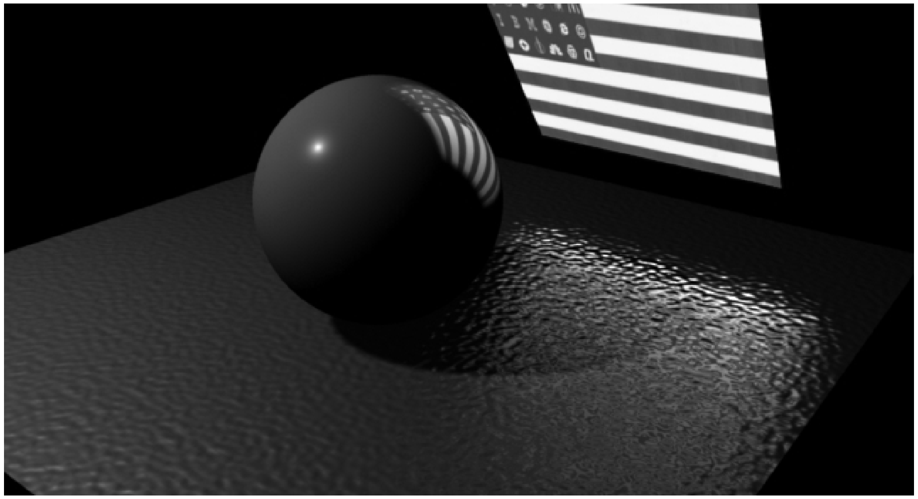
Area Lights

- Extremely common, but very difficult to fully emulate
- Cg lets us select key visual attributes, mix & match to get the idea across:

  Mix fake reflection w/soft diffuse…

Reflection Hack – “Softbox”

- One-bounce raytrace to a scrim card
  - Multiple cards can obscure one another
  - Inverse-square law can be used
  - Textures/shadows can be added
  - Can be used alongside cube maps



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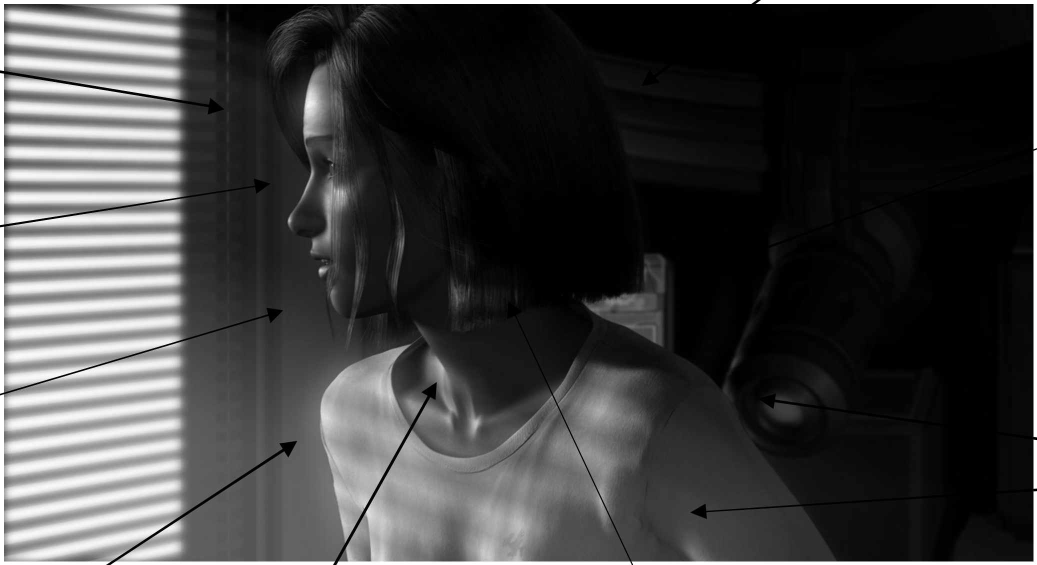
Cg Fragment Diff/Spec Example

CgFX DEMO

- Manipulating Individual Parts of the Lighting Equation....

Complexity Hidden in the Simple



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Composited glow helps define contour

Scrim to emulate shadow of un-modeled window

Composited 2D artwork

“Softbox” reflection of painted window to catch in eyes

Diffuse-only “bounces” from non-existent walls

Window is behind, but light is from front – okay because it reads in 2D

Blinds “shadow” is painted texture

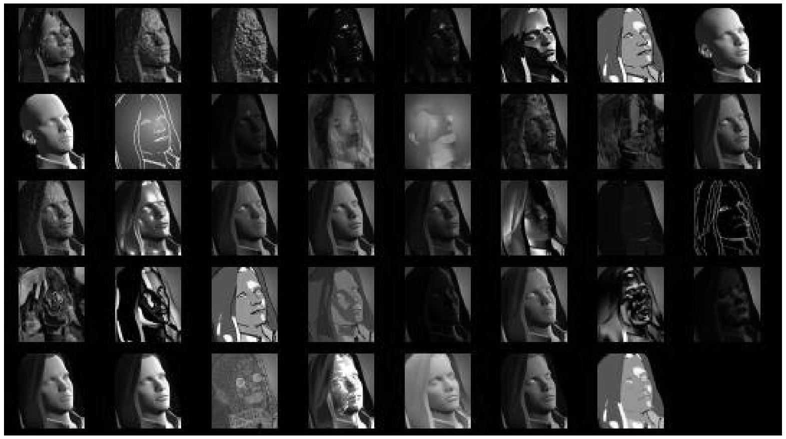
Woo-method (“midpoint”) hard shadow from skin/shirt

Blurry simple-method hair shadow from proxy object

- Simple to implement once the methods & ideas are part of your usual work process

Surface Shading

- Longer Pixel Shaders Give Us Lots of New BRDF Models
  - Oren-Nayar diffuse
  - Better Speculars
  - Physically-based shading
  - Etc. Etc. Etc.



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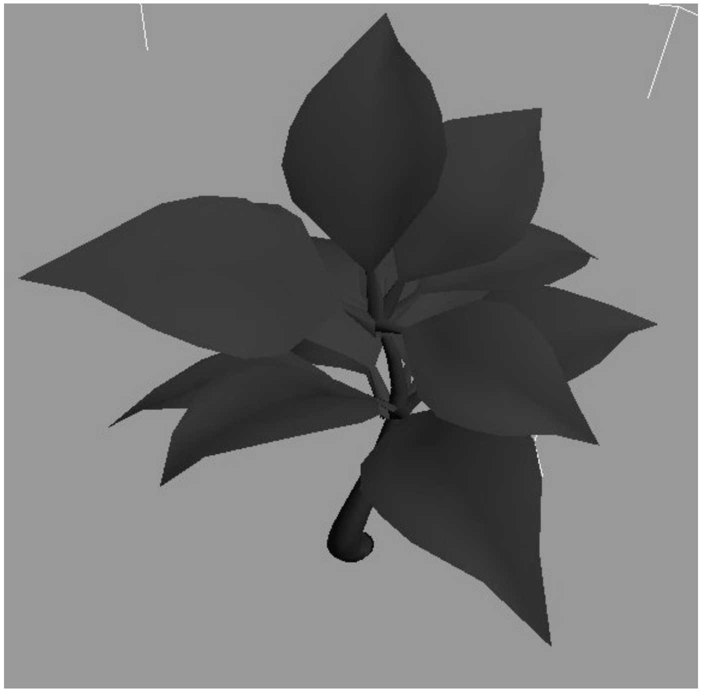
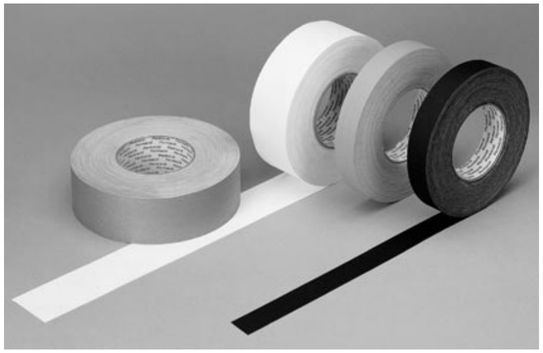


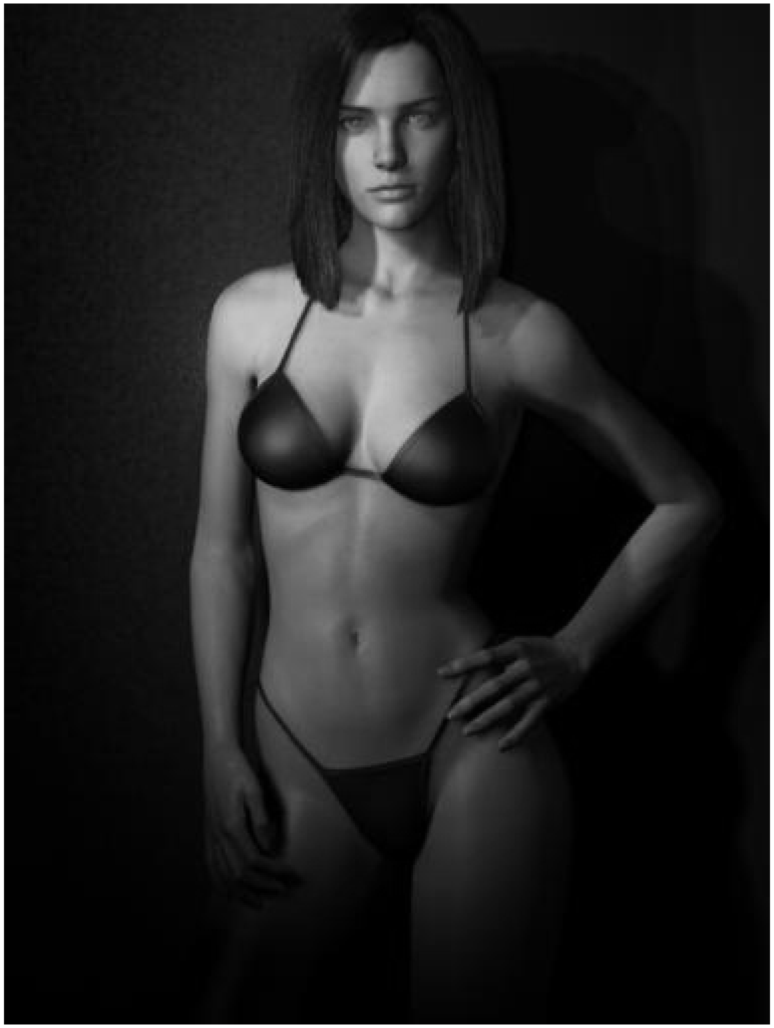
Blue Felt Based on Gonioreflectometric Data

Combining Appearance Models

- Complex ways to blend different kinds of surfaces via textures or procedures
  - Use `lerp()` function freely on BRDF arguments and/or on BRDF results
- Easier than ever to do in one pass
- No single BRDF, however flexible, will be right for all objects and shots, so…
- Whatever works!



Example: Skin



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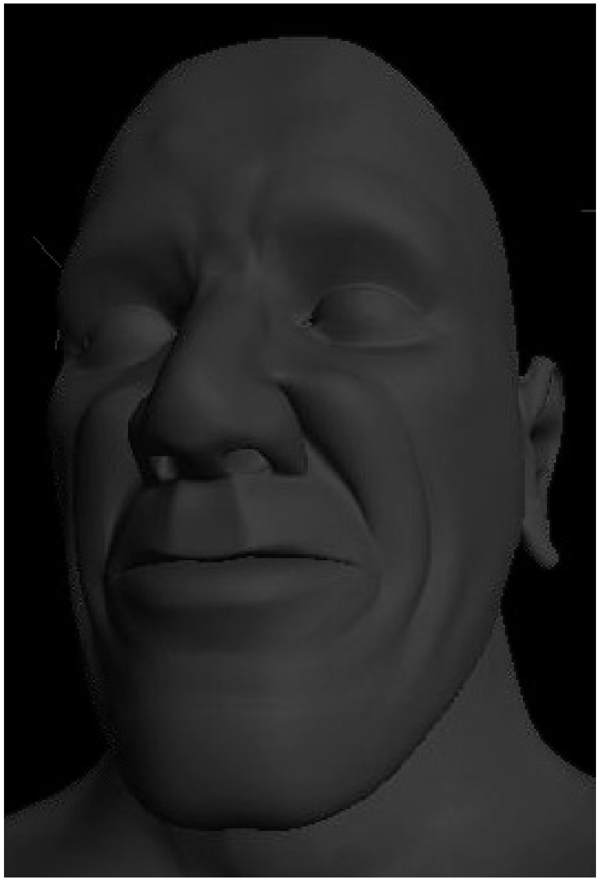
- Textures are important, but so is the underlying shading method
  - Only the face is textured in this image
- Skin has many properties that tell us about the character and their life – again, we want artistic control

Different Approaches to Skin

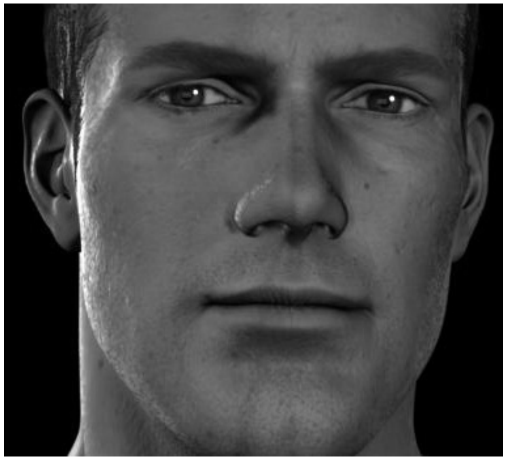
- Photographic / gonioreflectometric
  - Hard to measure live people
  - Hard to measure different areas
  - Leaves little room for artist control



Lafortune-Model Skin, Based on a real person's forehead

Different Approaches to Skin

- Analytical
  - Attempt to model skin based on scientific theory
    - Kubelka-Munk layering, Pharr et al scattering, Jensen et al scattering
  - Again, numerically-oriented and hard to control by artists
  - Worked for *Shrek* though!



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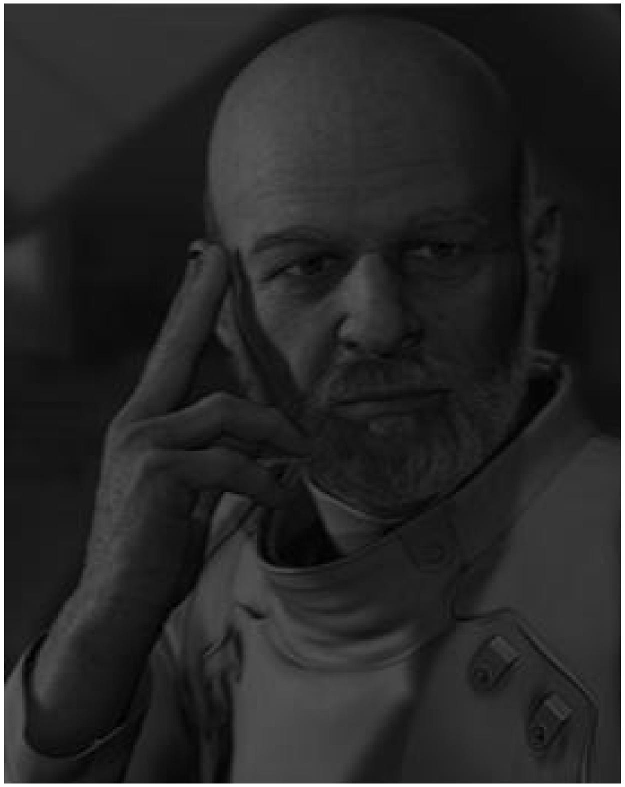
Kubelka-Munk Scattering

Shrek © Dreamworks/PDI

Different Approaches to Skin

- Fake It!
  - Use simple model of skin layering and properties
  - Depend on skilled artists for details
  - Make things approachable for the artists
  - Allow per-shot tweaking



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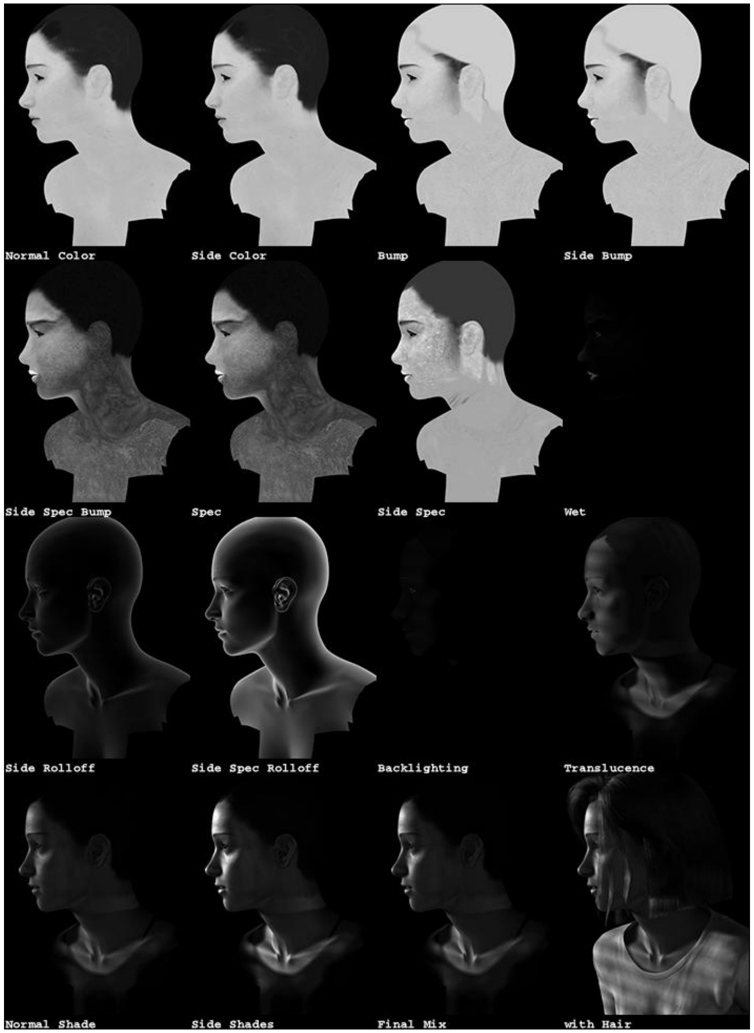
Whatever Works

Fake Skin – Multiple Layers



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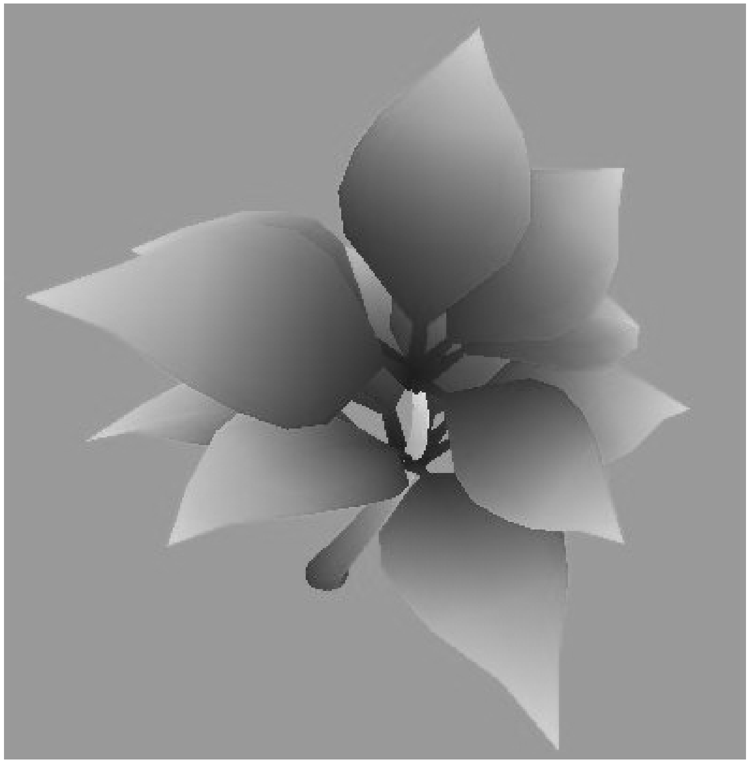
- **Layers combined by varying versions of N•V rolloff**
  - `pow(dot(N,V),Q)` **= “poor man’s fresnel”**
  - **Varying “Q” among layers creates illusion of depth**

Special Surfaces

- Cg lets us shade arbitrarily for any purpose
  - Custom Speculars
  - Surfaces for compositing
  - Non-photo-real (NPR) surfaces
  - “Baked” lighting
  - Analytic Anti-aliasing

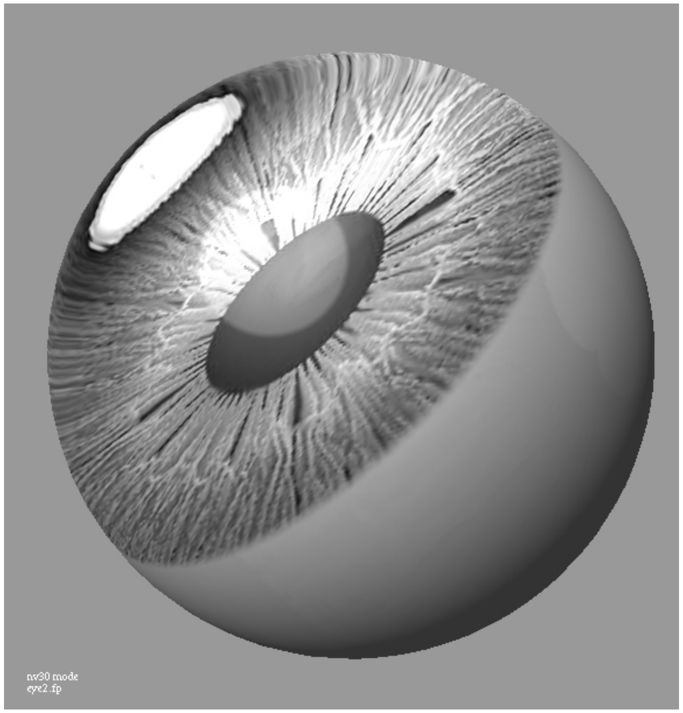


Normalizsed ST Gradients:

```
Color.xy = normalize(float2(
 ddx(IN.UV.s)+ddy(IN.UV.s),
ddx(IN.UV.t)+ddy(IN.UV.t)));
```

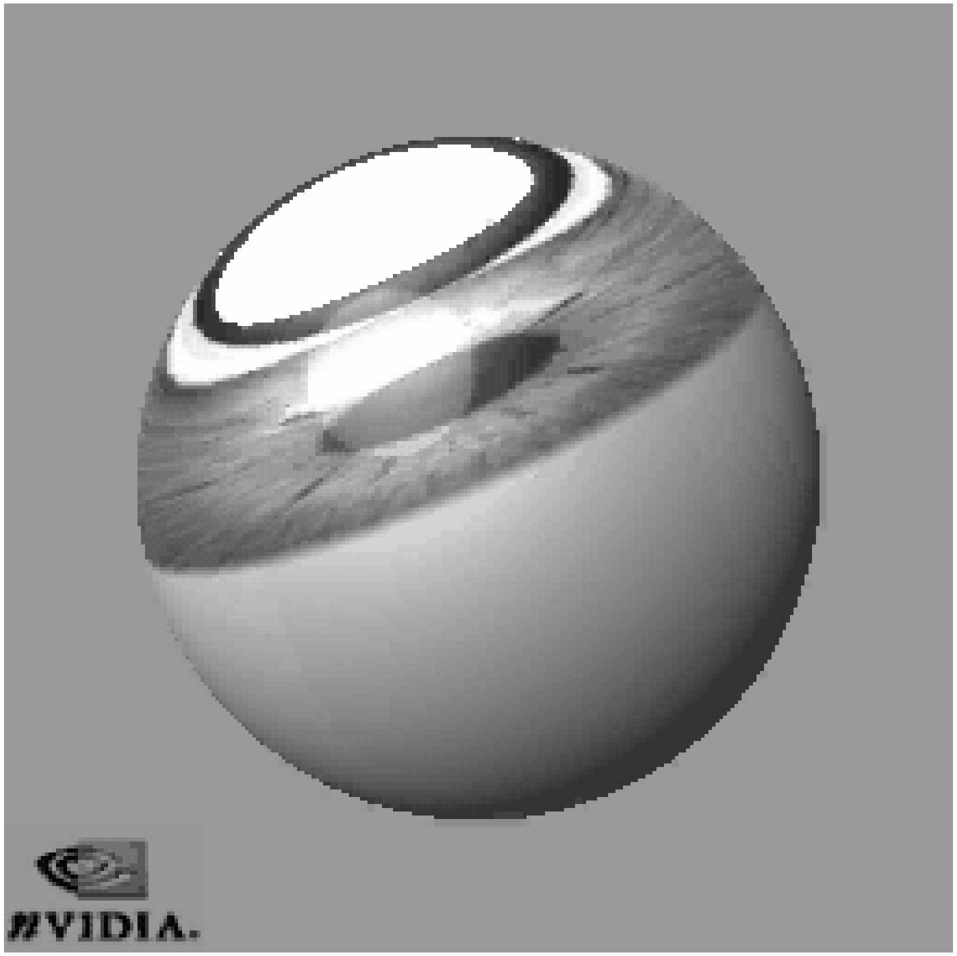
Raytracing in the surface

- When simple primitives are known, we can even raytrace in realtime
  - Refracted rays strike plane perpendicular to object X axis
  - Refraction and intersection maths can be done by vertex shader
  - Extra: Smoothstep() to threshhold specular term creates glossy surface effect



Raytrace against textured virtual surface

Cg Fragment Raytrace Example



CgFX DEMO

Compositing & Color Correction

- It’s all About Leading the Eye
  - Mood Control
  - Contrast & color palette control, tone mapping
  - Glares, Flares, Glows
  - Mixing Elements from Multiple Artists
  - Shadow Hacks
  - Depth of Field
  - Saving Time & Money

Brother Where Art Thou © Buena Vista

Compositing & Color Correction

- Consider it for every frame!
  - Can alter color & feel without changing models or the render pipeline
- *Amelie* is a great example of end-to-end color manipulation
  - ...and the DVD describes many of the details

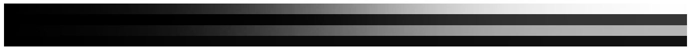
Amelie ©2002 Canal+

Color Correction as a Texture Operation

- We can encode color corrections in 1D RGB textures, 256 elements long
- To color correct an image “orig” with correction texture “cTex”:

```
half3 origColor = h3tex2D(orig,myST.xy);
half3 newColor;
newColor.r = h3tex1D(cTex,origColor.r).r;
newColor.g = h3tex1D(cTex,origColor.g).g;
newColor.b = h3tex1D(cTex,origColor.b).b;
```

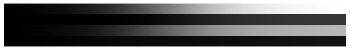
Unaltered colors
(channels expanded for viewing)

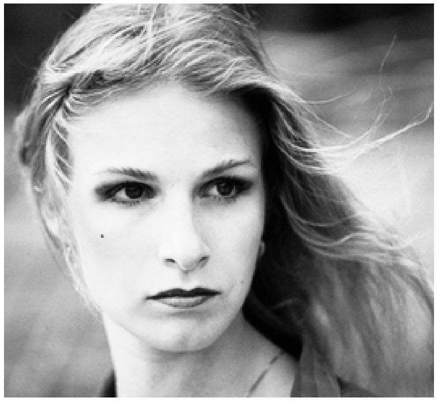


Typical corrected colors
(E6 film processed in C41)

Color Correction Example

- Using the same correction texture…





“Plain” Original

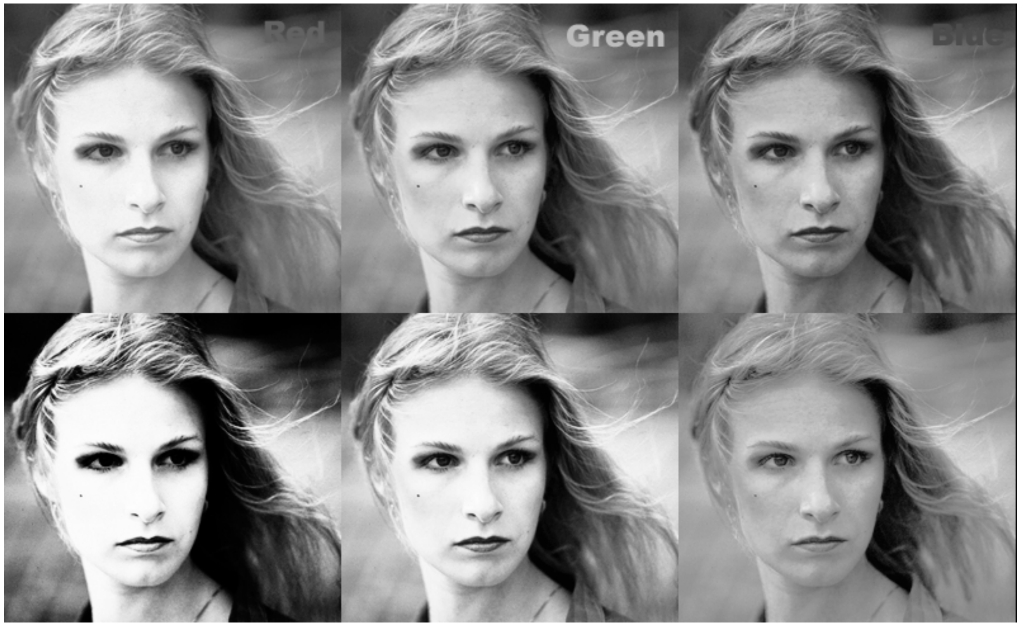


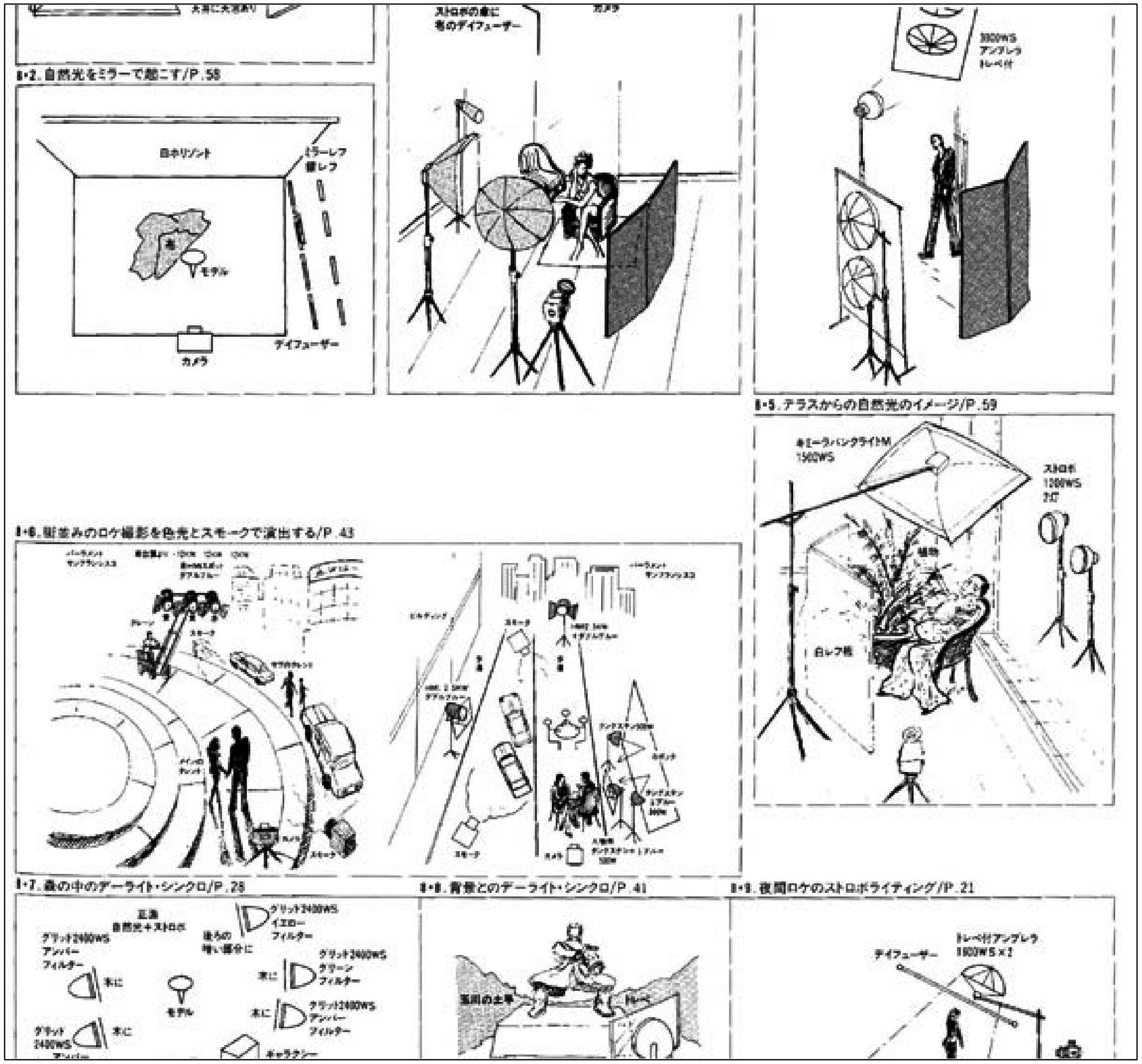
Photo © Kevin Bjorke

“Cross-Processed” Corrected

Useful References

- **Architecture and Interior Design References**
- **Painters: Caravaggio, Rembrandt, Leighton, Alma-Tadema, et al**
- **Cinematography: *Reflections, Painting with Light, The Light on Her Face, Matters of Light and Depth, Lumieres et Ombres, Masters of Light, Film Lighting* (Malkiewicz)**
- **Japanese Wonder Journal: *Commercial Photo***
- ***Light Science & Magic, Hollywood Portraits***

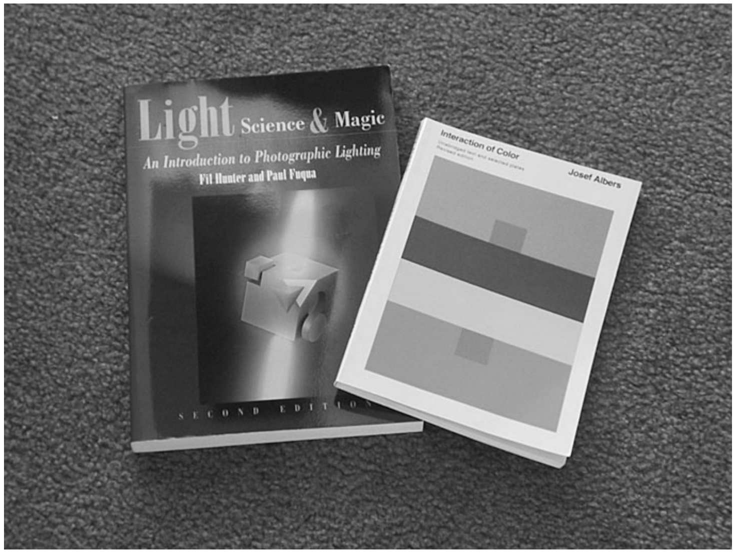
COMMERCIAL PHOTO Magazine/Books



- TV, Films, Print
- Details far beyond any Euro/US publication
- Available at some western booksellers, e.g. Kinokuniya, Books Nippon
- Also in Japan of course

Useful References w/Exercises

- *Light Science & Magic,* Hunter & Fuqua
  - Full of detailed descriptions of typical commercial practice for people and objects
- *Interaction of Color,* Albers
  - Simply the best on the skills of evaluating and understanding color and light perception.
  - Originals with colored-paper inserts expensive and hard to find, paperback around £8
  - Buy some colored paper!



Convergence

- Interactivity is changing movie production economics even as gaming rushes to supplant movies & TV
- Less Render Time == More Artistic Input Time
- Realtime will become important at the high-end, even if the technical gap never completely closes
  - Artist time is more valuable than render time
  - Programmable shading lets you tape-together almost any desired effect
- That’s Show Biz!

Thanks!

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