Game Developers Conference 2011

Approximating Translucency for a Fast, Cheap and Convincing Subsurface Scattering Look

Colin Barré-Brisebois (speaker)

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Agenda

- Prelude – Real-Time Demo
- 1. Translucency in Computer Graphics
- 2. Technique Details
- 3. Implementation Details
- Q & A

Fig. 1 – Real-Time Translucency in Frostbite 2

Real-Time Translucency Demo

Approximating Translucency for a Fast Cheap and Convincing Subsurface Scattering Look

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Colin Barré-Brisebois (EA)
Marc Bouchard (EA)

Translucency in Computer Graphics

Translucency

The quality of allowing light to pass partially and diffusely inside media.

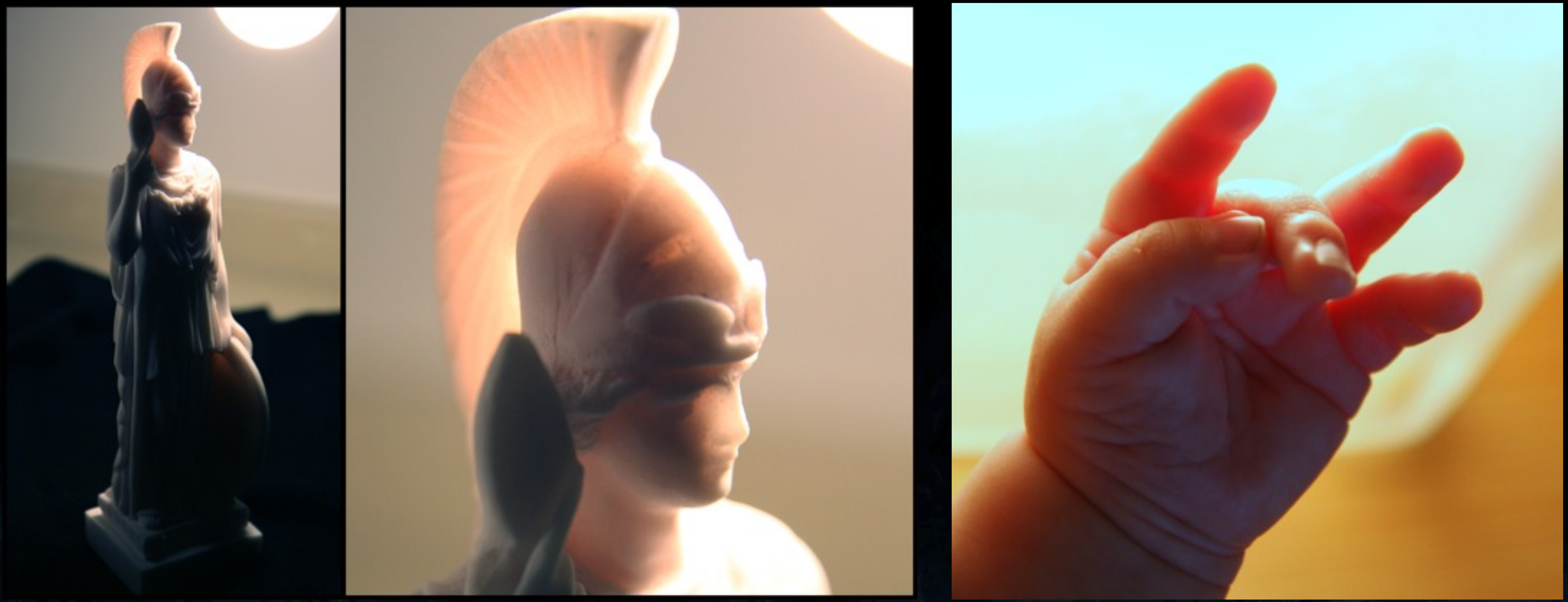


Fig. 2 – Translucency in Athena Statue (left) [BarréBrisebois11], and child's hand (right)

Translucency in Computer Graphics

- We rely heavily on BRDFs for describing local reflections
  - Simple and effective for opaque objects
- However, many objects in nature are (partly) translucent
  - Light transport also happens within the surface
  - BRDFs are not sufficient
- BSSRDFs allow for an even better simulation
  - But are usually more/too expensive
- In our case, we chose BSDFs (BRDF + BTDF), with some elements of BSSRDF

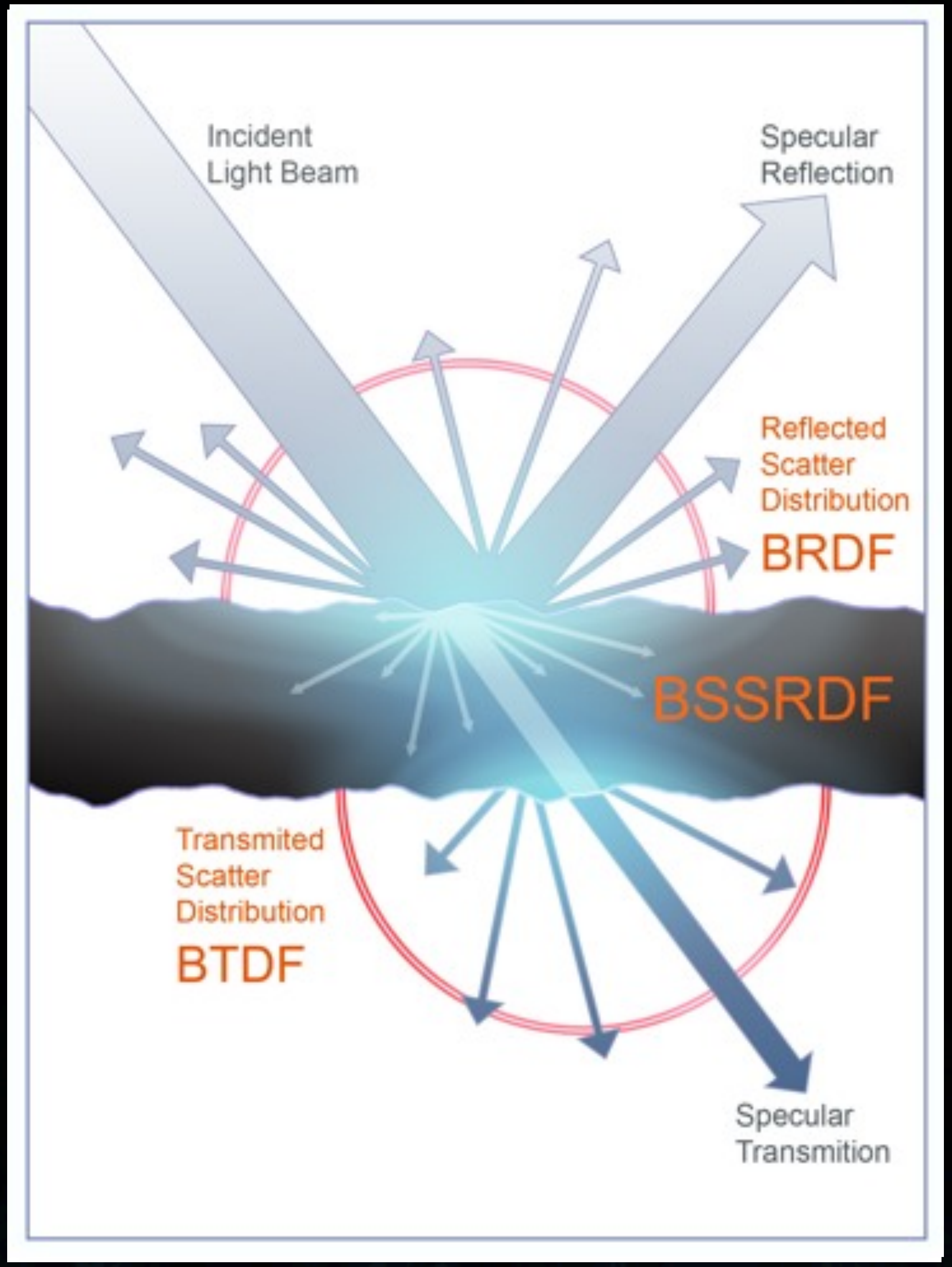


Fig. 3 – BRDF, BTDF and BSSRDF

The State of Translucency

Real-time translucency and derivatives come in different flavors:

- The more complex, but (relatively) expensive
  - [Chang08] Texture-space Importance Sampling
  - [Hable09] Texture-space Diffusion blurs, for skin / SSS
  - [Ki09] Shadowmap-based Translucency / SSS

Fig. 4 – Texture-space Importance Sampling [Chang08]

Fig. 5 – Texture-space Diffusion [Hable09]

The State of Translucency (cont.)

Real-time translucency and derivatives come in different flavors:

- The simpler, but faster
  - [Sousa08] double-sided lighting & attenuation for foliage
- We want: fast like [Sousa08], and nice / complex results like the others ☺

Fig. 6 – Foliage Translucency from Crytek's Crysis

And we got…

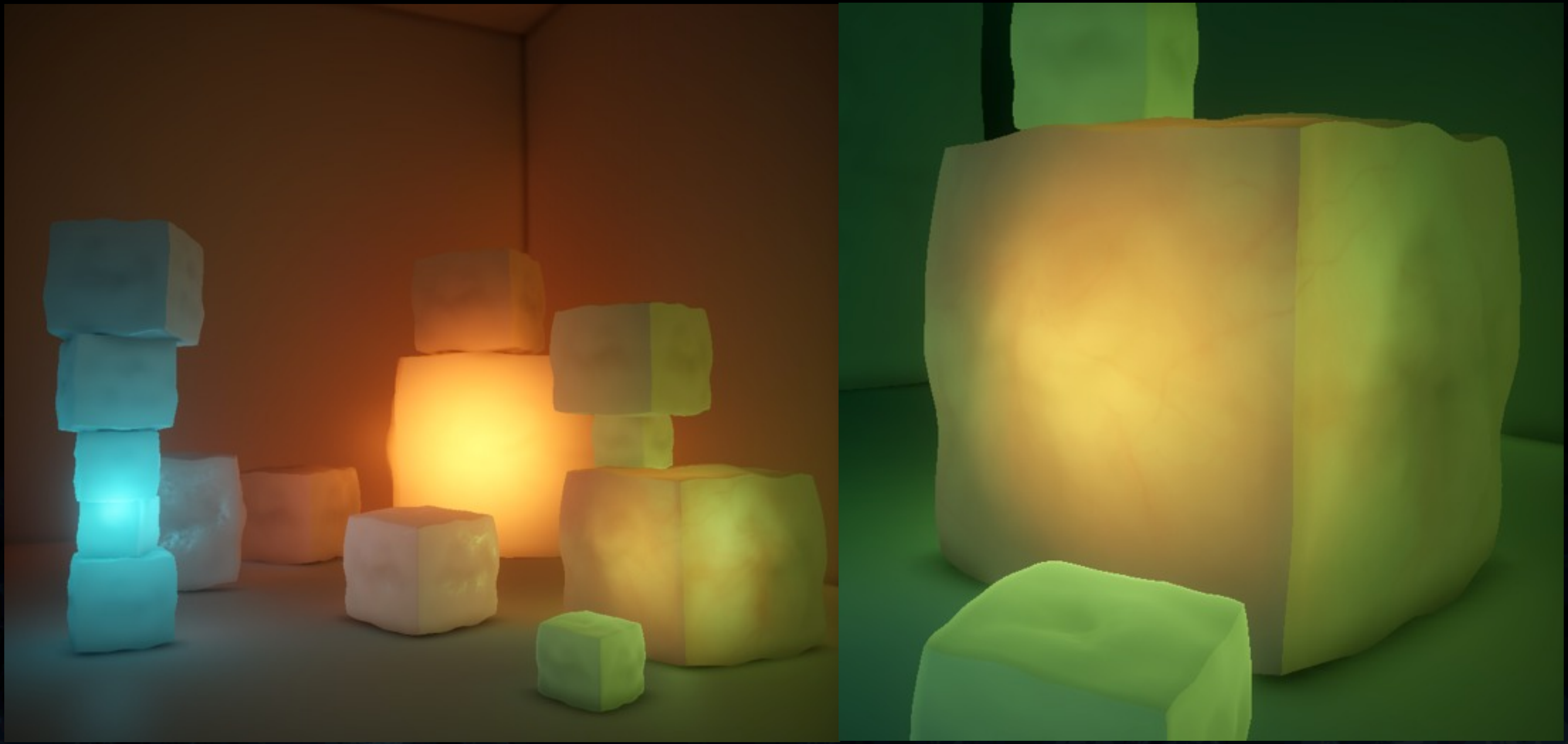


Fig. 7 – Real-Time Translucency in EA DICE's Frostbite 2 Engine

And we got… (cont.)

Fig. 8 – Real-Time Translucency (Skin/Left, Hebe/Right) in EA DICE’s Frostbite 2 Engine

Technique Details

Overview

- We don't want to rely on additional depth maps and texture-space blurs
  - Requires more memory (i.e. for depth maps)
  - Requires significant computation (i.e. for texture blurs)
  - The previous are still feasible, but what if we could do without...
- In essence, for convincing translucency, the light traveling inside the shape:
  - Has to be influenced by the varying thickness of the object
  - Has to show some view & light-dependent diffusion/attenuation
- We only really need a simple representation of inner surface diffusion
  - Most users will be convinced even if not fully accurate!
  - Also, if the effect is cheap, we are free to use it everywhere!* ☺

Overview (cont.)

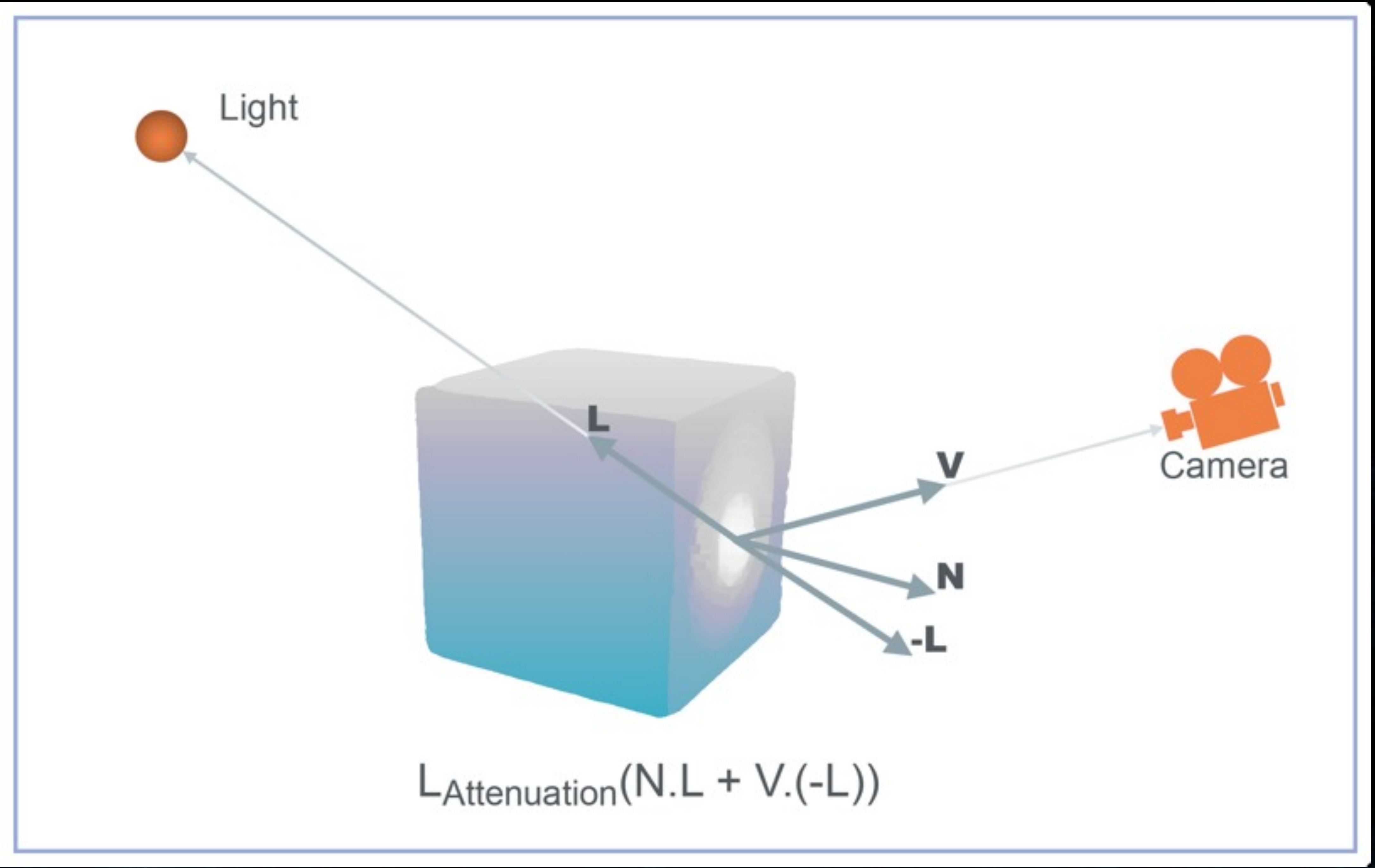


Fig. 9 – Direct and Translucency Lighting Vectors

Local Thickness

Fig. 10 – Local Thickness on Hebe

Computing Local Thickness

- We rely on ambient occlusion for computing this info:
  1. Invert the surface normals
  2. Render ambient occlusion
  3. Invert the colors and store in texture
- Can also be stored in vertex color, if tesselation allows
- Similar to [Sousa08], but streamlined for meshes of varying shapes and sizes.

Computing Local Thickness (cont.)

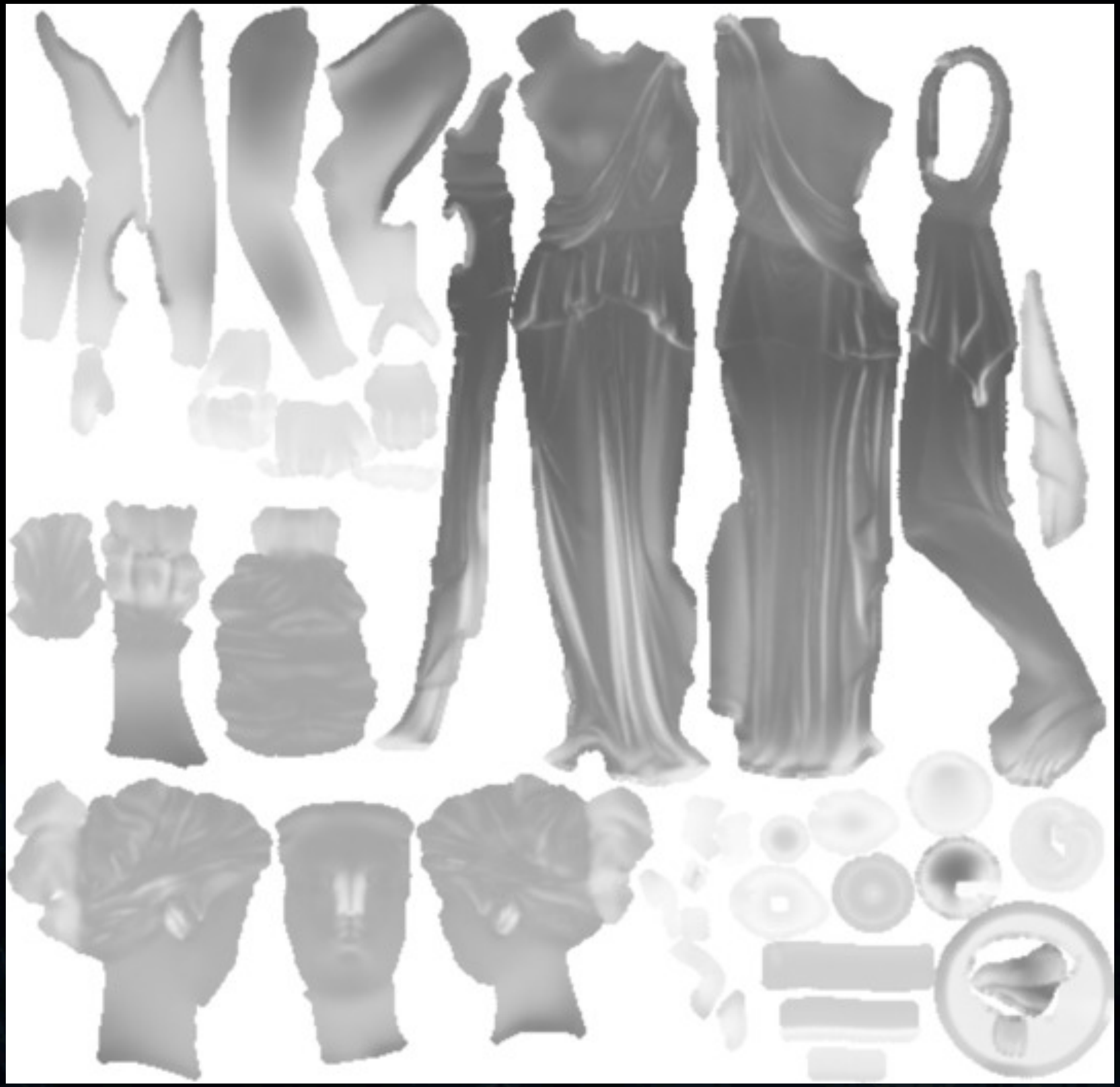


Fig. 11 – Local Thickness Texture for Hebe

What About Subsurface Scattering?

Even if not mathematically perfect, our technique gives an impression of SSS:

- Local thickness approximates light transport inside the shape
  - Different color for direct and indirect light gives convicing light color subsurface transfer
- View-oriented distortion and attenuation gives an organic result, breaking the uniformity

Fig. 13 – Our Technique, combined with Skin Shading

Implementation Details

Code

```
half3 vLTLight = vLight + vNormal * fLTDistortion;
half fLTDot = pow(saturate(dot(vEye, -vLTLight)), iLTPower) * fLTScale;
half3 fLT = fLightAttenuation * (fLTDot + fLTAmbient) * fLTThickness;
outColor.rgb += cDiffuseAlbedo * cLightDiffuse * fLT;
```

- Generates approx. 13 ALU instructions (based on platform)
  - More performance details in following slides
- Can precompute powers in order to get rid of the pow()

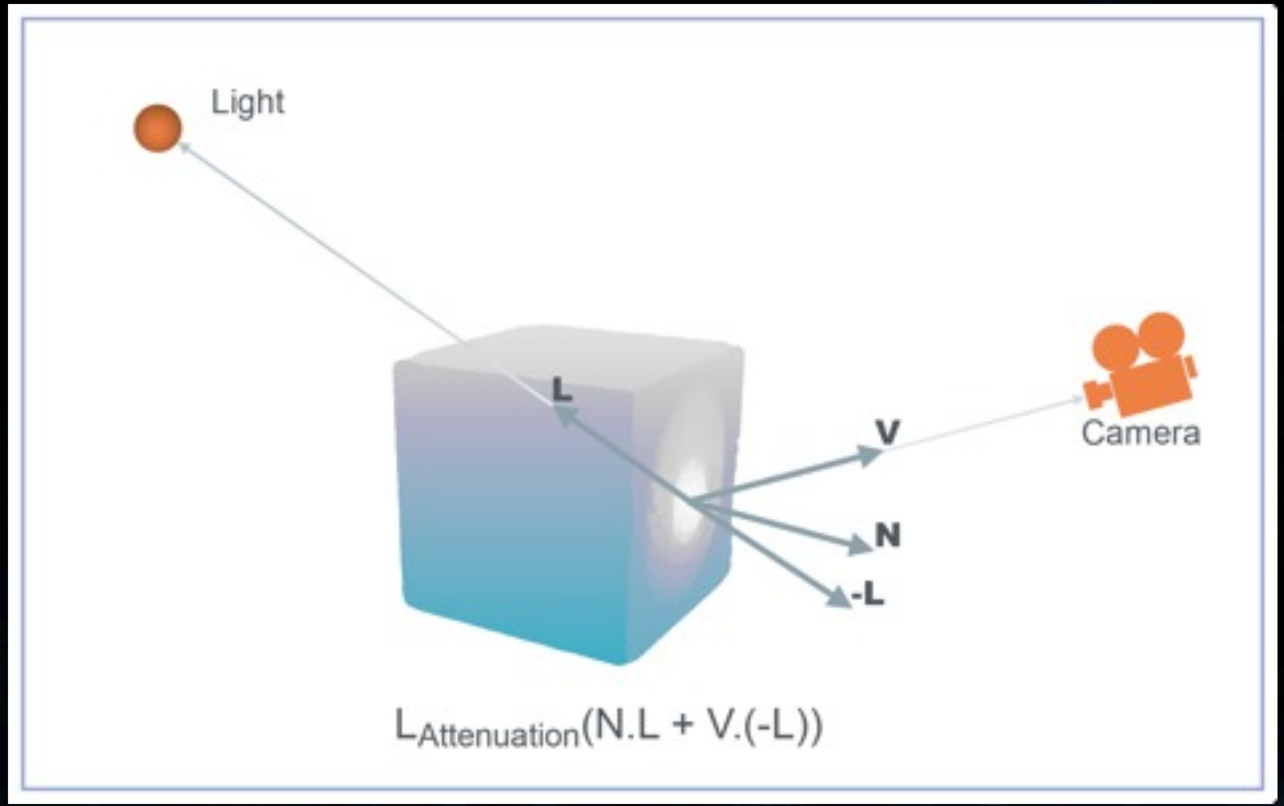


Fig. 9 – Direct and Translucency Lighting Vectors

Managing the Data at Runtime

At runtime, we have several parameters to manage, some per-light, some per-material:

- Per-light parameters are used during the deferred light pass
- Per-material parameters are stored in the g-buffer
  - Can also be stored in a separate buffer, if space-limited
  - Some parameters make more sense per-light, some per-material
  - This is very specific to your g-buffer setup
  - Might require some clever packing/unpacking
    - For packing more parameters on a per-material basis, instead of per-light
  - Using this technique with deferred shading definitely brings-the-thunder!

Managing the Data at Runtime (cont.)

```
half3 vLTLight = vLight + vNormal * fLTDistortion;
half fLTDot = pow(saturate(dot(vEye, -vLTLight)), iLTPower) * fLTScale;
half3 fLT = fLightAttenuation * (fLTDot + fLTAmbient) * fLTThickness;
outColor.rgb += cDiffuseAlbedo * cLightDiffuse * fLT;
```

fLTAmbient

- Ambient value
- Visible from all angles
- Representing both front and back translucency that is always present
- Optimally, per-material

Fig. 14 – Ambient Term

Managing the Data at Runtime (cont.)

```
half3 vLTLight = vLight + vNormal * fLTDistortion;
half fLTDot = pow(saturate(dot(vEye, -vLTLight)), iLTPower) * fLTScale;
half3 fLT = fLightAttenuation * (fLTDot + fLTAmbient) * fLTThickness;
outColor.rgb += cDiffuseAlbedo * cLightDiffuse * fLT;
```

iLTPower

- Power value for direct translucency
- Breaks continuity, view-dependent
- Can be optimized with pre-computed powers
- Optimally, per-material

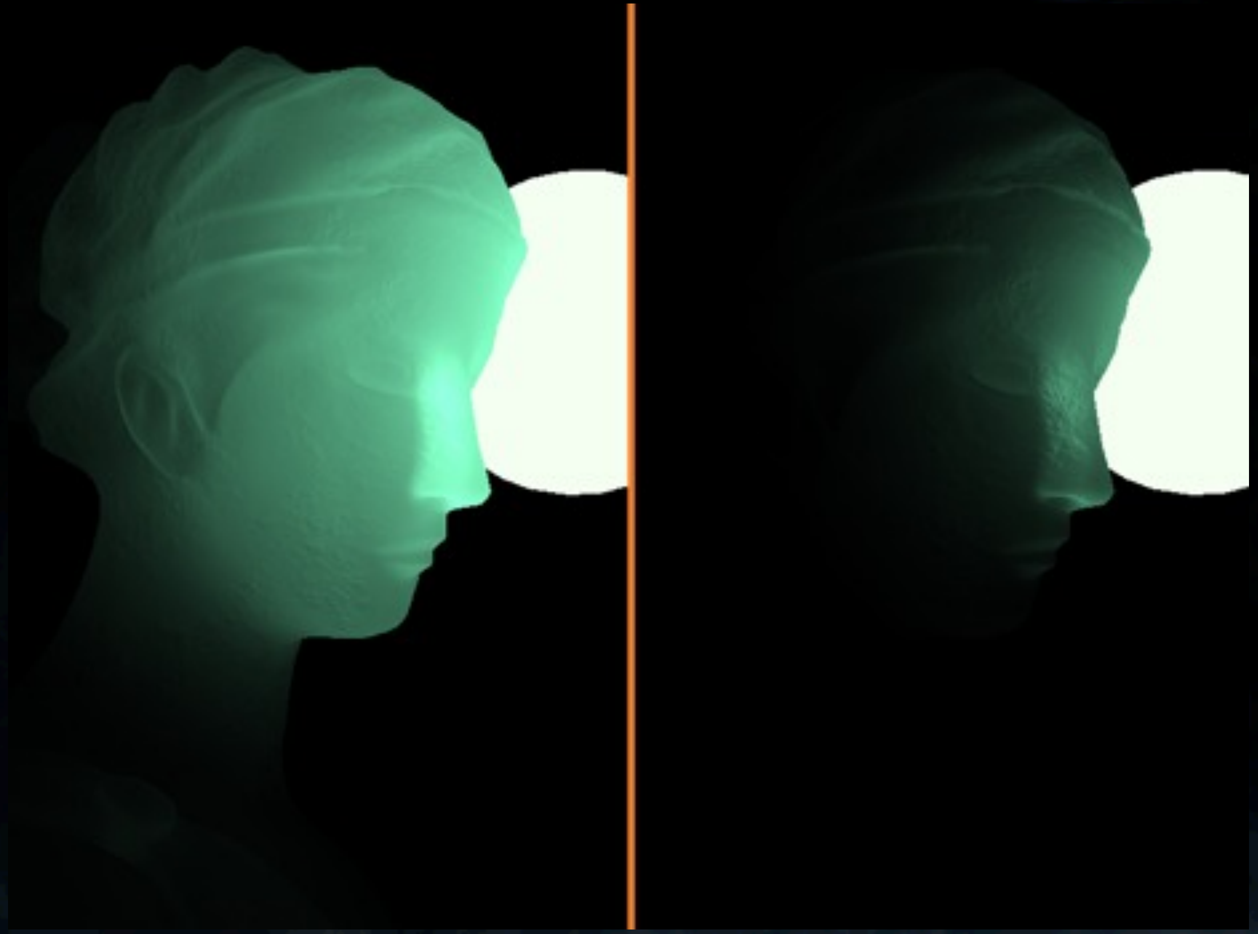


Fig. 16 – Power (4/Left, 12/Right) Term

Managing the Data at Runtime (cont.)

```
half3 vLTLight = vLight + vNormal * fLTDistortion;
half fLTDot = pow(saturate(dot(vEye, -vLTLight)), iLTPower) * fLTScale;
half3 fLT = fLightAttenuation * (fLTDot + fLTAmbient) * fLTThickness;
outColor.rgb += cDiffuseAlbedo * cLightDiffuse * fLT;
```

fLTDistortion

- Subsurface Distortion
- Shifts the surface normal
- Breaks continuity, view-dependent
  Allows for more organic, Fresnel-like
- Optimally, per-material

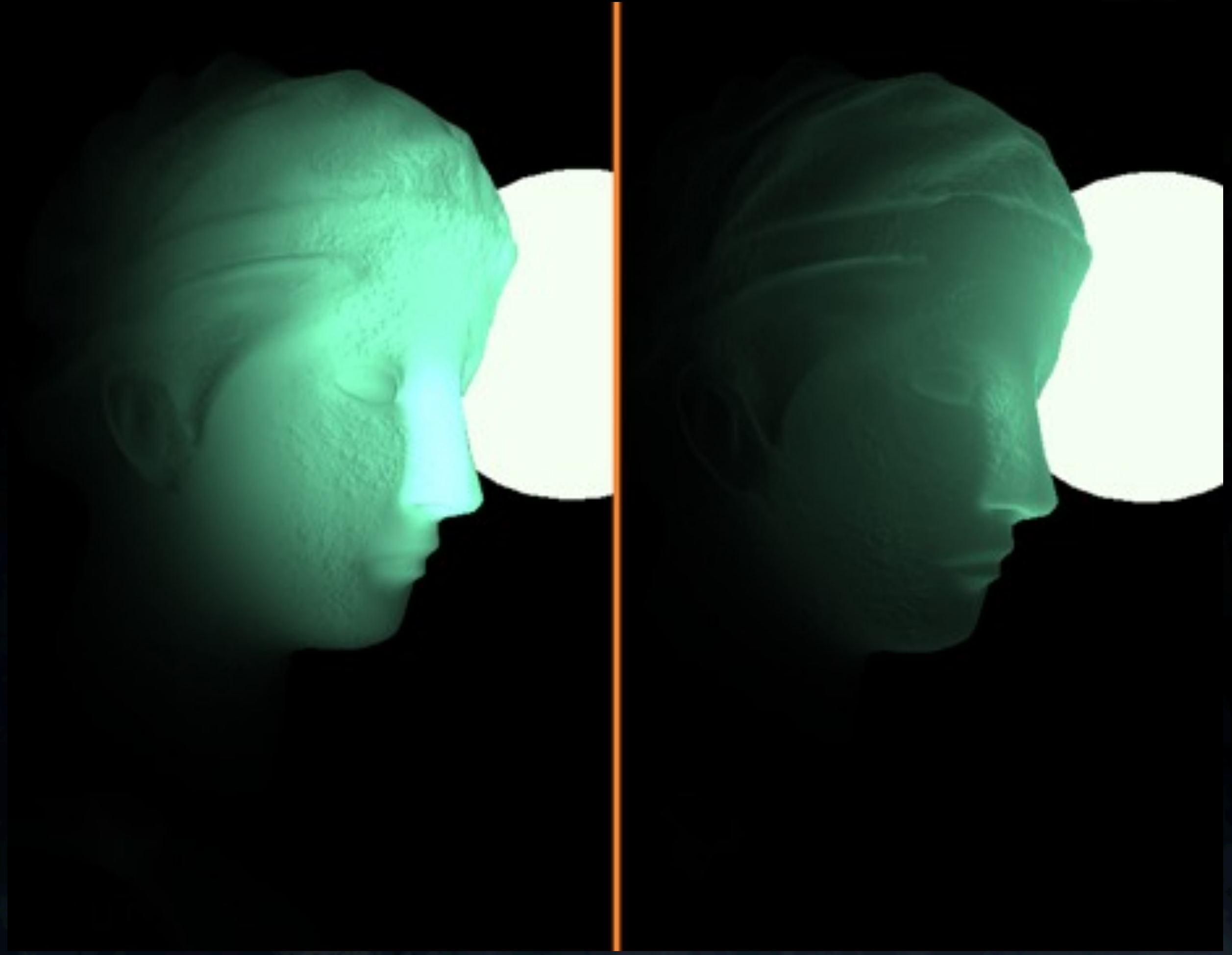


Fig. 17 – Distortion (None/Left, 0.2/Right) Term

Managing the Data at Runtime (cont.)

```
half3 vLTLight = vLight + vNormal * fLTDistortion;
half fLTDot = pow(saturate(dot(vEye, -vLTLight)), iLTPower) * fLTScale;
half3 fLT = fLightAttenuation * (fLTDot + fLTAmbient) * fLTThickness;
outColor.rgb += cDiffuseAlbedo * cLightDiffuse * fLT;
```

fLTThickness

- Pre-computed Local Thickness Map
- Used for both direct and indirect translucency
- Attenuates the computation where surface thickness varies
- Defined per-material

Fig. 18 – Local Thickness

Managing the Data at Runtime (cont.)

```
half3 vLTLight = vLight + vNormal * fLTDistortion;
half fLTDot = pow(saturate(dot(vEye, -vLTLight)), iLTPower) * fLTScale;
half3 fLT = fLightAttenuation * (fLTDot + fLTAmbient) * fLTThickness;
outColor.rgb += cDiffuseAlbedo * cLightDiffuse * fLT;
```

fLTScale

- Scale value
- Direct / Back translucency
- View-oriented
- Should be defined per-light. This makes it the central control point

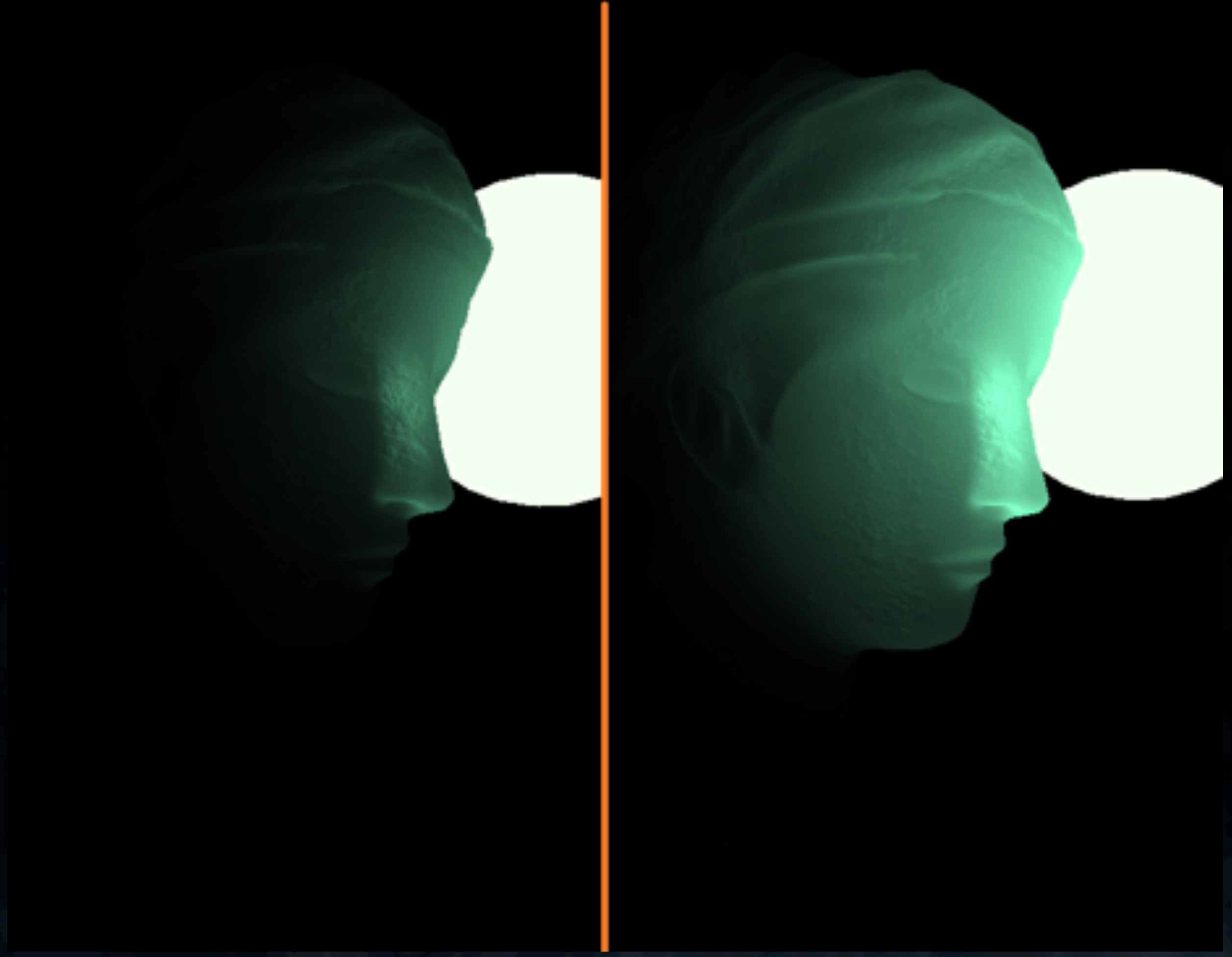


Fig. 15 – Scale (1/Left, 5/Right) Term

All-Together

Fig. 19 – The Final Result on Hebe

Deferred Shading G-Buffer Setup

Minimally, translucency can be stored in the g-buffer as a single greyscale value:

	R8	G8	B8	A8
GB0	Normal			Smoothness
GB1	Diffuse Albedo			Specular Albedo
GB2	Sky Visibility	Custom EnvMap ID	**Translucency**	Material ID
GB3	Dynamic Radiosity			

Fig. 20 – Our G-Buffer, with greyscale Translucency

Based on your game, this can be enough. The color will then only originate from the light sources (and also diffuse albedo).

Deferred Shading G-Buffer Setup (cont.)

All objects here are relying on a greyscale value for translucency →

Fig. 1 – Real-Time Translucency in Frostbite 2

Deferred Shading G-Buffer Setup (cont.)

Better results will be achieved if translucency is a color (here, with some packing):

	R8	G8	B8	A8
GB0	Normal			Smoothness
GB1	Diffuse Albedo			Specular Albedo
GB2	Sky Visibility	**Translucency.R**	**Translucency.G**	Material ID + **Translucency.B**
GB3	Dynamic Radiosity			

Fig. 21 – Our G-Buffer, with coloured Translucency (packed/offset)

This translucency color, representing our inner surface color diffusion, will be combined to the light color and the material's diffuse albedo.

Deferred Shading G-Buffer Setup (cont.)

Green Light
White Albedo
Red Translucency ->

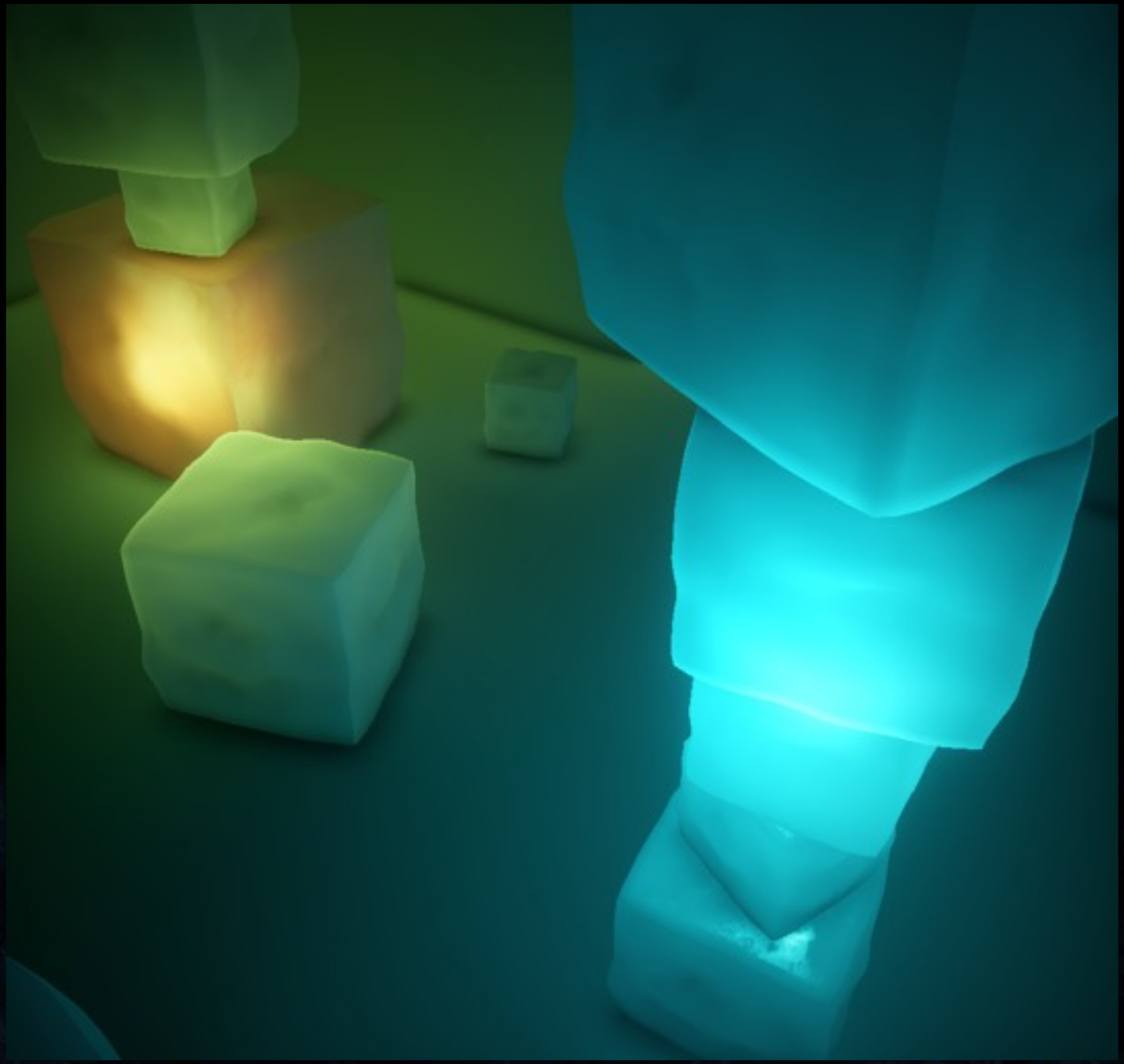


Fig. 22 – Real-Time Translucency in Frostbite 2

<- Blue Light
White Albedo &
Translucency

Performance

	XBOX 360	PLAYSTATION 3	PC (DX11)
Full-Screen Coverage	0.6 ms	1.0 ms	0.03 ms
Instructions	13	17	12

- PS3: Takes advantage of our light-tile rendering on SPUs
  - See Christina Coffin's "SPU Deferred Shading for BF3 on PS3"
- DX11: Supported in our Compute Shader solution
  - See Johan Andersson's "DX11 rendering in Battlefield 3" talk for more DX11-related details
- PC: AMD Radeon 6970

Caveats

- Doesn't take all concavities into account
- Technique is optimal for convex hulls
- Doesn't work with morphing/animated objects
  - Alternative: Though camera dependent, several cases could work with a real-time thickness approximat [Oat08]
  - Alternative: Could also use an hybrid dynamic AO computation, with inverted normals

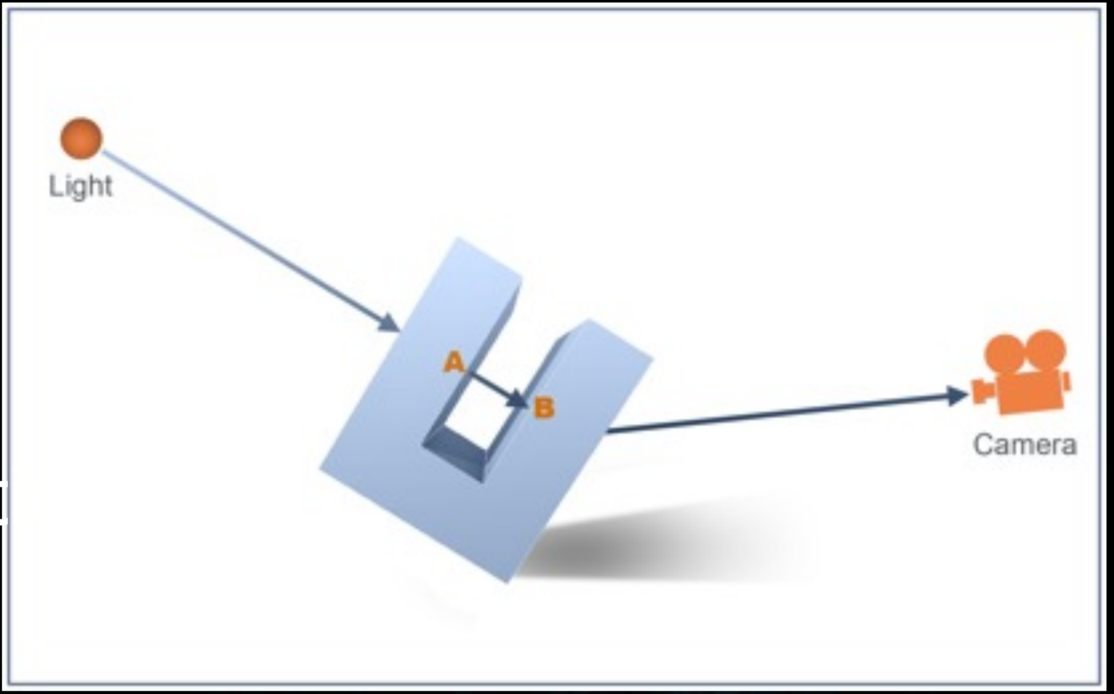
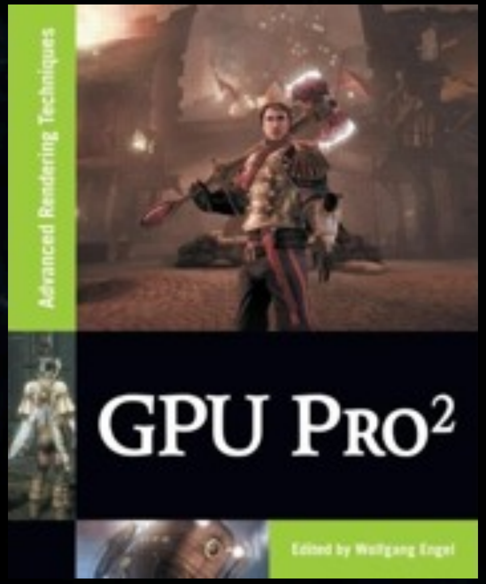


Fig. 23 – Concave Hull

Summary and Q&A

- We presented an artist-friendly, fast and scalable real-time approximation of light transport in translucent homogenous media:
  - Improves games visuals by adding a new dimension, with light traveling inside shapes
  - Has a scalable and reasonable impact on runtime
  - Provides convincing results even if not mathematically perfect
- This technique is also published in GPU Pro 2, released this week at GDC. Check out the book!



Questions?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Battlefield 3 & Frostbite 2 talks at GDC'11:

Mon 1:45	*DX11 Rendering in Battlefield 3*	Johan Andersson
Wed 10:30	*SPU-based Deferred Shading in Battlefield 3 for PlayStation 3*	Christina Coffin
Wed 3:00	*Culling the Battlefield: Data Oriented Design in Practice*	Daniel Collin
Thu 1:30	*Lighting You Up in Battlefield 3*	Kenny Magnusson
Fri 4:05	*Approximating Translucency for a Fast, Cheap & Convincing Subsurface Scattering Look*	Colin Barré-Brisebois

For more DICE talks: http://publications.dice.se

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- Dominik Bauset
- Sandra Jensen

- Mohannad Al-Khatib (@psychodesigns)
- Colin Boswell (@bozz)

References

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