



SUBSURFACE SCATTERING

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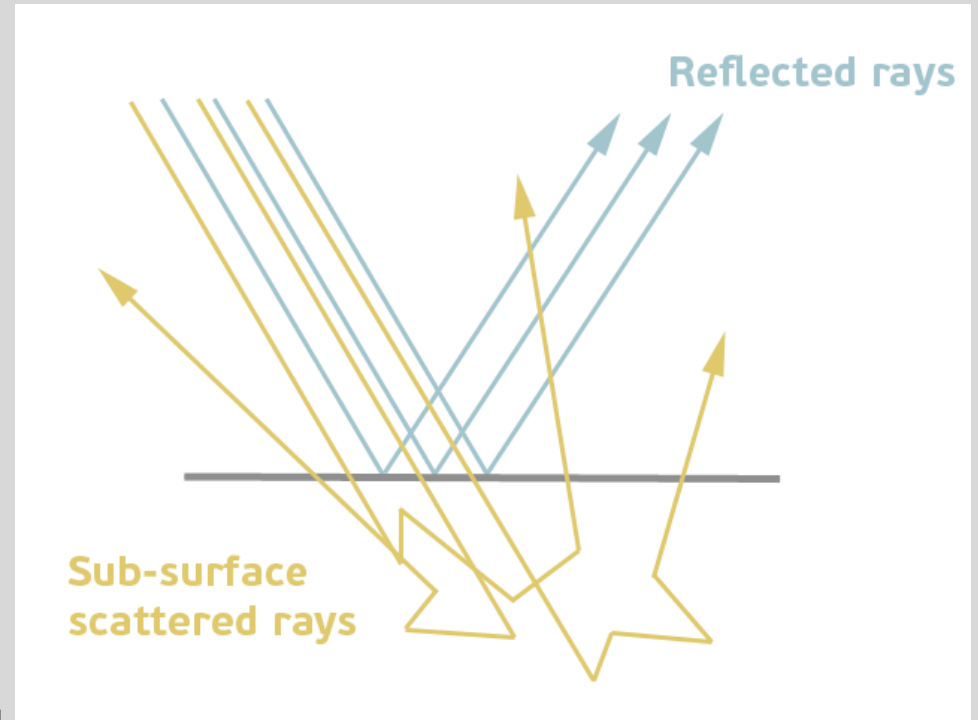
29.04.2022

Outline

- Basics of subsurface scattering (SSS)
- Examples and demo video
- Different implementations
- Conclusion
- Live demo in Blender
 - Install Blender <https://www.blender.org/download/> (~200 MB)

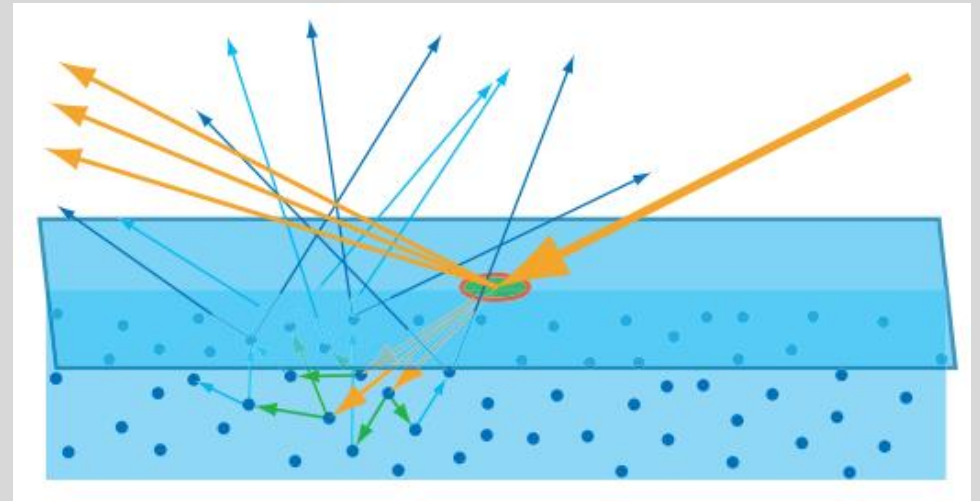
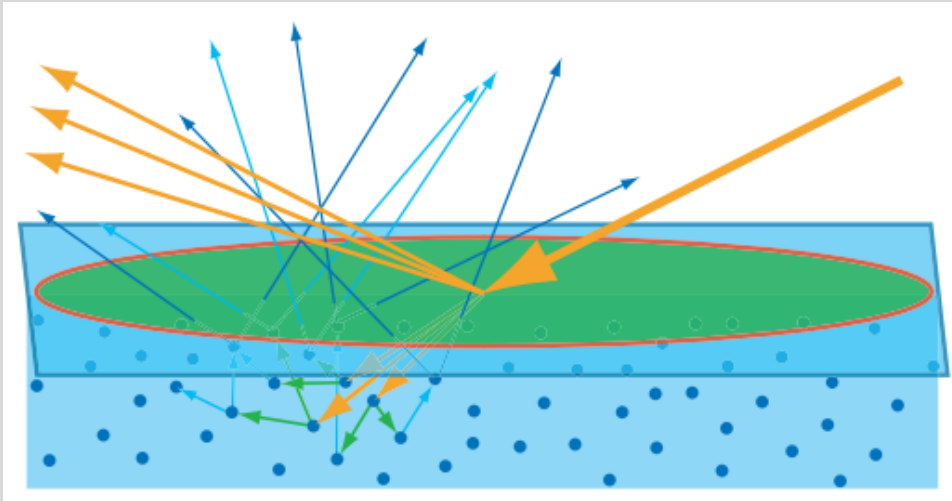
Basic principle

- Translucent objects or materials
- Incoming rays:
 - Reflected
 - Absorbed
- Arbitrary directions
- Softens lighting effects
- Forward vs backward scattering





SSS in graphics



On vs Off

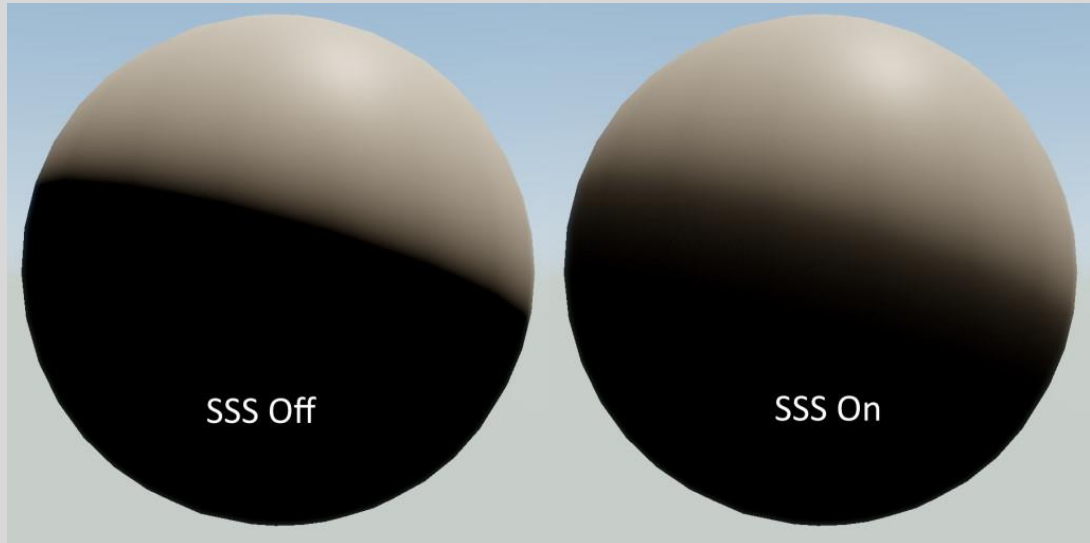
- [Demo video \(Skyrim\)](#)



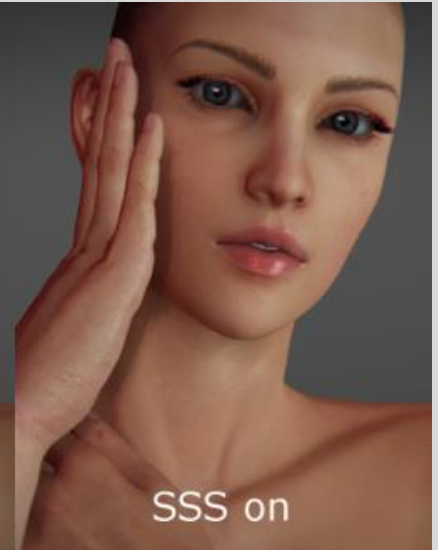
(a)



(b)



SSS off



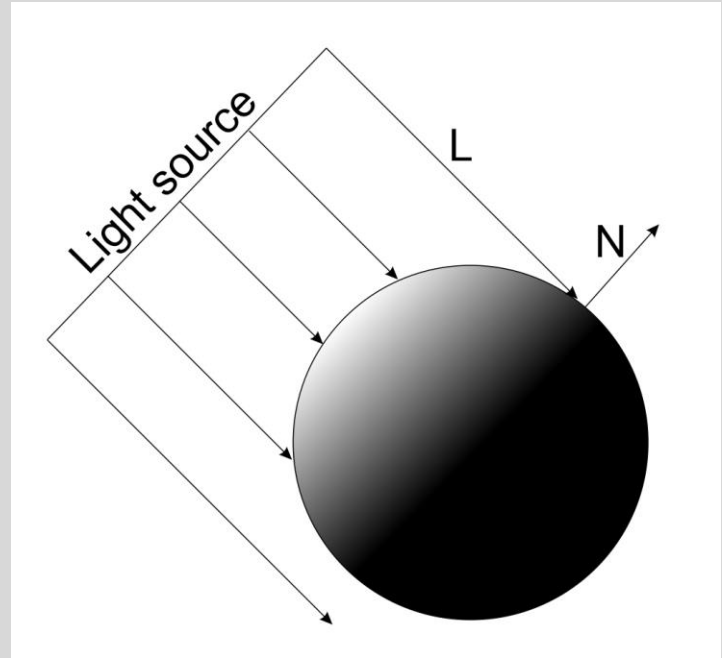
SSS on

Implementations

- Approximations:
 - Games and real-time
 - Wrap lightning
 - Depth maps
 - Space- and texture-space diffusion
 - Pre-integrated SSS
- Accurate SSS:
 - Offline
 - Real world lightning effects
 - Volumetric path tracing
 - Multiple layers

Wrap lightning

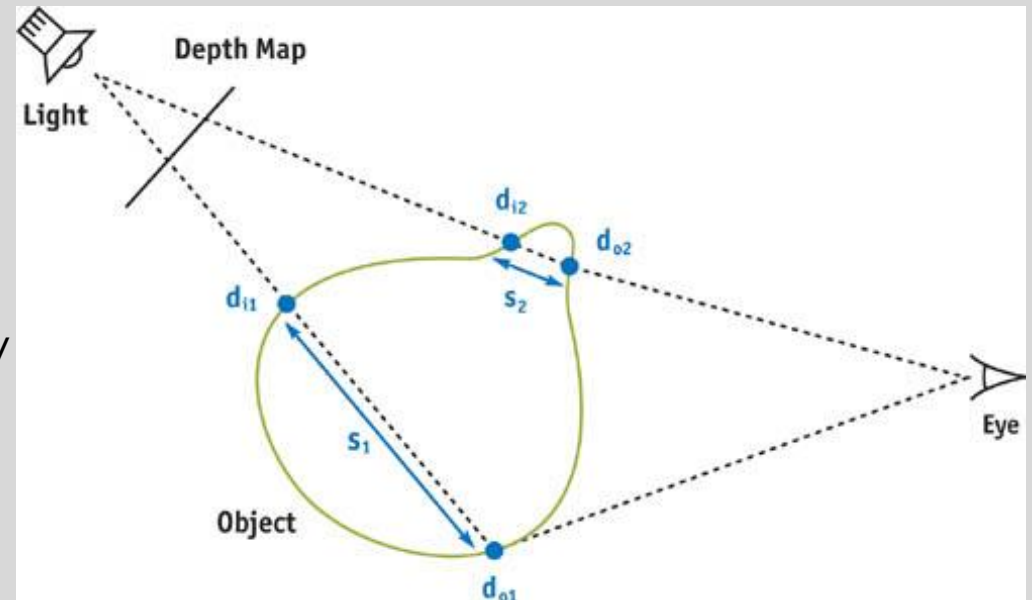
- Fake SSS
- Cheap operation
- Light wraps around curves
- Combine with different colours
- [Demo link](#)



Depth map based SSS

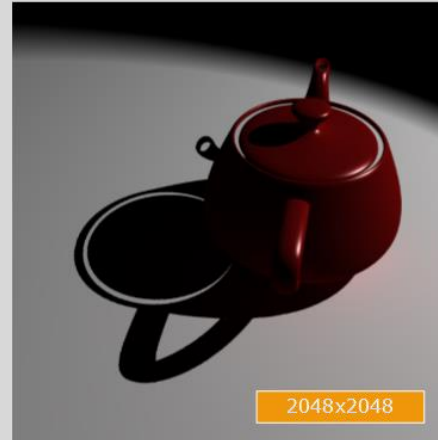


- Simulates absorption
- Backward scattering
- Similar to shadow mapping
- Workflow:
 1. Render from the point of view of light
 2. Measure distance from light to texture
 3. Render the scene using projective texture mapping
 4. Find the distance light travels through the object



Depth map based SSS

- Limited to convex objects
- Supports depth peeling
- Generated each frame
- No light diffusion
- Artifacts may appear around the edges



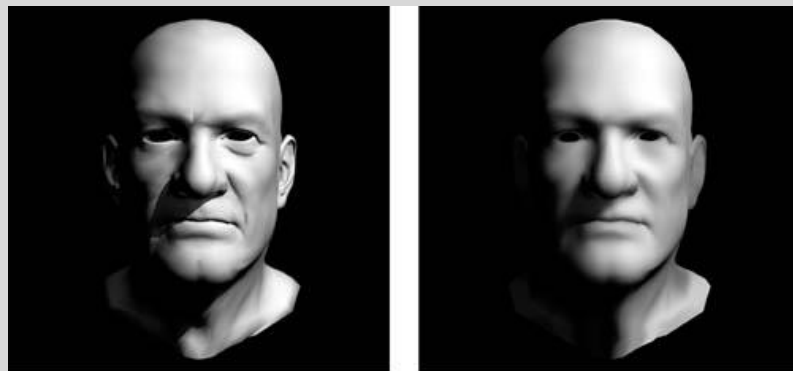
Texture-space diffusion

- Forward scattering
- Workflow:
 1. Unwrap 3D mesh to 2D texture
 2. Adding Gaussian blur
 3. Linear combine 2D textures and render to 3D
- Multiple diffusion profiles for blur
 - For skin:
 - Broad base
 - Sharp spike



(a)

(b)



(a)

(b)

Texture-space diffusion

- Decoupled from screen resolution
- Further and close objects rendered same way
- Operations are faster in 2D
- Deformations may appear
- Usages:
 - Uncharted 2
 - FaceBreaker
 - The Matrix Reloaded

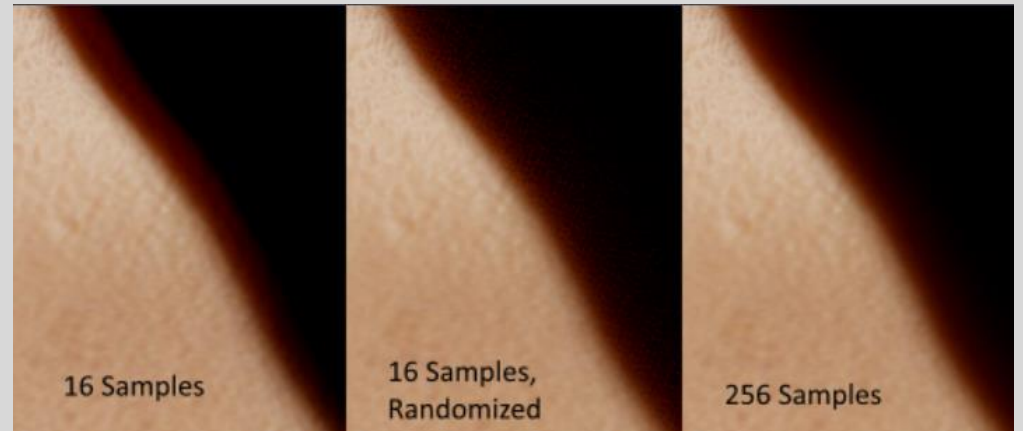


Screen-space diffusion

- Forward scattering
- Similar to texture-space diffusion
- Diffusion is added to rendered image
- Need for additional depth stencil:
 - Far pixels need narrower kernels
 - Pixels under steep angles need narrower kernels
- Combine with depth map SSS

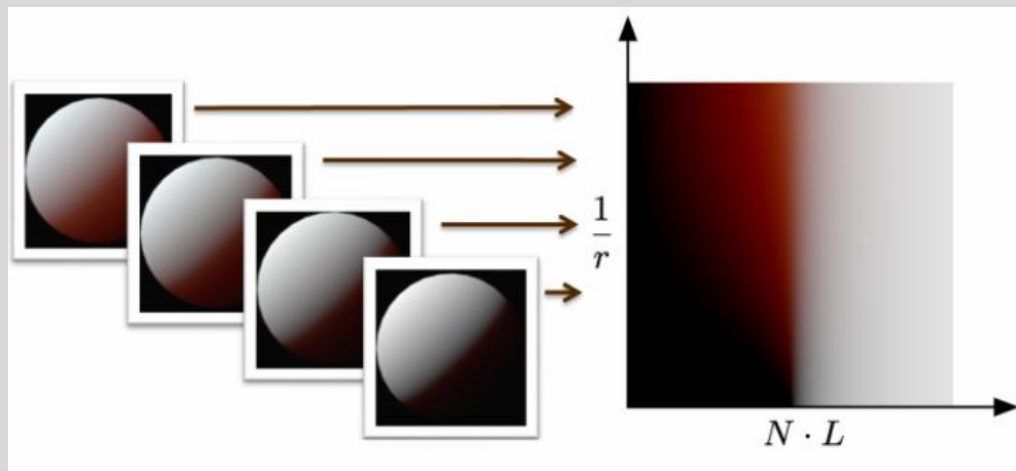
Screen-space diffusion

- Coupled with screen resolution
- Tagging for pixels that needs shading
- Edge colour banding
- Usage:
 - Unity
 - Unreal Engine
 - Disney



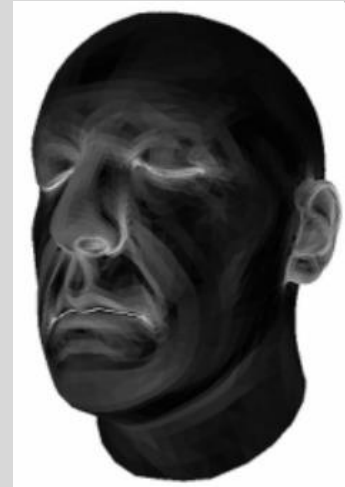
Pre-integrated SSS

- Pre-computes forward scattering
- No subsurface scattering on flat surfaces with uniform lightning
- Utilizes light wrapping idea
- Computes 2D lookup table
- Easily applied to spheres



Pre-integrated SSS

- For arbitrary mesh it compares local curvature with lookup table to get pixel colour
- All work is done in single pixel shader
- Complicated with point light source
- Each material need it's own lookup table
- Usage:
 - The Order: 1886
 - Lone Echo



Conclusion

- Real-time solutions are all approximations
- Backward scattering:
 - Depth map based SSS
- Forward scattering:
 - Texture- and space-diffusion
 - Pre-integrated SSS
- Use hybrid techniques:
 - Forward + backward scattering implementations
 - In example Battlefield V used screen-space and ray-tracing

Demo time



References

- Materials:
 - Simon Green, *Chapter 16. Real-Time Approximations to Subsurface Scattering*. GPU Gems. 2004
 - Eugene d'Eon and David Luebke, *Chapter 14. Advanced Techniques for Realistic Real-Time Skin Rendering*. GPU Gems 3. 2007
 - Jorge Jimenez and Diego Gutierrez, *Screen-Space Subsurface Scattering*. GPU Pro. 2010
 - *An Introduction To Real-Time Subsurface Scattering*. 2019. Link: <https://therealmjp.github.io/posts/sss-intro/>. Retrieved: 11. April 2022
 - *Understanding Subsurface Scattering - Capturing the Appearance of Translucent Materials*. 2014. Link: <https://www.pluralsight.com/blog/film-games/understanding-subsurface-scattering-capturing-appearance-translucent-materials>. Retrieved: 11. April 2022
 - *Practical Tips for Implementing Subsurface Scattering in a Ray Tracer*. 2020. Link: https://agraphicsguynotes.com/posts/practical_tips_for_implementing_subsurface_scattering_in_a_ray_tracer/. Retrieved: 27. April 2022
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 - <https://i.pinimg.com/originals/39/b0/69/39b069b84b7fe7a3ffd26d7b73a8be61.jpg>
 - <https://i.imgur.com/1E1rtIK.jpeg>
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