CSC 240 Computer Graphics
Video 21: Subsurface Scattering & Particle Systems

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Subsurface Scattering
Subsurface Scattering

For some materials, SSS is necessary for realistic rendering.
Subsurface Scattering

Many opaque objects still allow some light to travel through them

- The light travels an unpredictable path via **subsurface scattering (SSS)**
- Differing effects & techniques depending on the *mean path length*
  - Short mean path length: Localized SSS via texture space diffusion
  - Long mean path length: Simulated backlighting via depth map SSS
Subsurface Scattering

Human skin interacts with light in complex ways

- Some light reflects directly off oil layer
- Some penetrates and scatters

Subsurface Scattering

Depth map SSS works similar to shadow calculation

- Render scene from both light and camera; look at z buffer
- Distance between surface points gives material thickness

Subsurface Scattering

Short-range texture space diffusion SSS uses blurring in unwrapped UV map

- Reverse map object lighting onto texture plane
- Blur illumination image and re-map onto object
- Process different colors separately

Questions

1. What key measurement governs the type of subsurface scattering in a material? 
   *Mean path length*

2. Which SSS technique is used to model light diffusing short distances through a material? 
   *Texture space blurring*

3. Which SSS technique is used to model backlight shining through a bulk material? 
   *Depth map SSS rendering*
Particle Systems
Particle Systems

We’ve studied lots about rendering solid objects

- What about liquids and gases? Flexible stuff?
- These are best rendered using many small “particles”
Particle Systems

Overall effect made up of many interacting particles

- Typical particle lasts for limited time
- Has properties relevant to desired effect
  - Position & velocity
  - Color & appearance
  - Size, turbulence, stiffness, etc.
- Can interact with the environment
  - Physics!
  - Cartoon or otherwise!
Particle Systems

Each particle has internal state, updated over time (e.g., each frame)

Some possible simple models:

- Position only, with random updates (Brownian motion)
  \[ \vec{p} = \vec{p} + \vec{r} \]

- Position & velocity, with randomly updated velocity
  \[ \vec{p} = \vec{p} + \vec{v} \Delta t \quad \vec{v} = \vec{v} + \vec{r} \]

- Position, velocity & constant acceleration (gravity)
  \[ \vec{p} = \vec{p} + \vec{v} \Delta t \quad \vec{v} = \vec{v} + \vec{a} \Delta t \quad \vec{a} \text{ constant} \]
Particle Systems

Design choices affect the outcome of a particle system

- **Emitter**: Specifies where & how particles are created
  - Spawn rate, lifetime, properties
  - Usually randomly generated variation

- **Simulation/update**
  - Modify particle properties over time: follow trajectory, collide, etc.

- **Render**: use particles to create visual effect

https://giphy.com/gifs/water-sea-Cym7wdsiqNZ2U
https://www.digminecraft.com/decoration_recipes/make_monster_spawner.php
Particle Systems

Rendering choices can generate many effects

- **Textured billboard quad** or 3D mesh
- **Metaballs** simulate density
  - Add up density functions centered at each particle
  - Render *isosurface* for water/liquid simulation

“Marching Cubes” algorithm
Particle Systems

Rendering may be *animated* or *static*

- Animated rendering shows one particle state per frame
  - Water, gas, fire, etc.
- Static rendering shows all particle states at once
  - Hair, fur, cloth, etc.
CPU vs GPU?

Particles = simple behaviors in large numbers

- CPU can maintain limited number of particles (~2k)
- Real power comes from allowing GPU to handle the particle updates
- Limited communication from CPU to GPU: simple mechanics, high-level update
Particle Systems

Best way to see is by demonstration!

https://aerotwist.com/static/tutorials/creating-particles-with-three-js/demo/
https://squarefeet.github.io/ShaderParticleEngine/
https://threejs.org/examples/webgl_marchingcubes.html
https://threejs.org/examples/#webgl_points_dynamic
http://www.spacejack.ca/projects/terra/
Questions

1. How are particle states updated in a Brownian motion model?
   *The position is modified by a small random amount*

2. What is the advantage to using the same simple state updates across all particles?
   *Updates can be computed efficiently on a graphics processing unit (GPU)*

3. If we use particles to simulate hair, how can we control the hair properties (curliness, body, etc.)?
   *Change the state equations that govern the hair particles*
Review

After watching this video, you should be able to...

- Define subsurface scattering and identify cases where it is important for realism
- Describe two techniques for simulating subsurface scattering in rendered images
- Define a particle system in graphics and list three common uses
- Describe how the state model and its update governs the behavior of a particle
- Explain how similar mathematical processes can generate very different effects such as fire, water, hair, and cloth

Music: https://www.bensound.com