Particle Systems

CSCI 4239/5239
Advanced Computer Graphics
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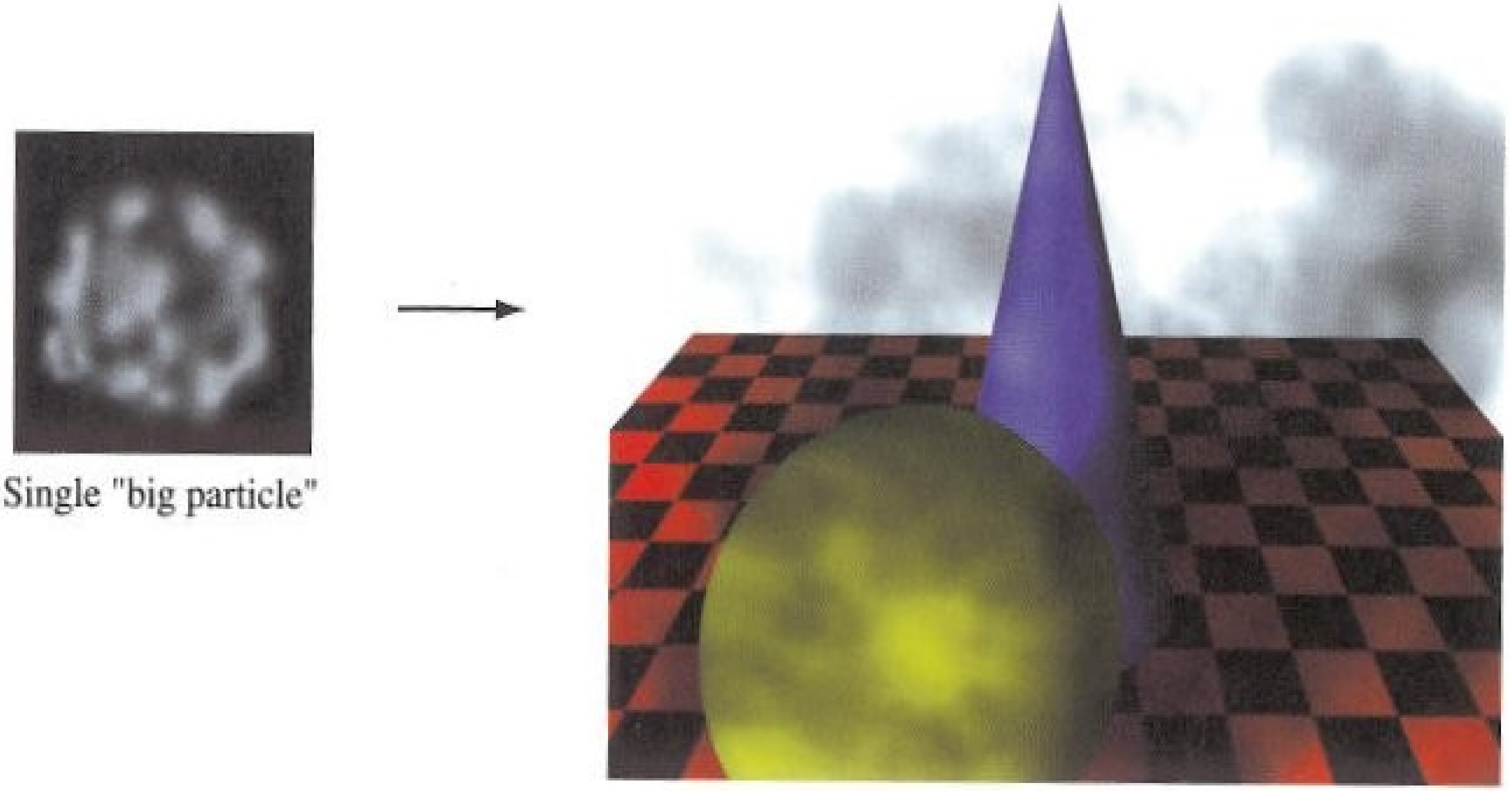
What is it?

- Use points to create a realistic visual effect
  - Rain
  - Smoke
  - Fire
- Particle properties
  - Movement
  - Color
  - Transparency
- Can be done efficiently in a shader
  - Lots of individual points

Big Particles

- Fair sized polygon
- Oriented to be face viewer
- Textured to provide details
- May be blended
- Typically uniform color
- Typically lit with constant normal

Big Particle Smoke



Single "big particle"

Smoke cloud composed of multiple big particles

From Advanced Graphics Programming Using OpenGL

Small Particles

- More suited to objects with diffuse, highly chaotic boundaries
  - Clouds
  - Fire
- One or two pixels in size, rarely textured
  - Point size may be a function of distance

From ICE Particle Shaders

Number of Particles

- Performance
- Size
- Too many may be too dense
- Too few may not be realistic
- The “best” answer is determined experimentally

Managing Particles

- Start time
- Initial properties
- Lifespan
- Behavior during lifespan
- Accumulation
- Reincarnation

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Efficiently Implementing Points

- Standard attributes
  - Position, Color, Normal, Texture Coordinates
- Vertex shader may need more attributes
  - Velocity, Start time
- OpenGL Support
  - glDrawArrays()
  - glBindAttribLocation()
  - glVertexPointer(), glColorPointer(), glAttribPointer()
  - glEnableClientState(), glEnableVertexAttribArray()

Point Sprites

- Large point with a texture applied
- OpenGL Support
  - glEnable(GL_POINT_SPRITE)
- Vertex Shader
  - Transform particle location
- Fragment shader
  - Set every pixel on point
  - gl_PointCoord varies 0-1 across pixel
    - Use as texture coordinates

Particle Interactions

- Particles may or may not interact with the environment or each other
  - Sand grains bouncing off each other
  - Sand grains bouncing off an object
- Particles may be made to appear to interact by blending
  - Order and blend modes are important
- Interaction adds computational cost

CPU vs. GPU Implementation

- CPU implementation allows more flexibility
  - Access to more functions (e.g. rand())
  - Significant computational costs
  - State changes are expensive (e.g. point size)
- GPU implementation
  - Huge efficiency increase
    - Parallelizable
  - A bit less flexible
  - Harder to do interactions with the environment

Applications

- Precipitation (rain, snow)
- Smoke
- Vapor trails
- Fire
- Explosions
- Cloud
- Distant lights (stars)

Application: Precipitation

- Effected by wind
- Rain drops are somewhat transparent
- Snow flakes are shiny
- Snow should accumulate
- Motion blur
- “Curtain” over scene vs. volumetric

Application: Smoke

- Smoke may rise from a source, or be everywhere in the scene
- Changes in density are a key feature
- Effected by air currents
- Turbulence
- Particles may be persistent or transitory

Application: Vapor trail

- Like smoke but fades over time
- Effected by air currents (drift)
- Generally not buoyant
- Particles typically have a finite life span

Application: Fire

- Luminescent particles
- Very dynamic
  - Buoyant
  - Turbulent
  - Short life span
- Hard to do realistically
  - Needs lots of small particles
  - Fewer large particles

Application: Explosions

- Very short lived
- Very dynamic
- Fireball
  - Centered on a point
  - Flash of light
  - Flames in Hollywood explosions
- Smoke
- Pieces of stuff blown up

Application: Clouds

- Amorphous
- Distant
- Like smoke but may be more persistent
- May be more efficient with large particles and textures using blending

Application: Light Points

- Stars
  - Twinkle due to atmospheric turbulence
  - Can be a temporal noise function
- Beacons, runway lights
  - Perspective (brightness) important depth cue
  - May be directional or periodic