Particle Systems

• Are used to simulate the appearance of particulate, hairy, or fuzzy phenomena.
• Involve the animation of large collections of (perhaps tiny) particles which have various graphics characteristics.
• Were originally developed by Pixar’s Bill Reeves for the “Genesis Sequence” in the movie Star Trek II: The Wrath of Khan
• Have been used to create effects of fire, smoke, rain, snow, fireworks, disintegration, dust, sand, explosions, flow, waterfalls, stars, comets, plants, hair, fuzz. Surely many more.
Particle Systems Examples

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Particle Systems Examples

The Lion King (2019) – Disney

"Particles" Don't Actually Have to Be Particles
The Process

The basic process is this:

1. Random Number Generator
2. Emit
3. Display
4. Update

The Emitter

The Emitter gives each particle a:

- Birth time
- Death time
- Start location
- Start velocity
- Start color
- Start size
- Start alpha (blending factor)

Plus, any information about how these quantities change over time

\[ \text{Color} = (1-\alpha)\text{Color}_0 + \alpha\text{Color}_1 \]
Creating Random Values for the Emitter

```c
#include <stdlib.h>

float Ranf( float low, float high )
{
    float r = (float) rand(); // 0 - RAND_MAX
    float t = r / (float) RAND_MAX; // 0. - 1.
    return low + t * (high - low);
}

int Ranf( int ilow, int ihigh )
{
    float low = (float) ilow;
    float high = ceil( (float) ihigh );
    return (int) Ranf(low,high);
}
```

The Displayer

And the displayer draws the scene using different graphics techniques such as:

- Dots
- Small line segments
- Polygons with billboarding
- Quads with textures and billboarding
- Sprites
- Spheres, Cubes
- “Rockets”
- Lighting
- Blending
- Smearing

Easiest way:

```c
glBegin( GL_POINTS );
glColor3f( r0, g0, b0 );
glVertex3f( x0, y0, z0 );
...
glEnd( );
```

Most efficient way: Vertex Buffer Objects
**OpenDX Scalar Glyphs**

- Square
- Circle
- Diamond
- Cube
- Sphere

**OpenDX Vector Glyphs**

- Needle
- Arrow
- Rocket
**Billboarding**

Apply the proper rotation about the proper axis such that the plane’s surface normal is always pointed towards the eye. The eye always sees the surface head-on. Besides particle systems, this is often used to create the appearance of 3D trees from 2D tree images.

\[
A = \hat{n} \times \hat{E} \\
\theta = \cos^{-1}(\hat{n} \cdot \hat{E})
\]

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**Sprites**

A “sprite” is a 3D object pre-rendered to a flat 2D texture and “slipped” into a certain depth in the scene.

[Sprite images]

http://sdb.drshnaps.com
The Updater

And the simulation updates the:

- Position
- Color
- Size
- Alpha
- Interaction with other particles and other objects

Note that these can change as a function of time, position, or anything else

Particle Systems

Circles only

Circles with traces
Particle Systems

Points only

Points with traces

Particle Systems using OpenGL Compute Shaders

1,000,000 particles
1.3 Gparticles / sec
Particle Systems in the OSU Shaders Course

1,000,000 particles

Particle Systems using Scratch

http://scratch.mit.edu
Particle Systems using Game Maker

http://www.yoyogames.com