High Speed Rendering Method for Complex Scenes

Matthew W. Johnson    玉木 徹    金田 和文
* 水上 嘉樹    * 多田村 克己

広島大学大学院工学研究科
* 山口大学大学院理工学研究科
Goal: Rendering Rainy Scenes

- Drive Simulators
  - Adverse conditions
- Entertainment
  - Atmosphere, mood

Test Drive Unlimited
Microsoft Xbox 360, 2004

Matrix Revolutions
Warner Bros. Pictures 2003
Previous Method

- Image based systems (rain streaks)
- Particle Systems
- Ray Tracing
• Shoot rays at pixels
• Find intersections
• Return color data
  – Red box
• Store color in pixel
Our Method: Rain Tracer

- Ray trace raindrops
- **Environment Map**
  - **Intersection Locations**
    - EMIL data
  - \((x,y,z)\rightarrow(\theta,\Phi)\rightarrow(U,V)\)
    - preprocessing
- \((U,V)\rightarrow RGB\) color - Runtime
- Interpolate \((U,V)\) data
  - [make new drops]
Environment Map

Environment Map:

Environment Map translated to sphere:
Representative Ray Trace Raindrops

- Raindrop “screen” stores EMIL data
- EMIL data allows for interpolation
- RGB does not allow interpolation
Ray Trace vs. Interpolation of EMILs

Ray Tracing:
- Intersection: 3x
  \[ DV = (D^*V); \]
  \[ D2 = (D^*D); \]
  \[ SQ = (DV*DV-D2*((V^*V)-R*R)); \]
  if (SQ<0)
    return (false);
  SQ = sqrt(SQ);
  T1 = ((DV+SQ)/D2);
  T2 = ((DV-SQ)/D2);
  if ((T1<0.0) && (T2>0.0))
    T = T2;
  else if ((T1>0.0) && (T2<0.0))
    T = T1;
  else
    T = MIN(T1,T2);
  if (T<0.0)
    return (false);
  point = P + (D * T);
  return (true);
- Refraction: 2x
  \[ n = (n1/n2); \]
  \[ c1 = -(normal^*incident); \]
  \[ ck = 1 - n*n * (1 - c1*c1); \]
  if (ck < 0.0)
    return (Reflect(refracted, incident, normal));
  c2 = sqrt(ck);
  refracted = (n^*incident) + (n * c1 - c2)*normal;
  return (refracted);
- Reflection: 1x
  \[ reflected = incident - 2*(incident*normal)*normal; \]

Ray Tracing continued:
- Intersection: 9mult., 6 add., 1 sqrt, 7 comp.
- Refraction: 14Mult., 8add., 1 comp., 1 sqrt
- Reflection: 7mult., 3add.
- Ray Tracing Total:
  62 multiplications, 37 additions, 5 square roots, 23 comparisons

Interpolation:
- Interpolate: 2x
  \[ (1-a)U1+a(U2) \]
- 4 additions, 4 multiplications
Interpolation

Drop A: \((x_1,y_1,z_1)\)
Drop B: \((x_2,y_2,z_2)\)
Drop C = \((1-z)A + z(B)\)

Environment Map:

Interpolated Raindrop: Interpolated from \((-500,0,0)\) and \((+500,0,0)\)
Quality Comparison

Ray Traced Raindrop Position(0,0,-500)

Interpolated Raindrop at Position(0,0,-500) Interpolated from (-500,0,0) and (500,0,0)

Total Difference: 9776
Reflection Difference: 9976
Average Difference in Reflection: 0.149
Number of Pixels: 65536
Screen Size: 256x256

Pixels with Error in Reflection U: 29.83%
Quality Comparison

Interpolated Raindrop at Position(0,0,-500) Interpolated from (-500,0,0) and (500,0,0)

Ray Traced Raindrop Position(0,0,-500)

Reflection U Error in 19552 pixels

No error: Alpha, Reflection V, Refraction U, Refraction V

Calculation Times: (per 1000 raindrops)

<table>
<thead>
<tr>
<th>Rain drop Size</th>
<th>Ray Trace</th>
<th>Interpolate</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>512x512</td>
<td>45 min</td>
<td>13.4 sec</td>
<td>200x</td>
</tr>
<tr>
<td>40x40</td>
<td>170 sec</td>
<td>0.042 sec</td>
<td>400x</td>
</tr>
<tr>
<td>14x14</td>
<td>2.3 sec</td>
<td>0.006 sec</td>
<td>380x</td>
</tr>
</tbody>
</table>

*0.000006 sec. Required to start/stop the clock
Results Example: Light Probe

Light Probe: 1500x1500 pixels

512x512 Raindrop Result:
Fresnel Effect
Results Example: Raindrop Resolutions

- 32x32 raindrop scaled up to 256x256
- Fresnel Effect is still visible

No Fresnel effect, refraction only
Fresnel effect, reflection & refraction
Results: A Rainy Scene

Raindrop sizes: 5 px, 8px, 11px, 14px
Results: Functioned Raindrops

Advantage:
No preprocessing

Examples:
- 30x30 Functioned
- 30x30 Ray Traced
- 40x40 Functioned
- 40x40 Ray Traced
Level of Detail

- Functioned Drops
- Ray Traced
- Interpolated
Limitations

- Approximated 3D Location
  - Non-real time
  - No objects in real time
- View area restricted
  - Can't interpolate everywhere
Future Work

- Anti-aliasing
- Video Animation
- Real time Environment

Madden 2008
EA Sports
Future Work: Many Viewpoints

• Current:
  – One view, many drops

• Next:
  – One drop, many views

• Final:
  – Many drops, many views