High Speed Rendering Method for Complex Scenes

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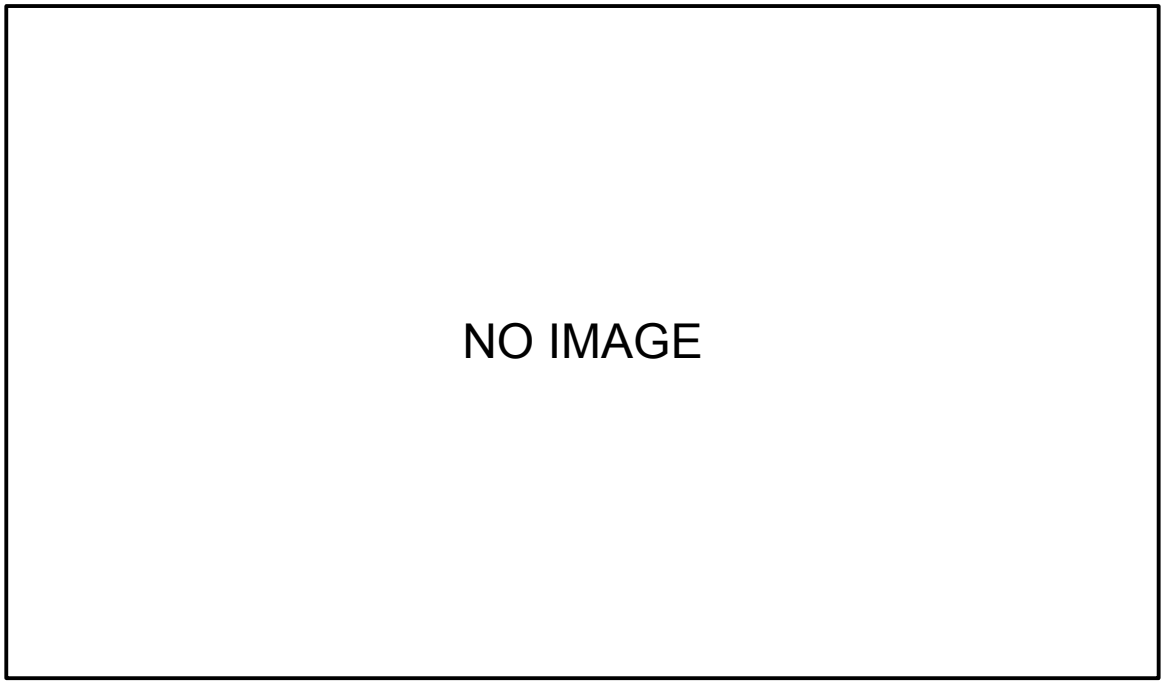
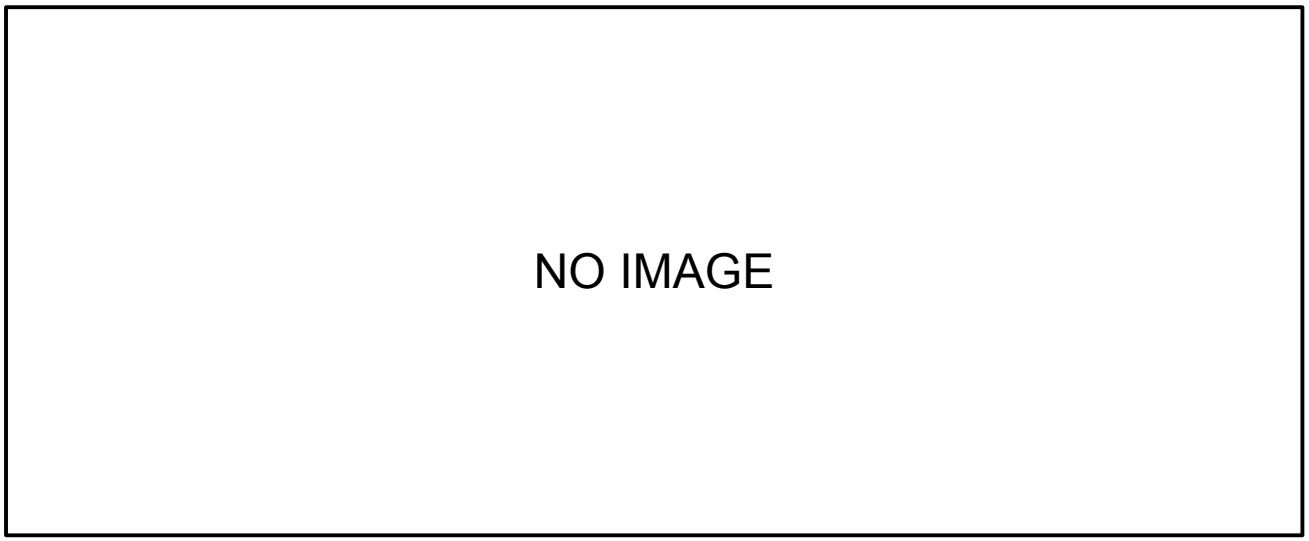
Goal: Rendering Rainy Scenes

- 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)

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- Particle Systems

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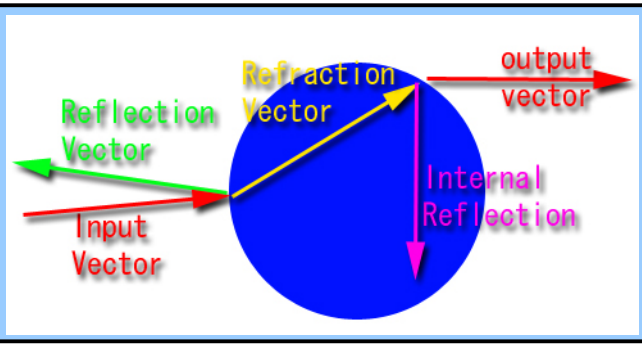
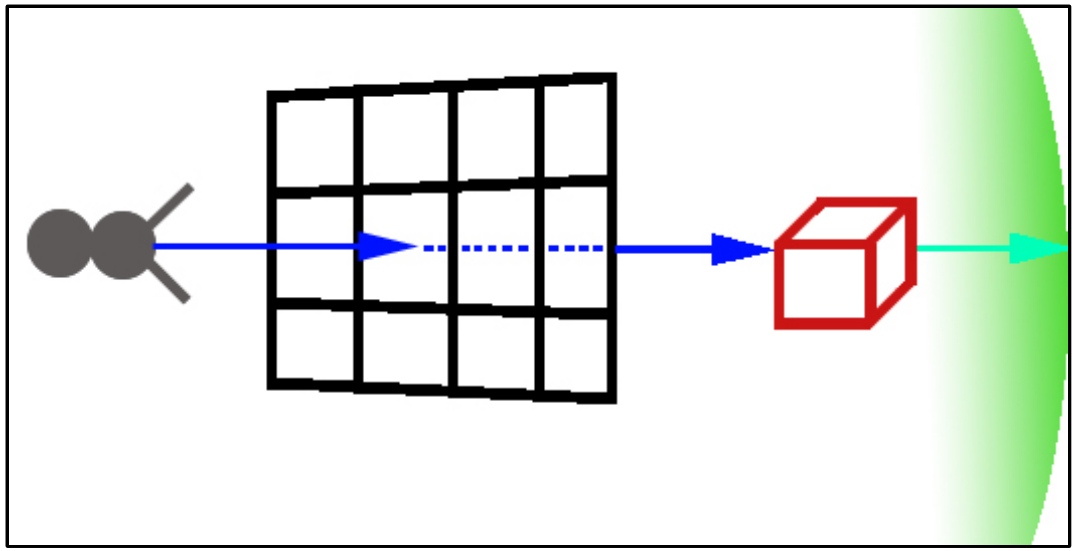
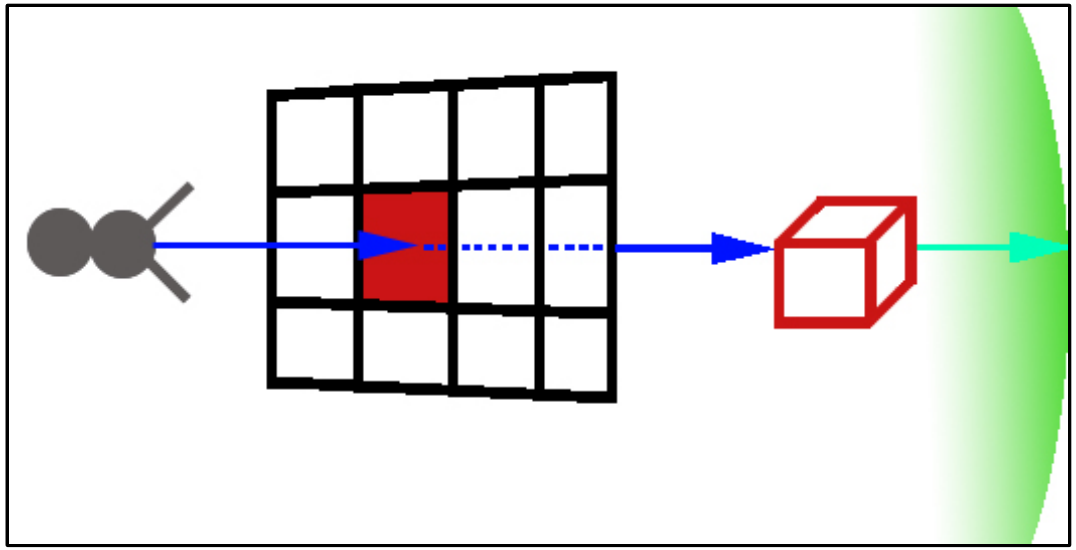
- Ray Tracing



Ray Tracing

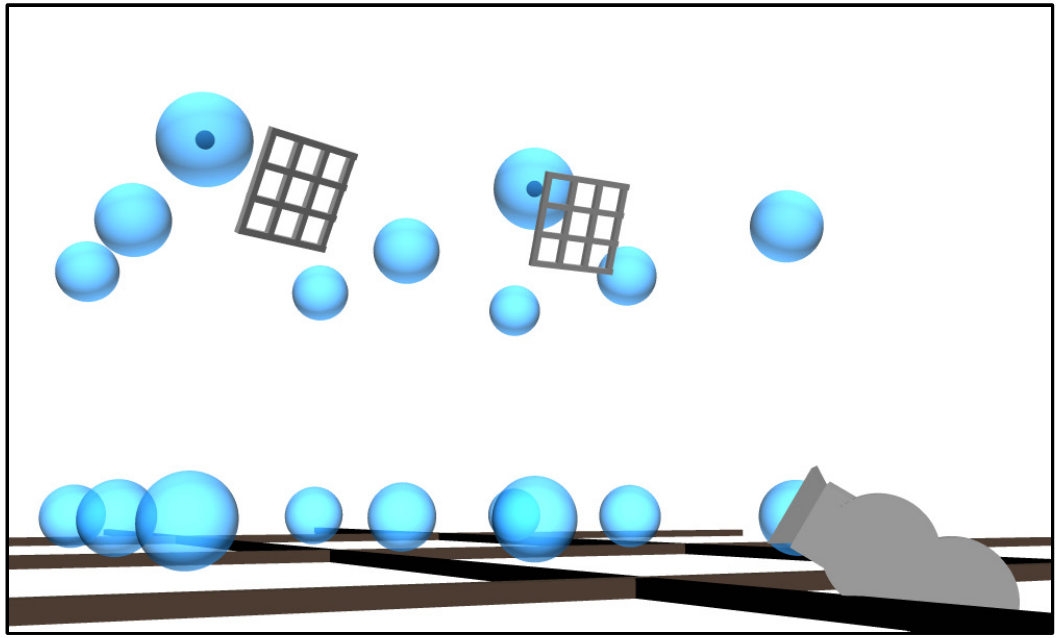
- Shoot rays at pixels
- Find intersections
- Return color data
  - Red box
- Store color in pixel

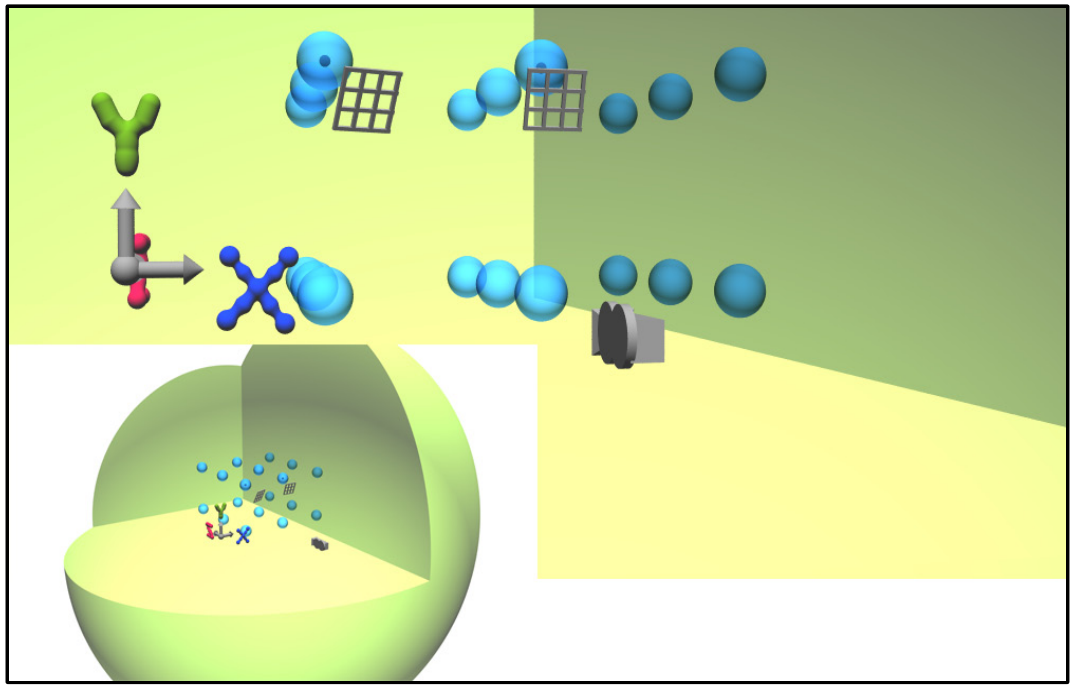




Our Method: Rain Tracer

- Ray trace raindrops
- **E**nvironment **M**ap **I**ntersection **L**ocations
  - EMIL data
- (x,y,z)~>(θ,Φ)~>(U,V) -preprocessing
- (U,V) ~> RGB color - Runtime
- Interpolate (U,V) data [make new drops]





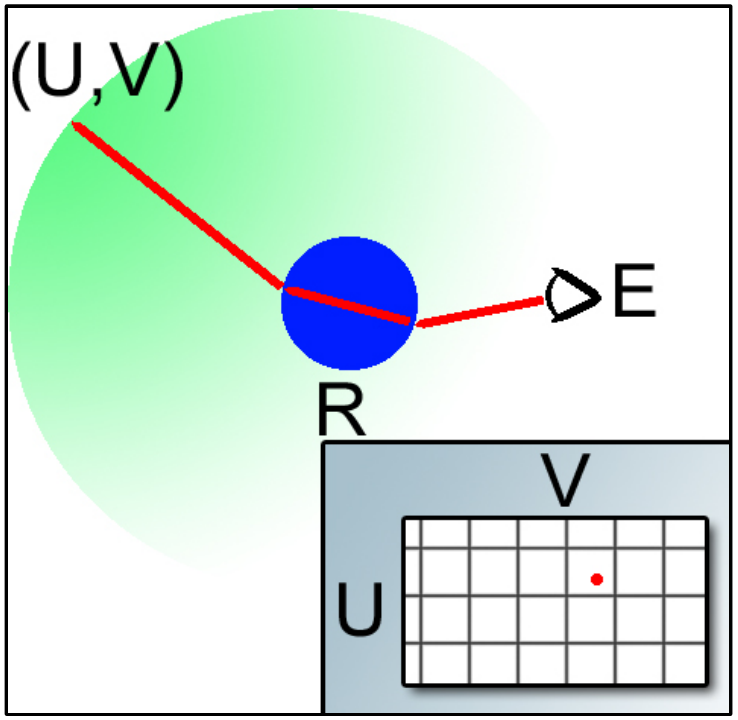
Environment Map

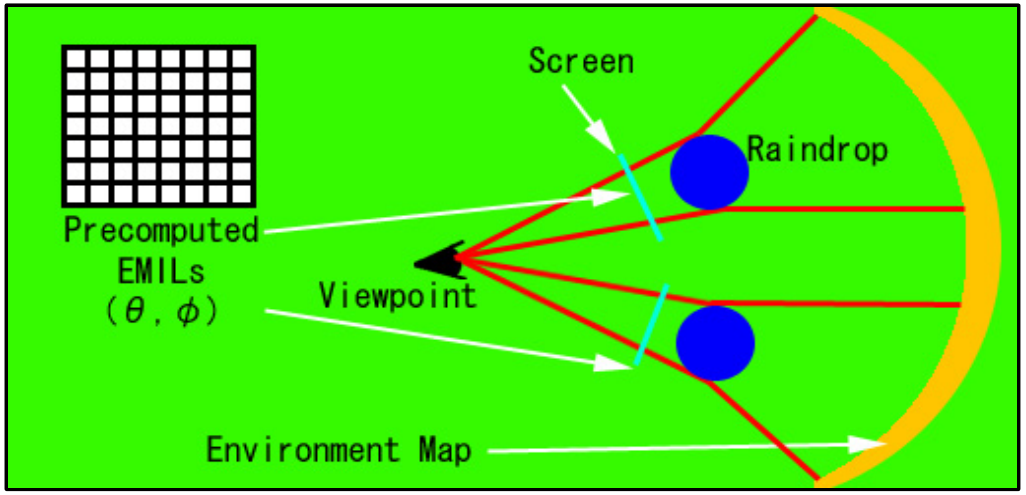
Environment Map:

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

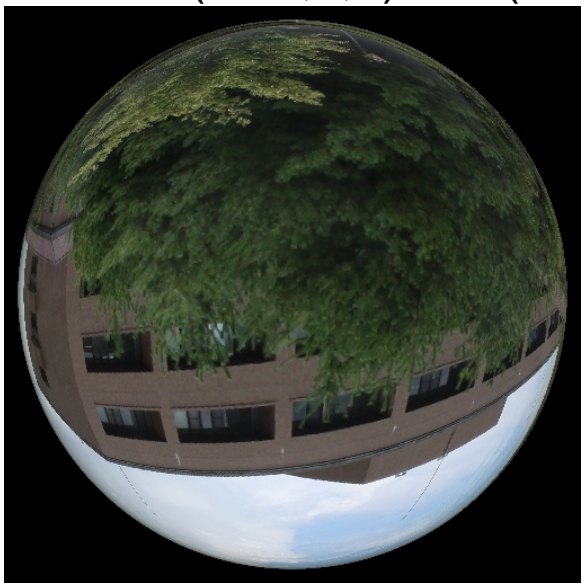
Interpolation:

- Interpolate: 2x
  - (1-a)U1+a(U2)
- **4 additions, 4 multiplications**

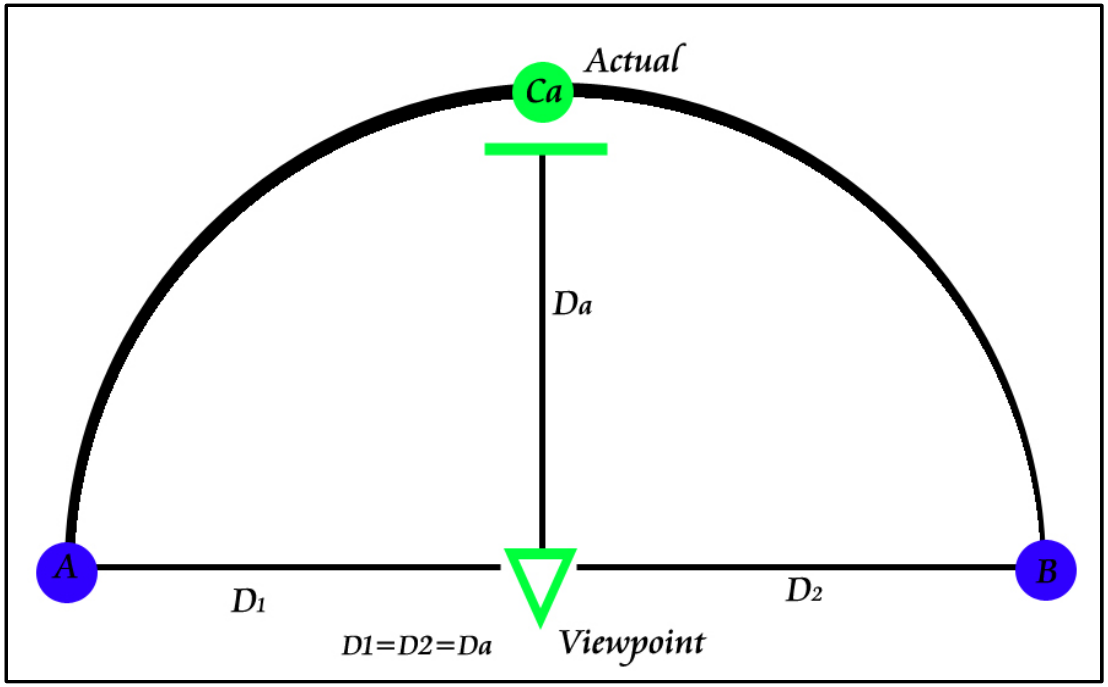
Interpolation

Drop A: (x1,y1,z1)
Drop B: (x2,y2,z2)
Drop C = (1-z)A + z(B)

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

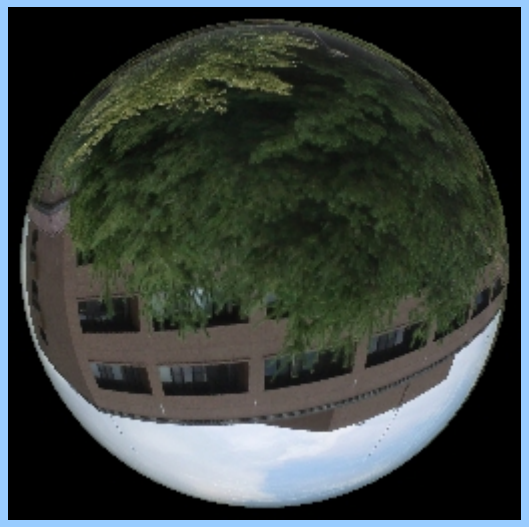


Environment Map:

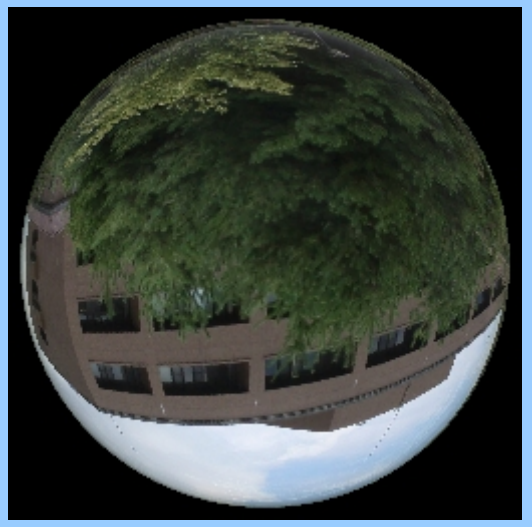


Quality Comparison

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



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

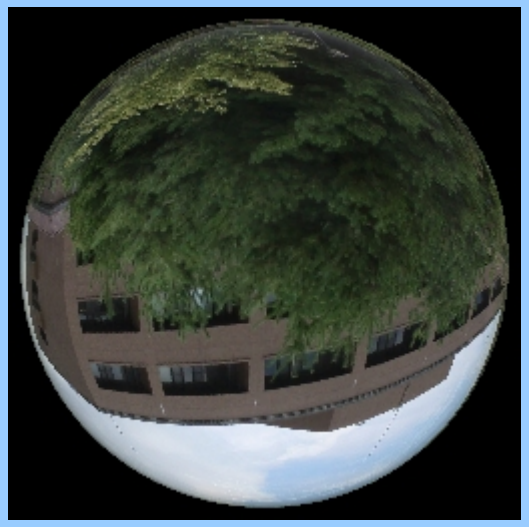


Total Difference: 9776
Reflection Difference: 9976
Average Difference in Reflection: 0.149
Number of Pixels: 65536
Screen Size: 256x256

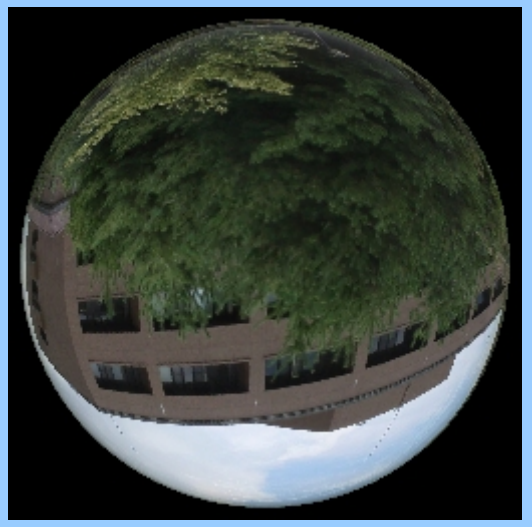
Pixels with Error in Reflection U: 29.83%

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

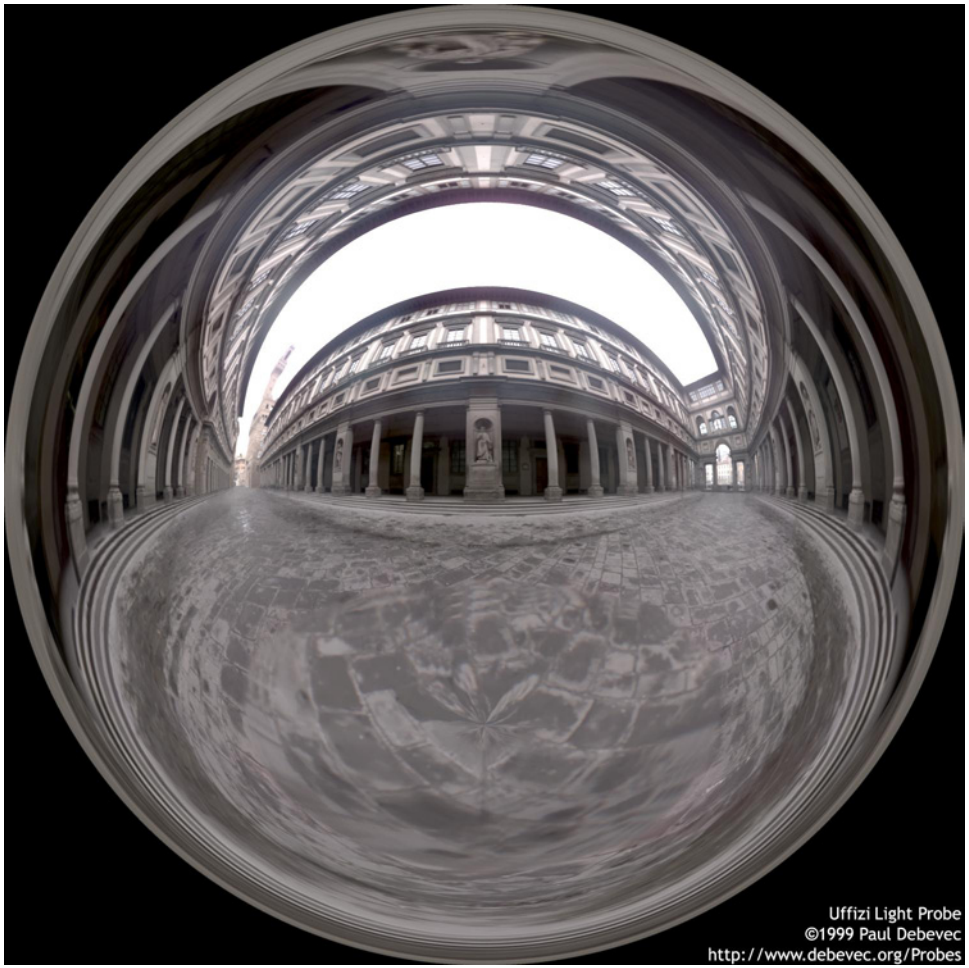
Calculation Times: (per 1000 raindrops)

Rain drop Size	Ray Trace	Interpolate	Speed
512x512	45 min	13.4 sec	200x
40x40	170 sec	0.042 sec	400x
14x14	2.3 sec	0.006 sec	380x

*0.000006 sec. Required to start/stop the clock

Results Example: Light Probe

Light Probe:

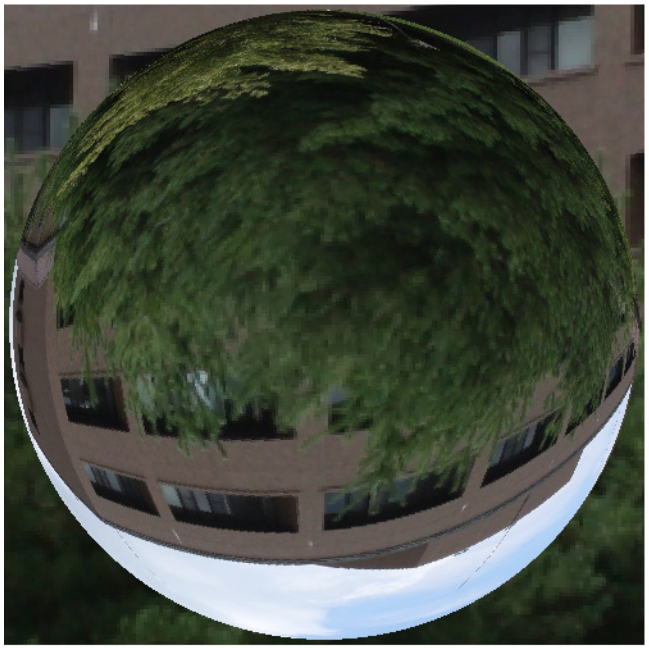


1500x1500 pixels

512x512 Raindrop Result:

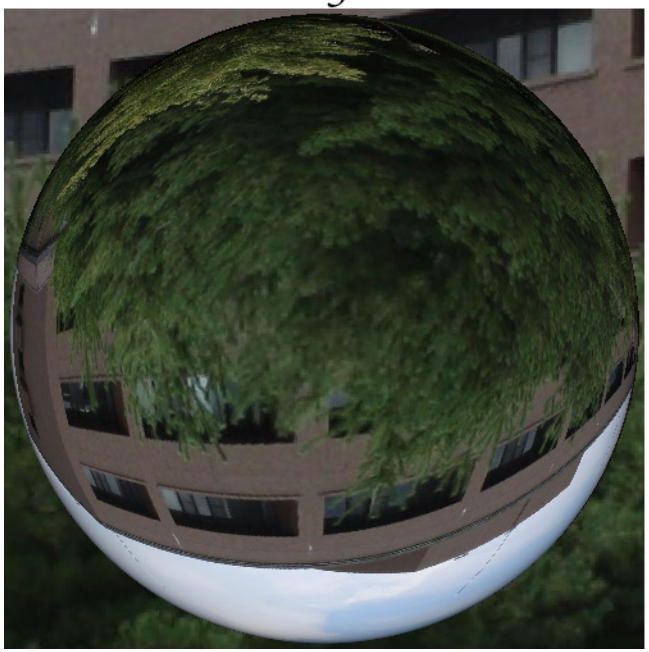
Fresnel Effect

No Fresnel



Reflection

Refraction



Fresnel

Results Example: Raindrop Resolutions

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

No Fresnel effect, refraction only

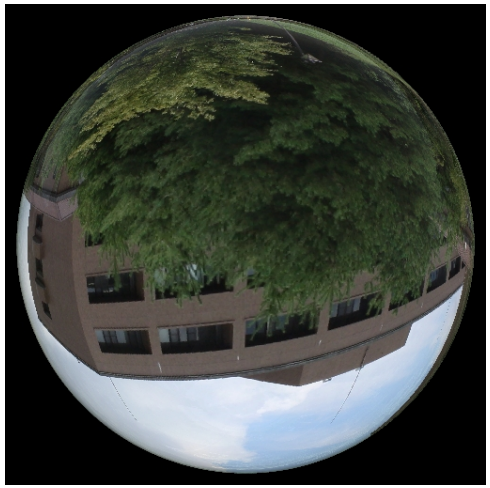
Fresnel effect, reflection & refraction

Results: A Rainy Scene

Raindrop sizes: 5 px, 8px, 11px, 14px

Results: Functioned Raindrops

Advantage:
No preprocessing



Ray Traced

Surface Fitting

Line Fitting

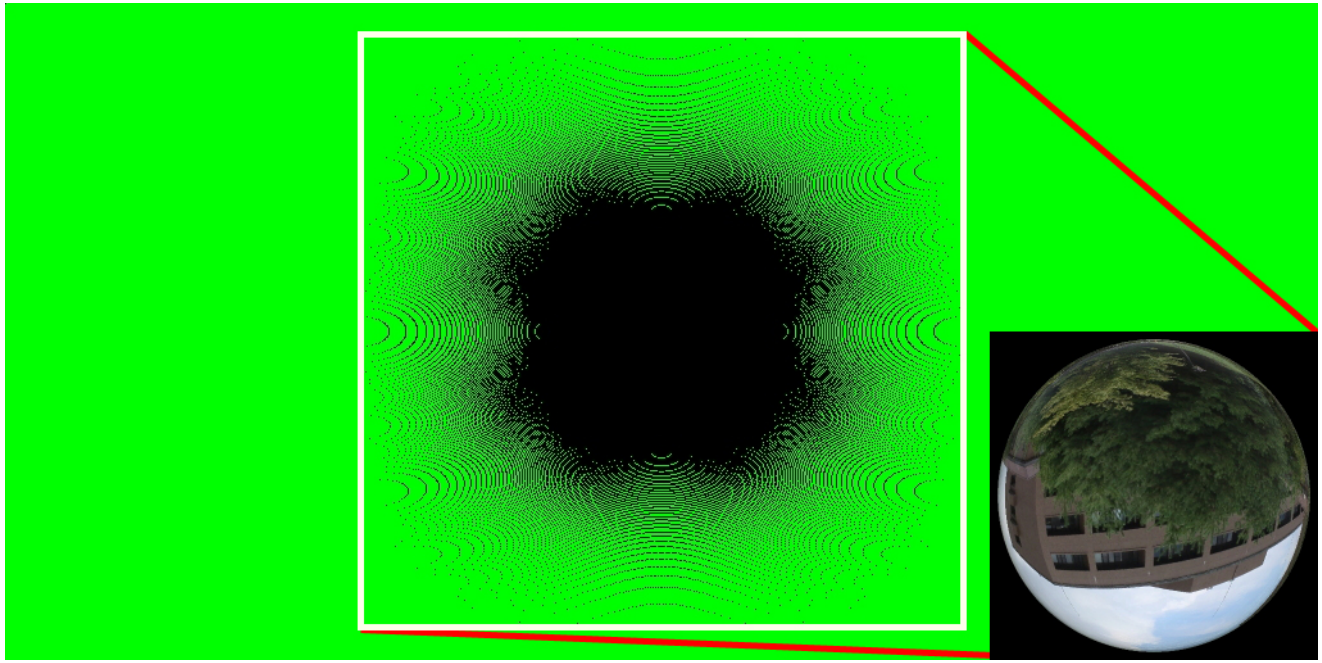
Examples:

30x30 Functioned

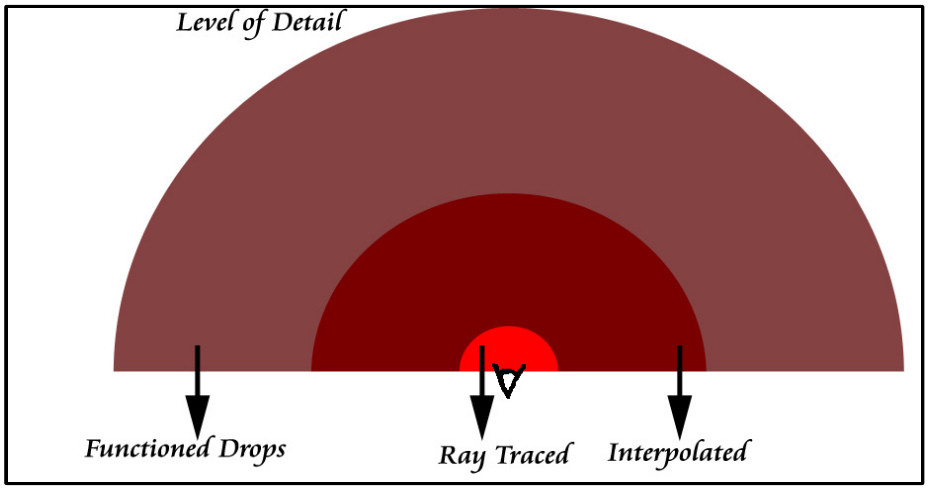
30x30 Ray Traced

40x40 Functioned

40x40 Ray Traced



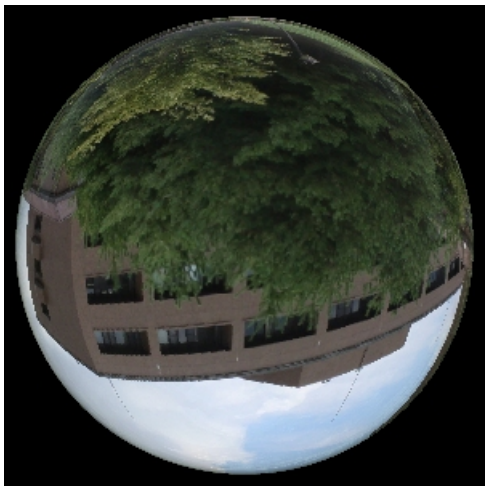
Level of Detail

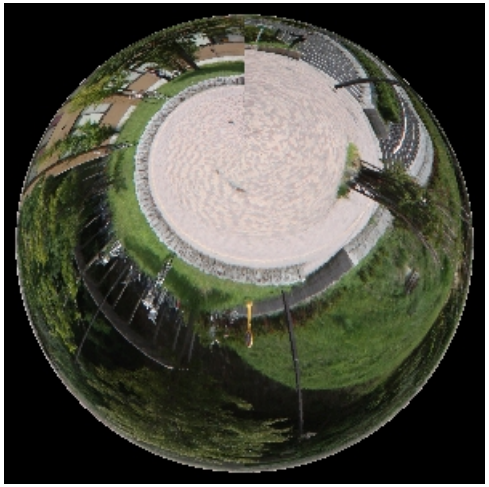


Limitations

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

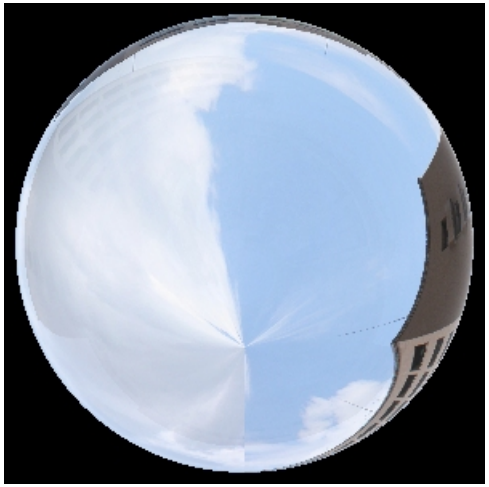
Desired Result





Look Down

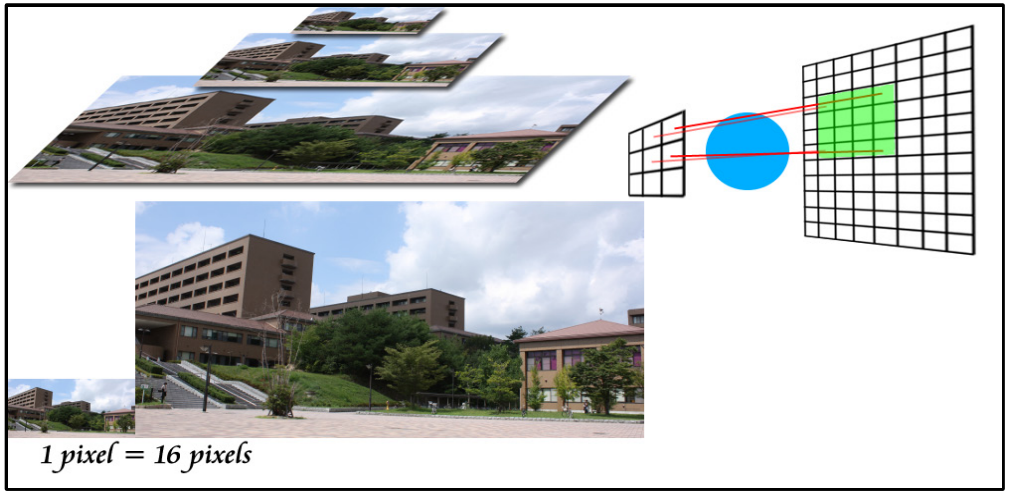
Interpolated



Look Up

Future Work

- Anti-aliasing
- Video Animation
- Real time Environment



NO IMAGE

Madden 2008
EA Sports

Future Work: Many Viewpoints

- Current:
  - One view, many drops
- Next:
  - One drop, many views
- Final:
  - Many drops, many views