Game Developers Conference

EVOLVE GDC>04

It's All Done with Mirrors

GPU Gems Showcase

Kevin Bjorke, NVIDIA

GDC2004

NVIDIA.

Shiny Is Good

- Making objects shiny via reflection maps is one of the *cheapest* ways to add visual complexity
- If there's no bump map, simple cases can be done in the vertex shader

Polishing “Shiny”

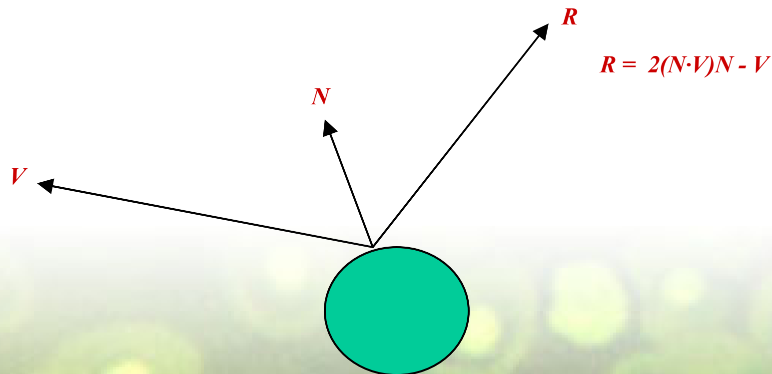
- All specular light is actually scatteed shiny reflection
- Can we use reflections in place of specular light?
- Can we make reflections behave more like… lights?

Localizing Reflections

- Finite-Radius cube maps
- Adding reflective primitive objects
- Both are forms of *very limited* ray tracing

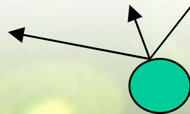
The usual way to use cube maps

- We assume the cube is infinitely far away (like the sky)
- We calculate the reflection vector and look up in the cube map



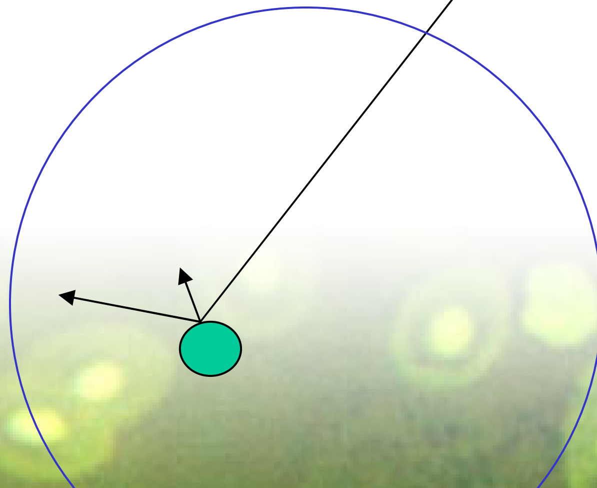
Infinite Map Characteristics

- Since ***R*** is known at each vertex, we can just use a vertex shader (barring bump maps)
- Every point is at the "center" of the map
- Translation of object w/camera has no effect



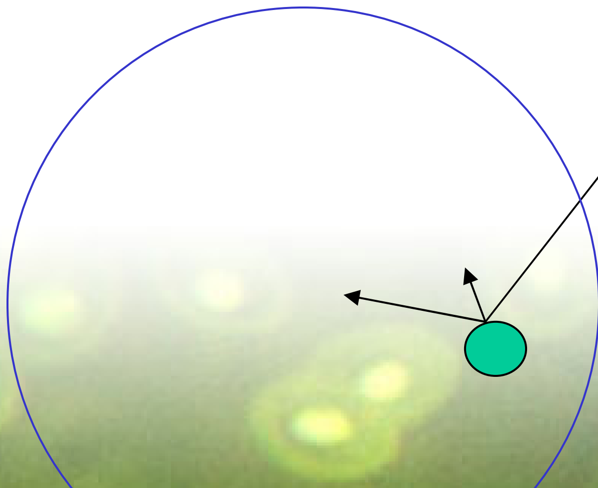
Finite-Radius Maps

- If the map has a specific radius and center location, then:
- Only one point is at the “center” of the map



Every Reflection is "Local"

- Translating the object (or the map) means a change in the reflection
- We need just a little pixel-shader math (ray-sphere intersection test)



Finite Reflections at Home

- “simplerFiniteReflection.fx” is part of the FX Composer release
  - Lets us pick a map center and radius
  - Applies bump-normal map
- ***GPU Gems*** version describes map rotations too

Shader Connectors

```
/* data from application vertex buffer */
struct appdata {
    half3 Position  : POSITION;
    half4 UV        : TEXCOORD0;
    half4 Normal    : NORMAL;
    half4 Tangent   : TANGENT0;
    half4 Binormal  : BINORMAL0;
};

/* data passed from vertex shader to pixel shader */
struct vertexOutput {
    half4 HPosition          : POSITION;
    half4 TexCoord           : TEXCOORD0;
    half3 UserNormal         : TEXCOORD1;       // "User" Space == Env Map Coords
    half3 WorldEyeVec        : TEXCOORD2;
    half3 UserTangent        : TEXCOORD3;
    half3 UserBinorm         : TEXCOORD4;
    half3 UserEyeVec         : TEXCOORD5;
    half3 UserPos            : TEXCOORD6;
};
```

GameDevelopers Conference

EVOLVE GDC>04

Vertex Shader

```
vertexOutput mainVS(appdata IN) {
    vertexOutput OUT;
    half4x4 userXf;
    half ir = 1.0/ReflScale;
    userXf[0] = half4(ir,0,0,ReflCenter.x);   // These constant xforms could be built by the Direct X Virtual Machine
    userXf[1] = half4(0,ir,0,ReflCenter.y);
    userXf[2] = half4(0,0,ir,ReflCenter.z);
    userXf[3] = half4(0,0,0,1);
    half4x4 userITXf;
    userITXf[0] = half4(ReflScale,0,0,0);
    userITXf[1] = half4(0,ReflScale,0,0);
    userITXf[2] = half4(0,0,ReflScale,0);
    userITXf[3] = half4(-ReflCenter.xyz,1);
    half4 Po = half4(IN.Position.xyz,1.0);
    half4 Pw = mul(Po, World);
    OUT.TexCoord = IN.UV;
    half3 WorldEyePos = ViewIT[3].xyz;
    half4 UserEyePos = mul(half4(WorldEyePos,1.0),userXf);
    half4 hpos = mul(Po, WorldViewProj);
    half4 Pu = mul(Pw,userXf);
    half4 Nw = mul(IN.Normal, WorldIT);
    half4 Tw = mul(IN.Tangent, WorldIT);
    half4 Bw = mul(IN.Binormal, WorldIT);
    OUT.UserEyeVec = (UserEyePos - Pu).xyz;
    OUT.WorldEyeVec = normalize(WorldEyePos - Pw.xyz);
    OUT.UserNormal = mul(Nw,userITXf).xyz;
    OUT.UserTangent = mul(Tw,userITXf).xyz;
    OUT.UserBinorm = mul(Bw,userITXf).xyz;
    OUT.UserPos = mul(Pw,userXf).xyz;
    OUT.HPosition = hpos;
    return OUT;
}
```

NVIDIA.

Pixel Shader

```
half4 mainPS(vertexOutput IN) : COLOR
{
	half3 Vu = normalize(IN.UserEyeVec);
	half3 Nu = normalize(IN.UserNormal);
	half3 Tu = normalize(IN.UserTangent);
	half3 Bu = normalize(IN.UserBinorm);
	half3 bumps = Bumpiness * (tex2D(NormalSampler,IN.TexCoord.xy).xyz-(0.5).xxx);
	half3 Nb = Nu + (bumps.x * Tu + bumps.y * Bu);
	Nb = normalize(Nb);      // expressed in user-coord space
	half vdn = dot(Vu,Nu);
	half fres =  KrMin + (Kr-KrMin) * pow((1.0-abs(vdn)),FresExp);
	half3 reflVect = -normalize(reflect(Vu,Nb));          // yes, normalize in this instance!
	// we are using the coord sys of the reflection, so to simplify things we assume (radius == 1)
	half b = -2.0 * dot(reflVect,IN.UserPos);
	half c = dot(IN.UserPos,IN.UserPos) - 1.0;
	half discrim = b*b - 4.0*c;
	bool hasIntersects = false;
	half nearT = 0;
	half3 reflColor = half3(1,0,0);         // red
	if (discrim > 0) {
		discrim = sqrt(discrim);
		nearT = -(discrim-b)/2.0;
		hasIntersects=true;
		if (nearT <= 0.0001) {
			nearT = (discrim - b)/2.0;
			hasIntersects = (nearT>0.0001);
		}
	}
	if (hasIntersects) {
		reflVect = -IN.UserPos + nearT*reflVect;
		reflColor = fres * texCUBE(EnvSampler,reflVect).xyz;
	}
	half3 result = SurfColor * reflColor.xyz;
	return half4(result,1);
}
```

Finite Results

Small Environment

Large Environment

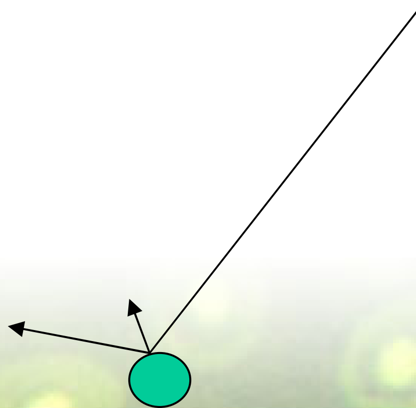
Possible Variations

- Refraction
- Integrate Diffuse Terms
- Distance Falloff
- Other shapes (e.g., a cube instead of a sphere)
- Fresnel Terms

Reflection Cards

- Like finite-radius environment maps, we can do limited raytracing against simple, known objects in the scene – for example, a (textured) plane….

R



“reflCard.fx” in GDC Web Pkg

- Available soon at http://developer.nvidia.com

Vertex Shader

```
vertexOutput sa2VS(appdata IN, uniform REAL4x4 CardXf)
{
    vertexOutput OUT = (vertexOutput)0;
    REAL3 Nw = mul(IN.Normal,WorldITXf).xyz;
    REAL4 Po = REAL4(IN.Position.xyz,(REAL)1.0);    // obj coordinates
    REAL4 Pw = mul(Po,WorldXf);    // world coords
    REAL4 Pc = mul(Pw,CardXf);     // card coords
    OUT.CPos = Pc.xyz;             // card coords
    REAL4 Ec = mul(float4(ViewIXf[3].xyz,1),CardXf);
    OUT.View = normalize(Ec.xyz - Pc.xyz); // card coords
    REAL3x3 rx = REAL3x3(CardXf[0].xyz,CardXf[1].xyz,CardXf[2].xyz);
    OUT.Normal = mul(Nw,rx);                  // card xf
    OUT.HPosition = mul(Po,WorldViewProjXf);// screen clipspace coords
    OUT.UV = IN.UV.xy;
    return OUT;
}
```

Pixel Shader

```
REAL4 reflCardPS(vertexOutput IN) : COLOR
{
    REAL3 Nn = NORM(IN.Normal);
    REAL3 Vn = NORM(IN.View);
    REAL3 refl = reflect(Vn,Nn);
    REAL t = (IN.CPos.z/refl.z);
    REAL3 result = 0;    // or potentially, set to border color
    if (t > 0.0) {
        REAL3 zIntersect = IN.CPos - refl*t;
        REAL2 cardUV = (zIntersect.xy /
                            REAL2(CardWidth,CardHeight)) +
                        REAL2(0.5,0.5);
        result = tex2D(CardSampler,cardUV).xyz;
    }
    return REAL4(result,1);
}
```

Game Developers Conference

EVOLVE GDC>04

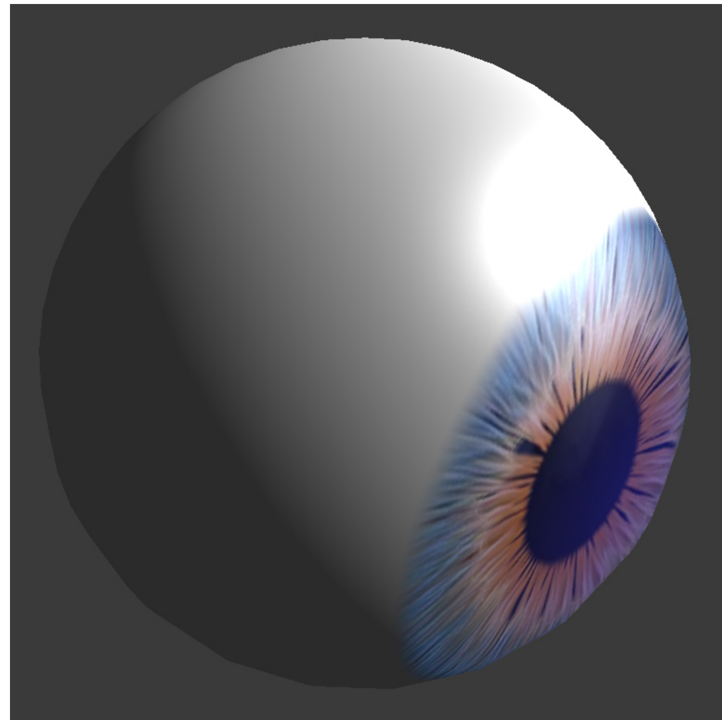
Card Result

NVIDIA.

Possible Enhancements

- Distance Falloff – Make Cards into Light Sources
- Transparency – make arbitrary shapes
- Multiple Cards can obscure one another
- When we miss the card(s), default to a background (potentially finite) Cube Map reflection
- Bump Maps
- Refraction
- Fresnel

Questions?



Thanks!

kbjorke@nvidia.com