Shaders and Visual Realism

Very Brief History

- The state of the art in computer graphics was in offline rendering in the 80s and early 90s.
- A sophisticated and flexible rendering pipeline was being built in software – geared towards ultimate realism.

The Genesis Effect from Star Trek II - The Wrath of Khan © Pixar

Very Brief History

- The development was mostly driven by research and commercialization of CGI (Computer Generated Imagery in films and commercials).
- This lead to special shading languages being invented, of which the RenderMan language has been the most successful (used by Pixar).

"Toy Story" - Pixar, 1995 – Using the Pixar RenderMan Language
(Programmable Photorealistic Off-line Rendering)

Photorealistic rendering in Pixie, an Open Source RenderMan

Very Brief History

- When OpenGL 1.0 was announced in 1992, by SGI, DEC, IBM, Intel and Microsoft, they decided to keep the rendering pipeline fixed function and NOT programmable.
- They said: "..programmability would conflict with keeping the API close to the hardware and reduce optimum performance."

Very Brief History

- OpenGL nevertheless took off, and showed many ground breaking applications, including games (e.g. Quake).
- Although OpenGL was fixed function, it was open to extensions.
- Around this time, new powerful graphics hardware was popping up on regular PCs.

1996 – Quake by id

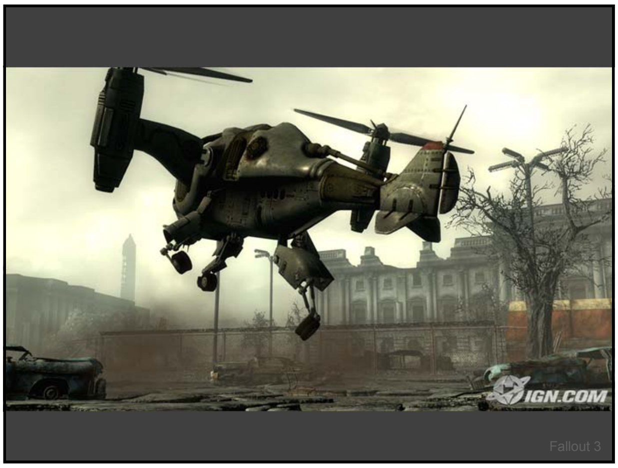
Part I

VISUAL REALISM IN GAMES

Codemasters: Dirt 2

Codemasters: Dirt 2

Fallout 3



Fallout 3

"Bioshock"


"Unreal Engine 3.0"


030


POWERED BY
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speedtree


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speedtree

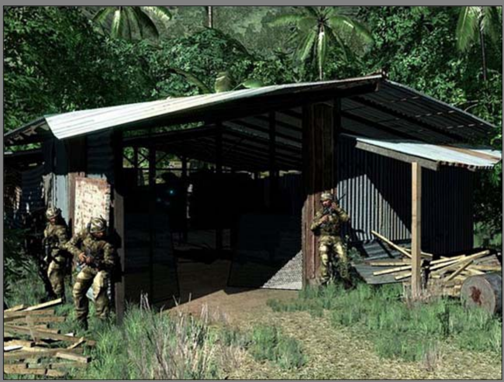
"Alan Wake"

"Alan Wake"

"Alan Wake"

"Alan Wake"


"Unreal Tournament 2007"



"Crysis"

"Test Drive Unlimited"

"Test Drive Unlimited"

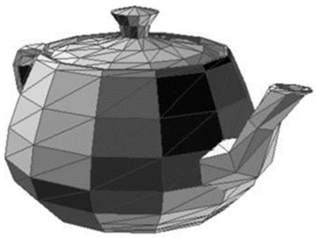
Part II

SHADER PROGRAMMING

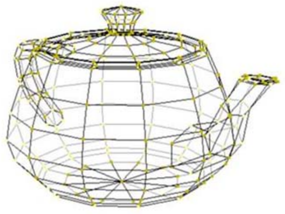
Most of the following images were taken from
"Shaders for Game Programmers and Artists" by Sebastien St-Laurent,

3D Object (Shaded and colored)

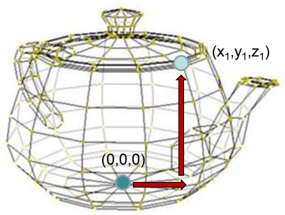
Polygons (Triangles)



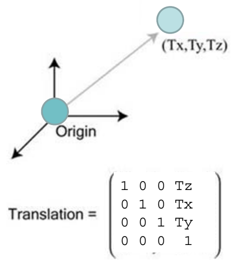
Vertices

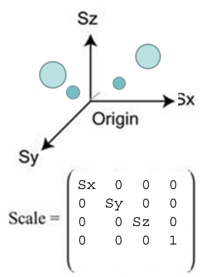


Vertex Transformation

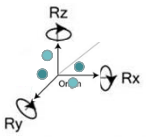


Translating and Scaling





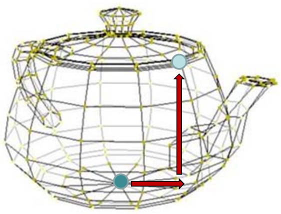
Rotating



$$Rx = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$Ry = \begin{pmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad Rz = \begin{pmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

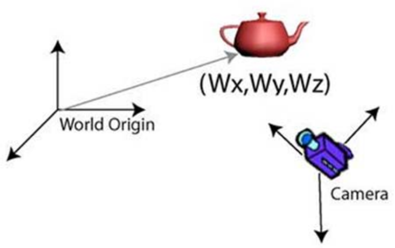
Vertex Transformation



Object vertices in Object coordinates:

$Tobj_{local}$

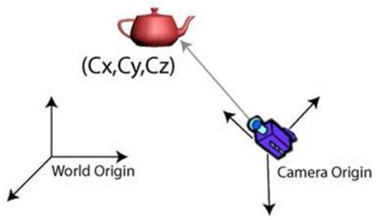
World Coordinates



Object vertices in World Space coordinates:

$Tobj_{world} \bullet Tobj_{local}$

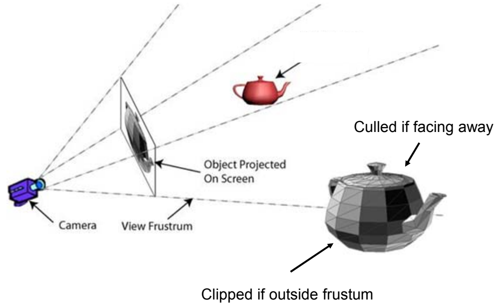
Camera Coordinates



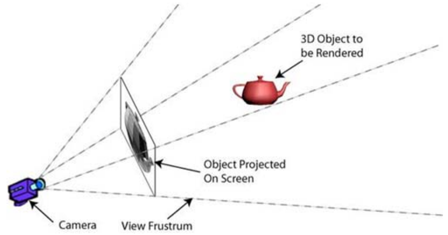
Object vertices in Camera Space coordinates:

$Tcam_{world}^{-1} \bullet Tobj_{world} \bullet Tobj_{local}$

Face Culling and Clipping



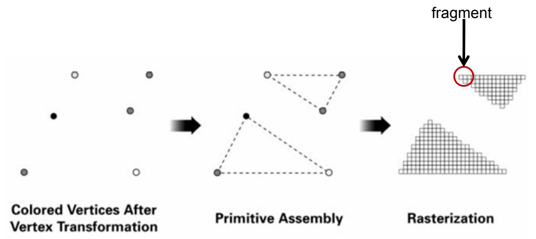
View Projection



Object vertices in Screen Space coordinates:

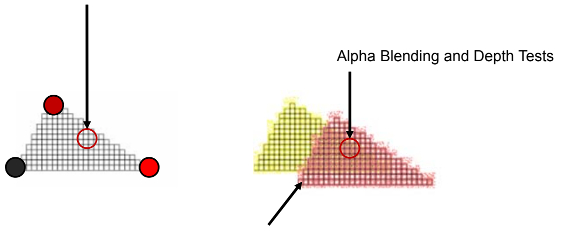
$Tviewproj \bullet Tcam_{world}^{-1} \bullet Tobj_{world} \bullet Tobj_{local}$

Rasterization



Fragment Coloring and Blending

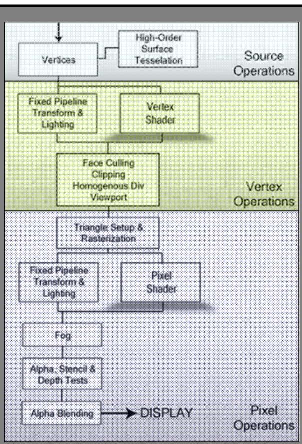
Coloring of fragments based on interpolated information from nearby vertices (e.g. Vertex colors, Vertex UV coordinates, Vertex Normals)

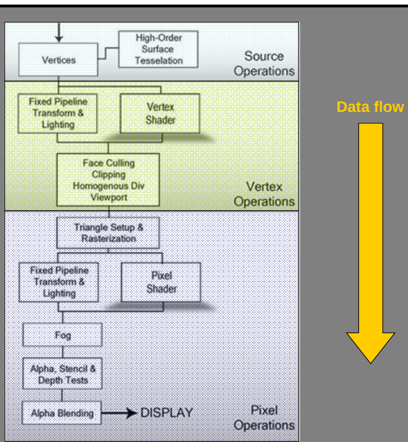


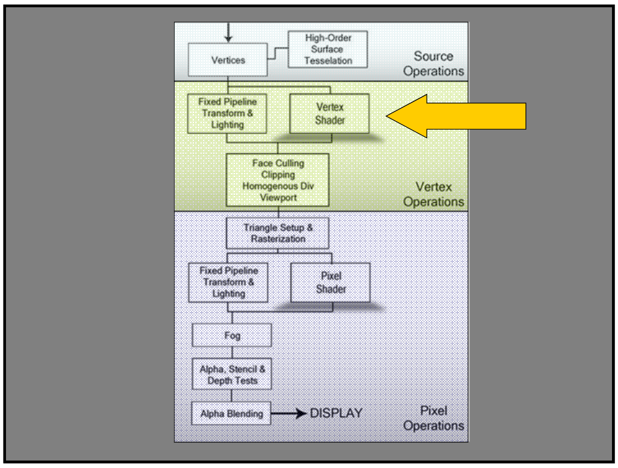
Pixels (what we see on the screen)

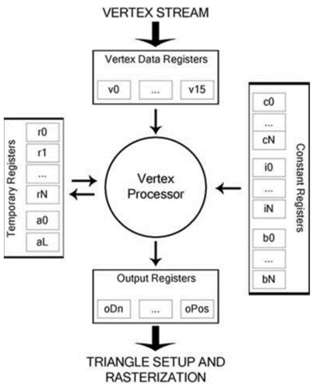
PC 3D Rendering in Hardware

Year	Graphics Card	Milestone
1987	IBM VGA	Provides a pixel frame buffer that the CPU has to fill
1996	3dfx Vodoo	Rasterizes and textures pre-transformed vertices (triangles)
1999	nVidia GeForce 256	Applies both transformation and lighting to vertices (T&L) – fixed pipeline
2001	nVidia GeForce 3	Configurable pixel shader and programmable vertex shader
2003	nVidia GeForce FX	Fully programmable pixel and vertex shaders



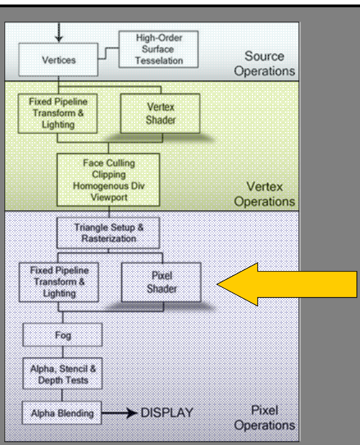


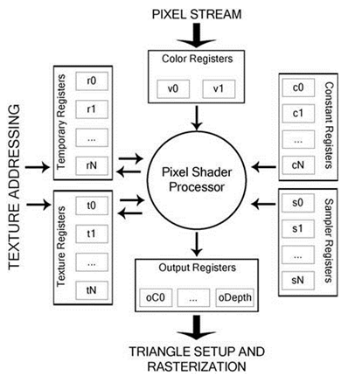




Vertex Shader

```
// Simplest Vertex Shader
// input vertex
struct VertIn {
        float4 pos   : POSITION;
        float4 color : COLOR0;
};
// output vertex
struct VertOut {
        float4 pos   : POSITION;
        float4 color : COLOR0;
};
// vertex shader main entry
VertOut main(VertIn IN, uniform float4x4 modelViewProj) {
        VertOut OUT;
        OUT.pos = mul(modelViewProj, IN.pos); // calculate output coords
        OUT.color = IN.color; // copy input color to output
        return OUT;
}
```





Pixel Shader

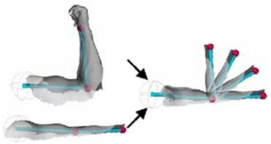
```
// Small Pixel Shader (Grayscale Converter)
// input pixel
struct PixIn {
        float3 color      : COLOR0;
        float3 texcoord : TEXCOORD0;
};
// output pixel
struct PixOut {
        float3 color : COLOR0;
};
// vertex shader main entry
PixOut main(PixIn IN, uniform sampler2D texture : TEXUNIT0) {
        PixOut OUT;
        float3 color = tex2D(texture, IN.texcoord).rgb;
        OUT.color = dot(color,float3(0.299,0.587,0.184)).xxx
        return OUT;
}
```

Some Categories of Shaders

- Vertex Skinning
- Vertex Displacement Mapping
- Screen Effects
- Light and Surface Models
- Non-photorealistic Rendering

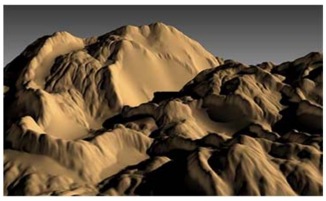
Vertex Skinning

- The vertices on a surface, like the human body, get moved around based on an underlying skeletal structure. An additional deformation may also simulate the dynamic shape of a muscle.



Vertex Displacement

- Vertices can be displaced, for example vertically, based on an algorithm or an existing height map.

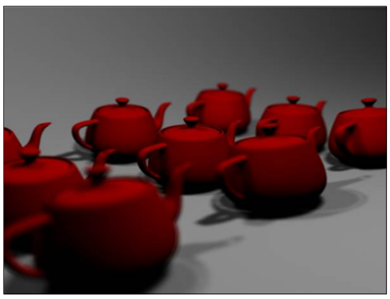


Sceen Effects

- Pixel shader renders to a temporary texture that it then processes with filters before returning the color values.

Sceen Effects: Glow

Sceen Effects: Depth of Field



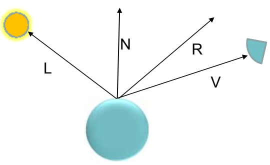
Sceen Effects: Distortion

Sceen Effects: High Dynamic Range + Bloom

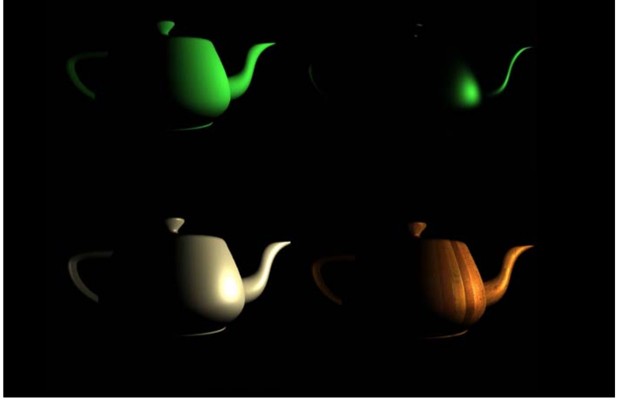
Half-life 2 (Valve) – HDR on Right

Lighting Models

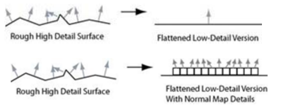
- Shaders calculate new color values by applying various lighting models, involving parameters such as surface normals (N), light angle (L), reflected light angle (R) and view angle (V).



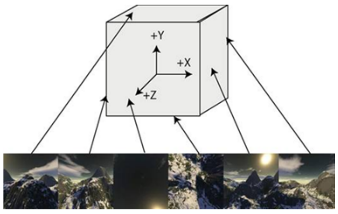
Lighting Models: Per-Pixel Lighting



Lighting Models: Normal Mapping



Lighting Models: Environment Reflection



Lighting Models: Shadows

Non-Photorealistic Rendering

- Light models do not have to imitate the “real world”, but can instead assign color values according to imaginary worlds, such as the world of cartoons or oil paintings.
- In fact, any of the aforementioned effects could be taken into the realm of the imaginary or expressionistic art.

Non-Photorealistic Rendering

Non-Photorealistic Rendering