Real - Time Rendering

Lighting / Shading

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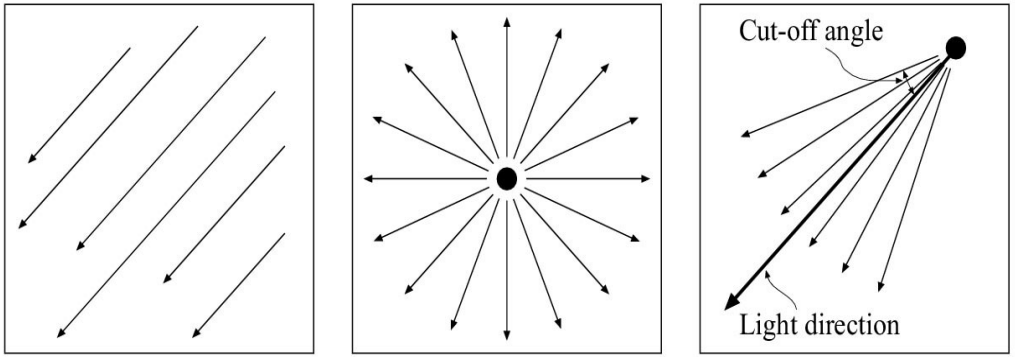
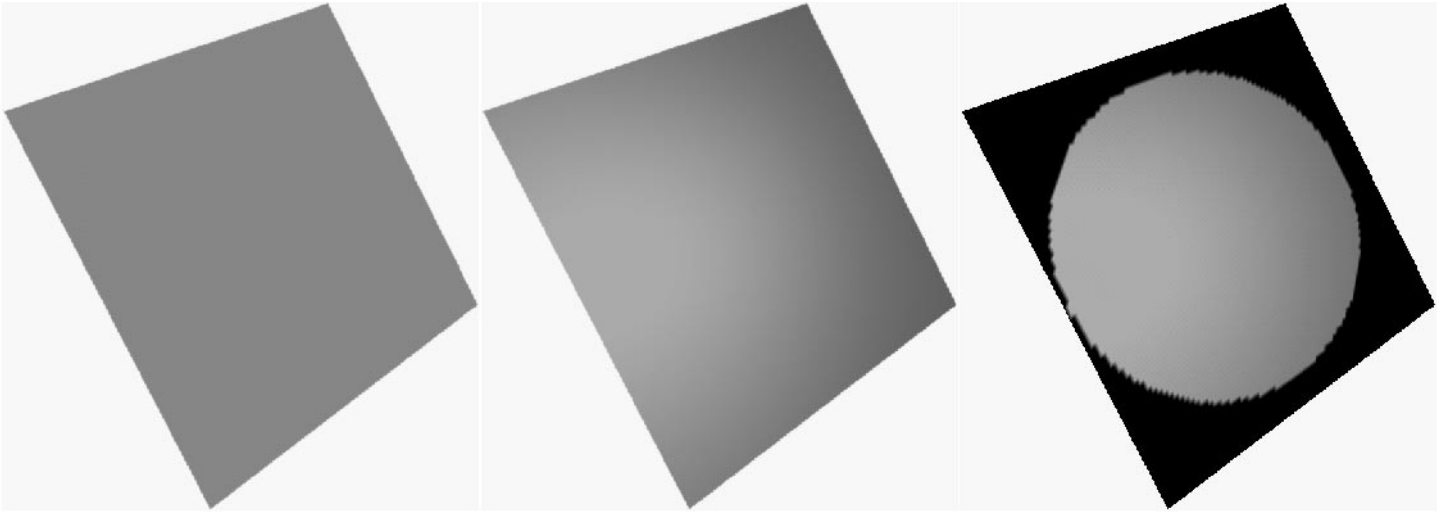
Overview

- Light Sources
- Lighting
- Shading
- Texturing
- Alpha Mapping
- Gloss Mapping
- Light Mapping
- Rough Surface

Light Sources

- Directional light
- Point light
- Spot light
- Colour, intensity





Lighting model

- Phong model
- Colour, Intensity
- Ambient, Diffuse, Specular

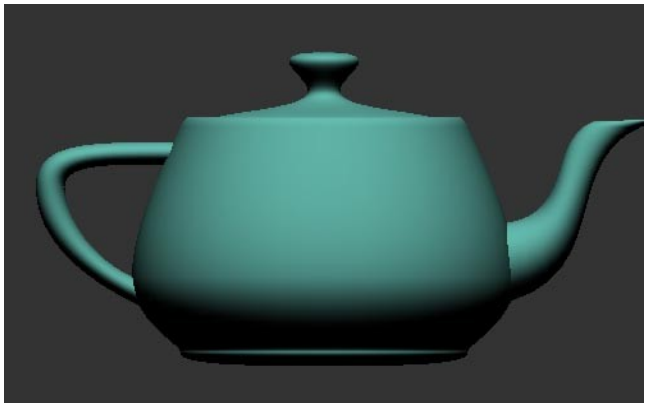
Lighting model - ambient

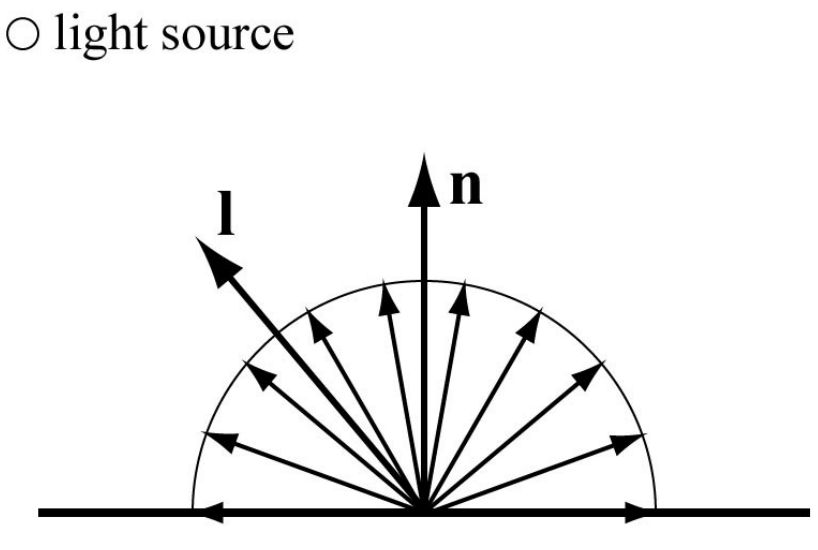
- Constant colour
- Light form other surfaces

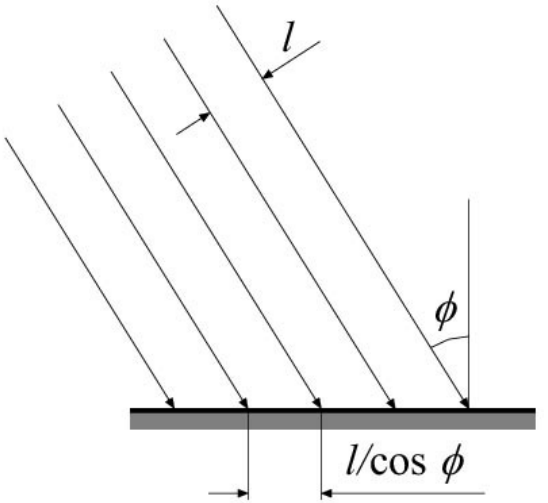
Lighting model - diffuse

- Lambert's law $i_{diff} = \mathbf{n} \cdot \mathbf{l} = \cos\phi$
- Photons are scattered equally

$$\mathbf{i}_{diff} = (\mathbf{n} \cdot \mathbf{l})\mathbf{m}_{diff} \otimes \mathbf{s}_{diff}$$







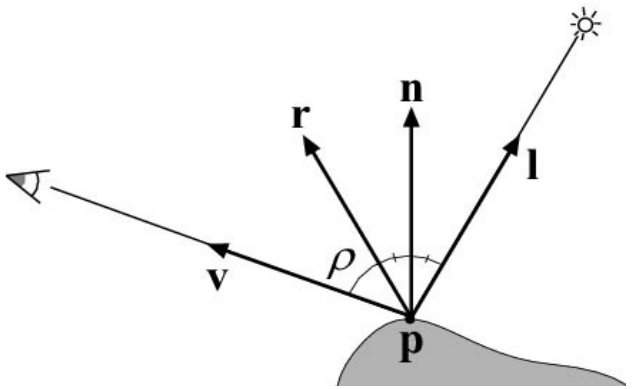
Lighting model - specular

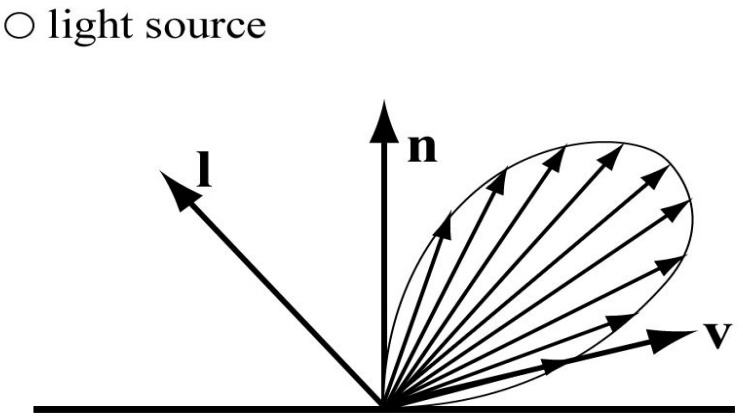
- The highlight simulation

$$\mathbf{r} = -\mathbf{l} + 2(\mathbf{n} \cdot \mathbf{l})\mathbf{n}$$

$$i_{spec} = (\mathbf{r} \cdot \mathbf{v})^{m_{shi}} = (\cos \rho)^{m_{shi}}$$

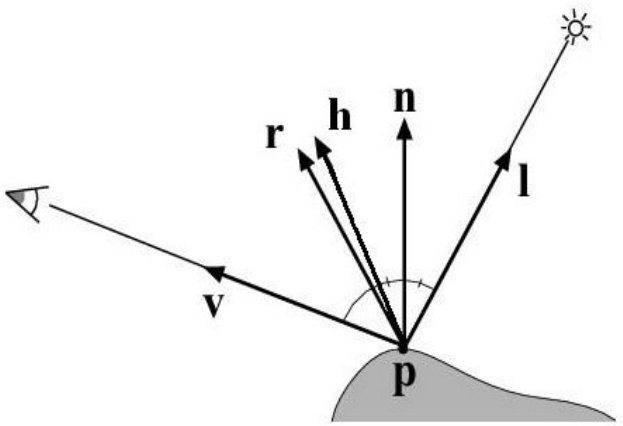
$$\mathbf{i}_{spec} = \max(0, (\mathbf{r} \cdot \mathbf{v})^{m_{shi}})\mathbf{m}_{spec} \otimes \mathbf{s}_{spec}$$





Lighting model (2)

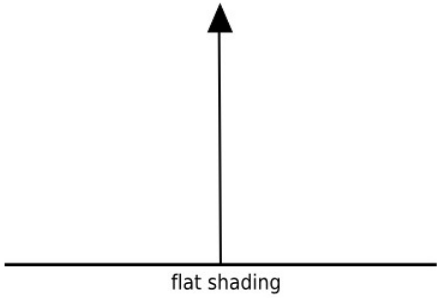
- Half vector $H = \frac{L+V}{|L+V|}$
- Speed-up
- $i = i_{amb} + i_{diff} + i_{spec}$

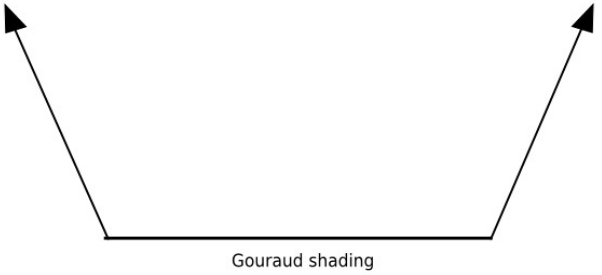


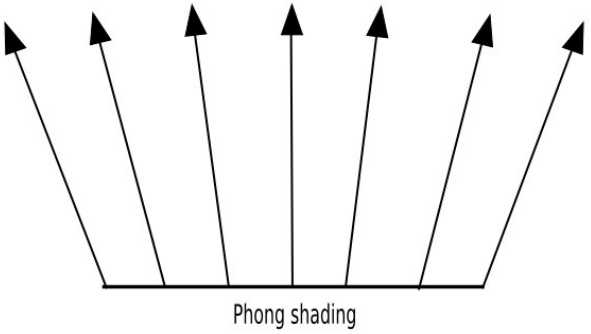

```
float4 color = tex2D(TexMaterial, IN.texcoord1);
float3 normal = (tex2D(TexNormal, IN.texcoord1)-0.5).rgb;

float3 vecToEye   = normalize(posEye   - IN.FragPos);
float3 vecToLight = normalize(posLight - IN.FragPos);

float3 vecHalf = normalize(vecToLight+vecToEye);

float difLight = max(dot(normalize(normal), vecToLight),0);
float specLight= pow(max(dot(normalize(normal),vecHalf),0),15);

if(difLight <= 0) specLight = 0;

float3 difColor  = difLight*color.rgb;
float3 specColor = specLight*color.rgb;
float3 ambColor  = float3(0.1,0.1,0.1);

OUT.color.xyz = difColor + specColor + ambColor;
```

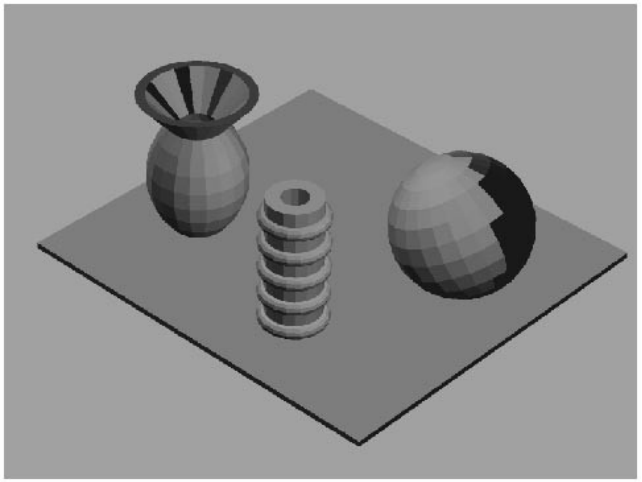
Shading

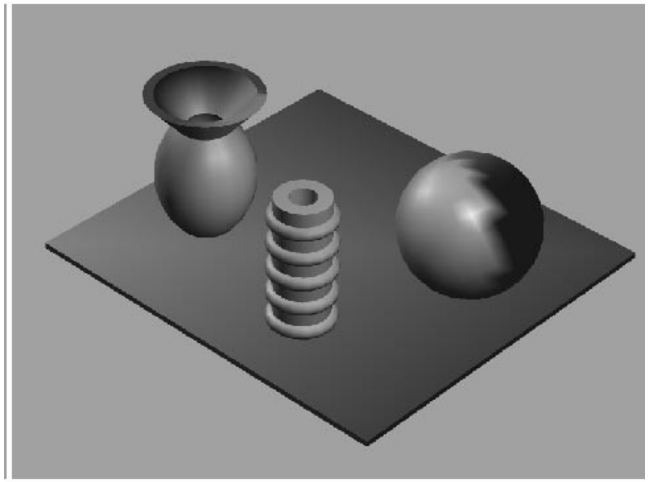
- Flat, Gouraud, Phong
- Per - primitive, vertex, fragment

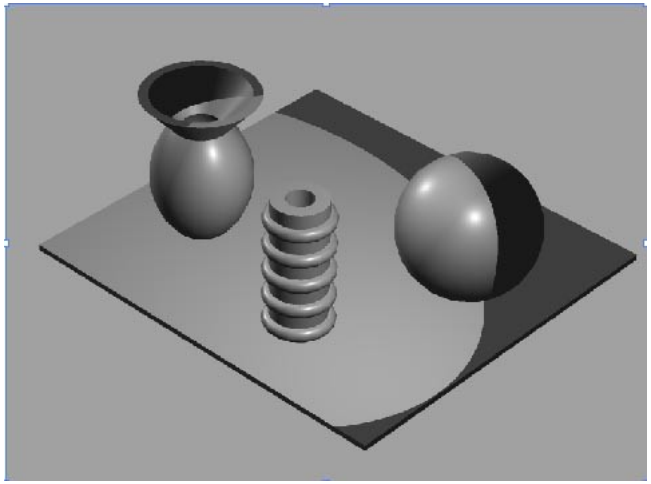






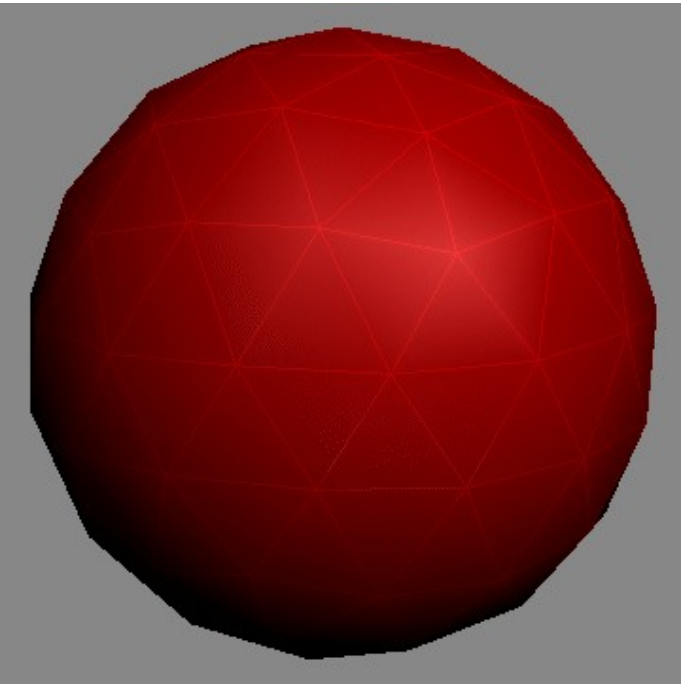
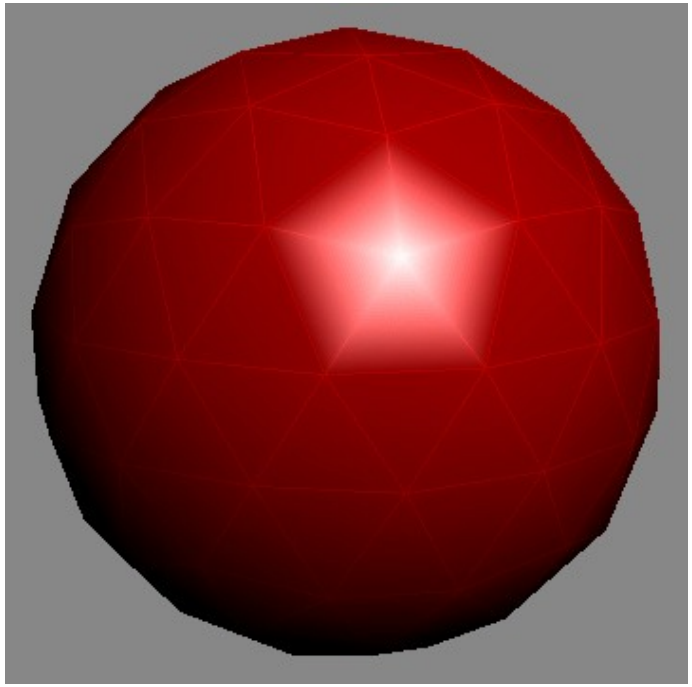
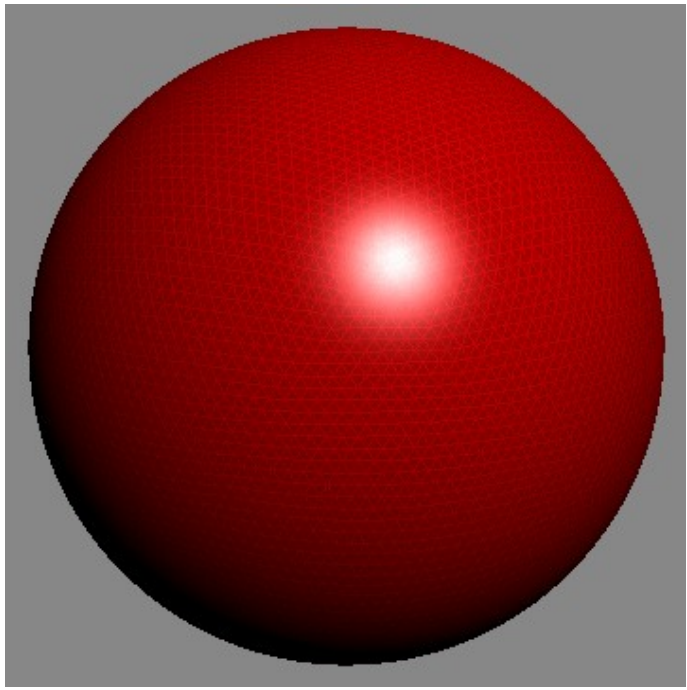






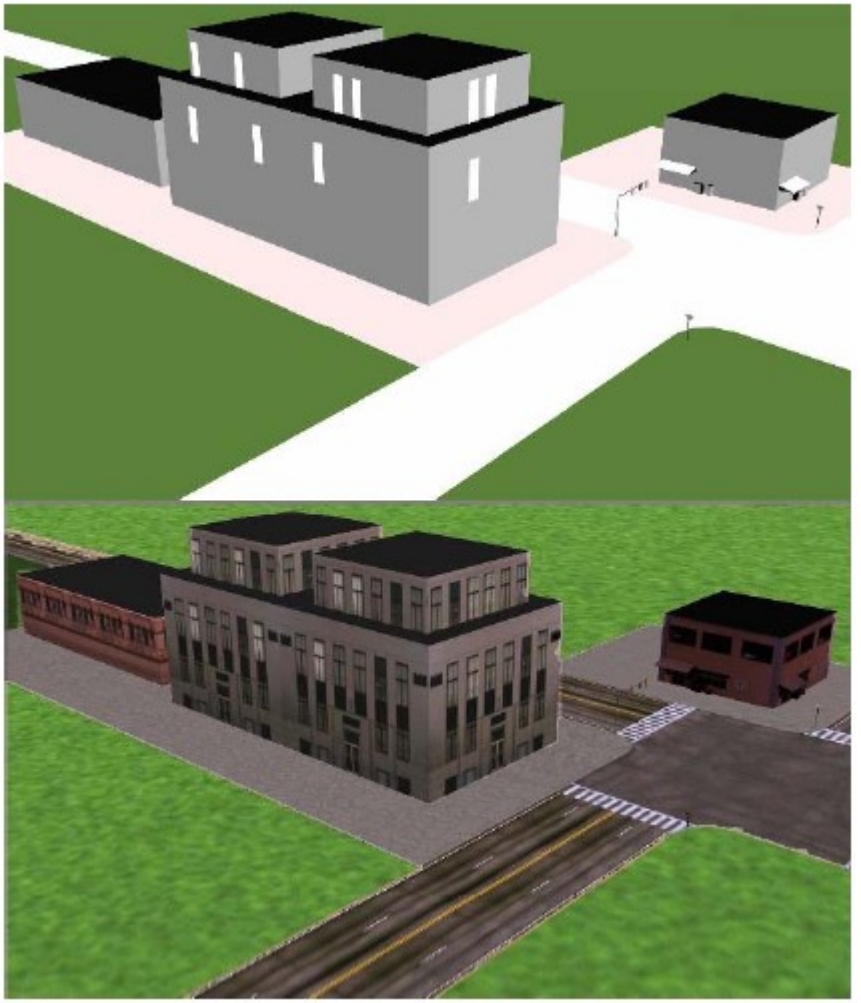
Shading (2)

- Tessellation is important

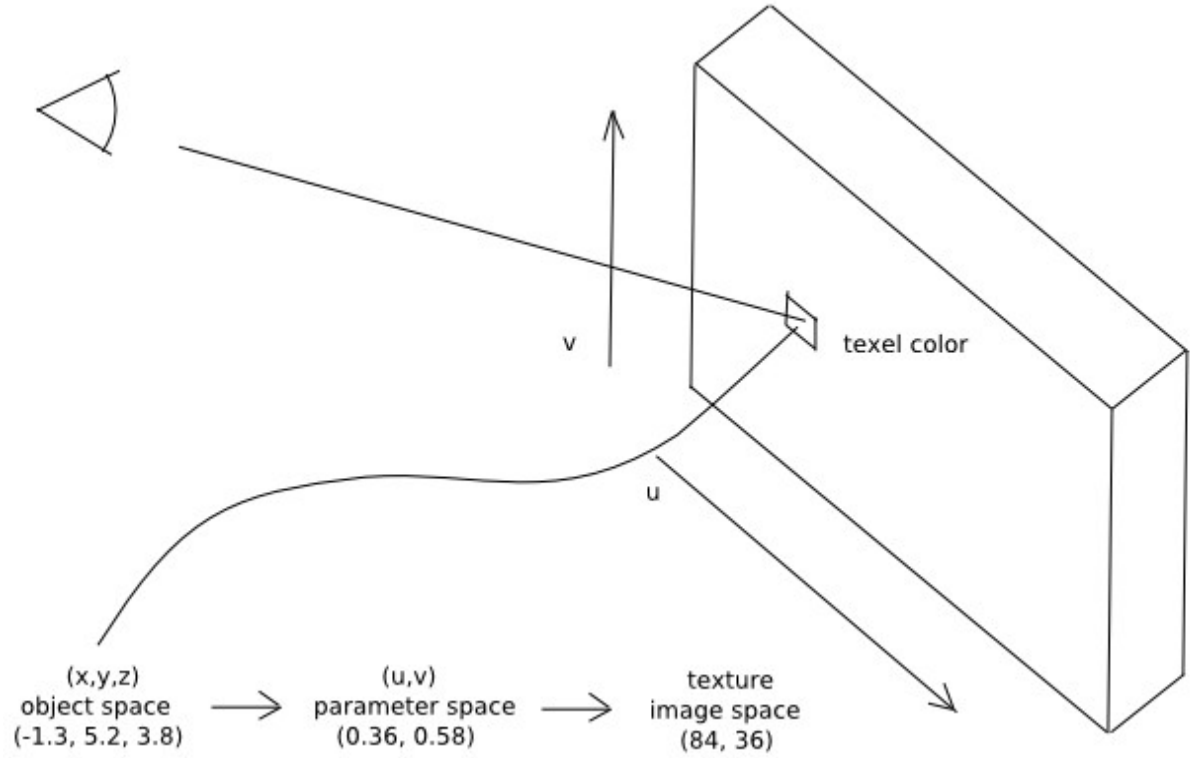
Texturing

- Light Sources
- Lighting
- Shading
- Texturing
  - Texture mapping
  - Texture settings
  - Texture filtering
- Alpha Mapping
- Environment Mapping
- Gloss Mapping



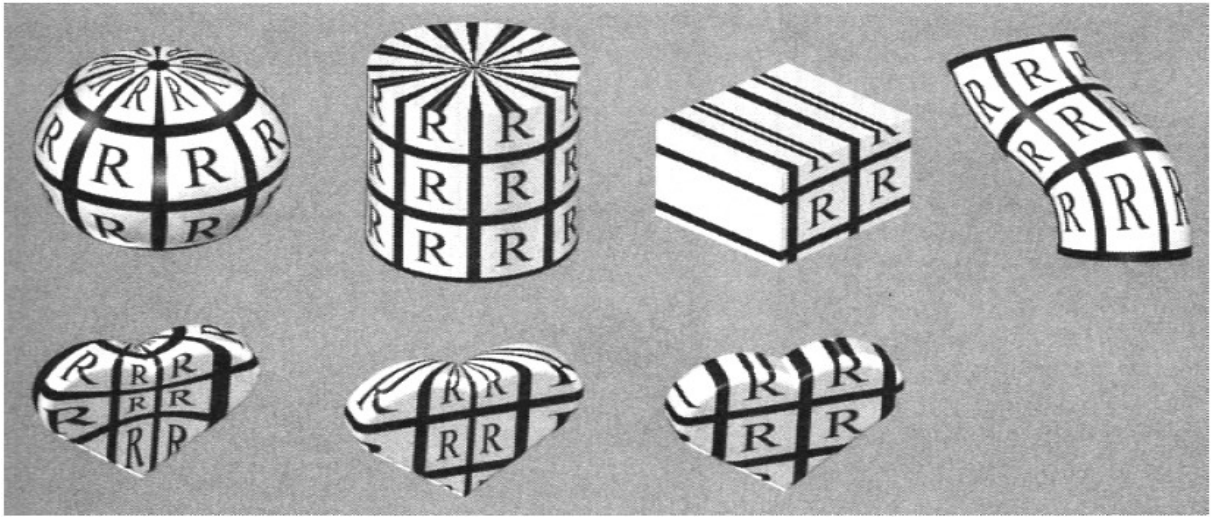
Texture mapping

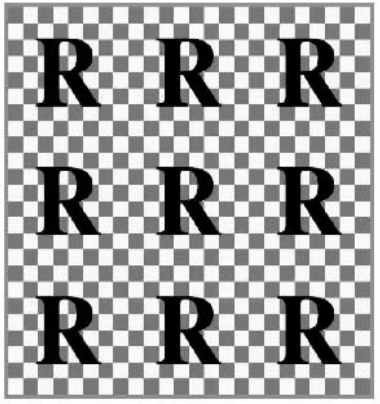
- 1D, 2D, 3D, Cube
- Texture transformations
- Texture projections (spherical, cylindrical, planar, natural)

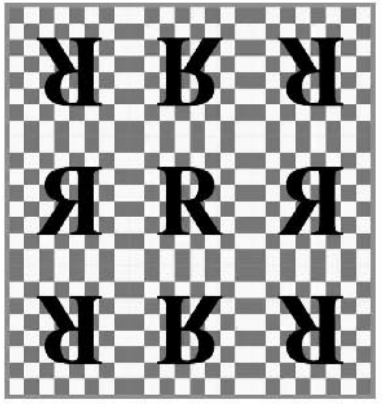


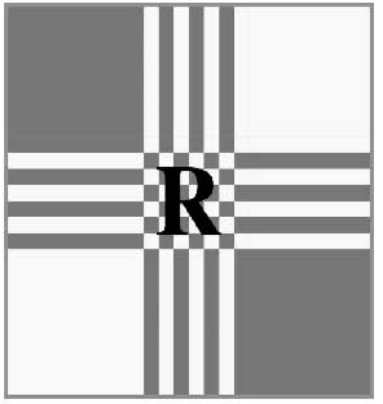
Texture settings

- Wrap modes (repeat, mirror, clamp, border)
- Compression (DXT, S3C, …)
- Multi-texturing



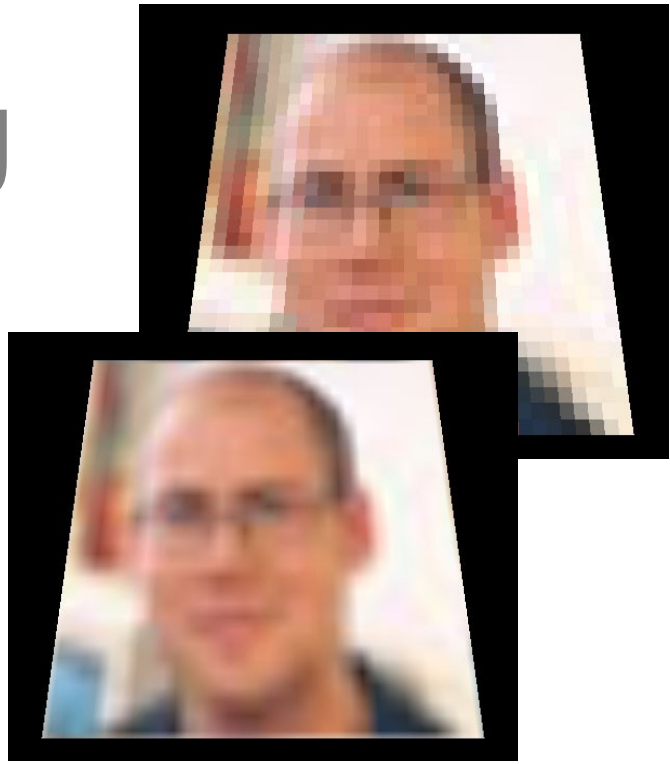


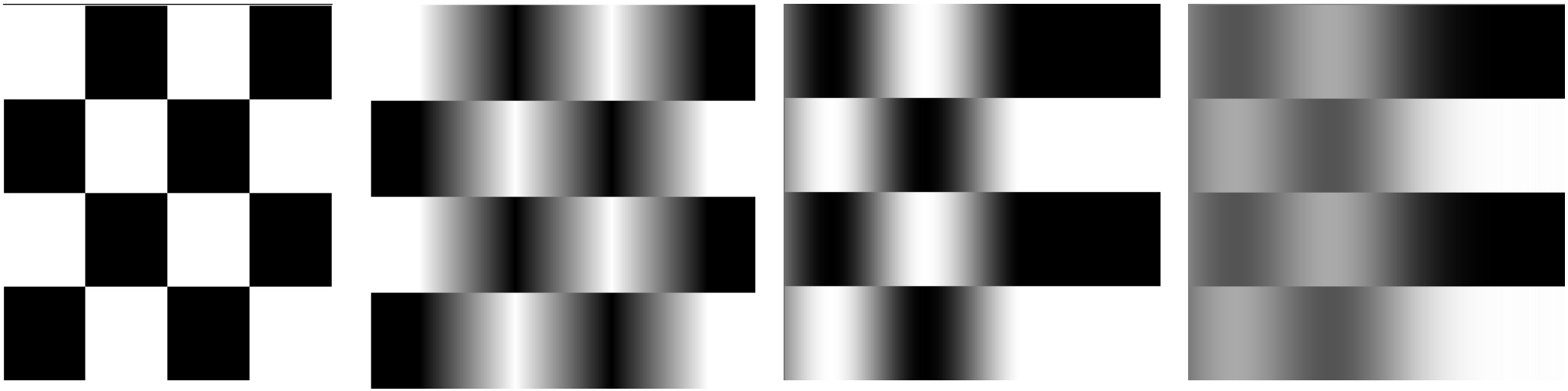




Texture filtering

- Nearest
- Linear – (tri/bi)linear interpolation
- Bi-cubic – ATI or shaders

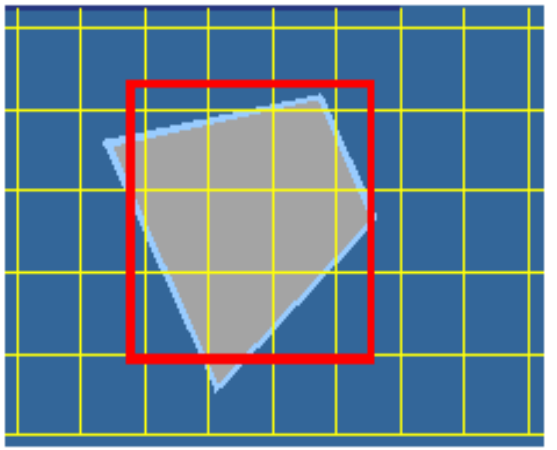


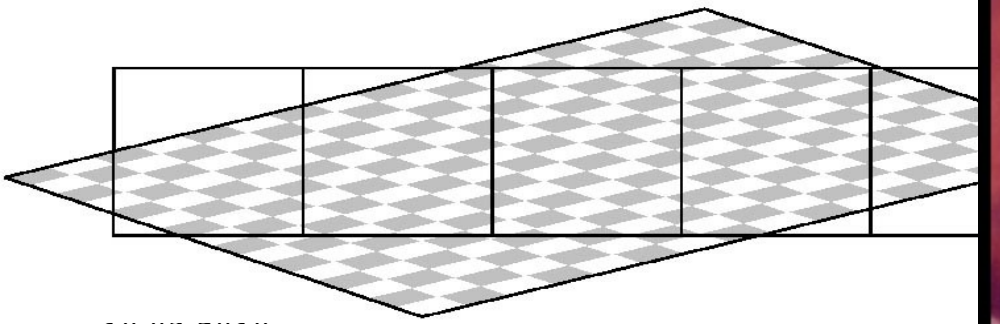


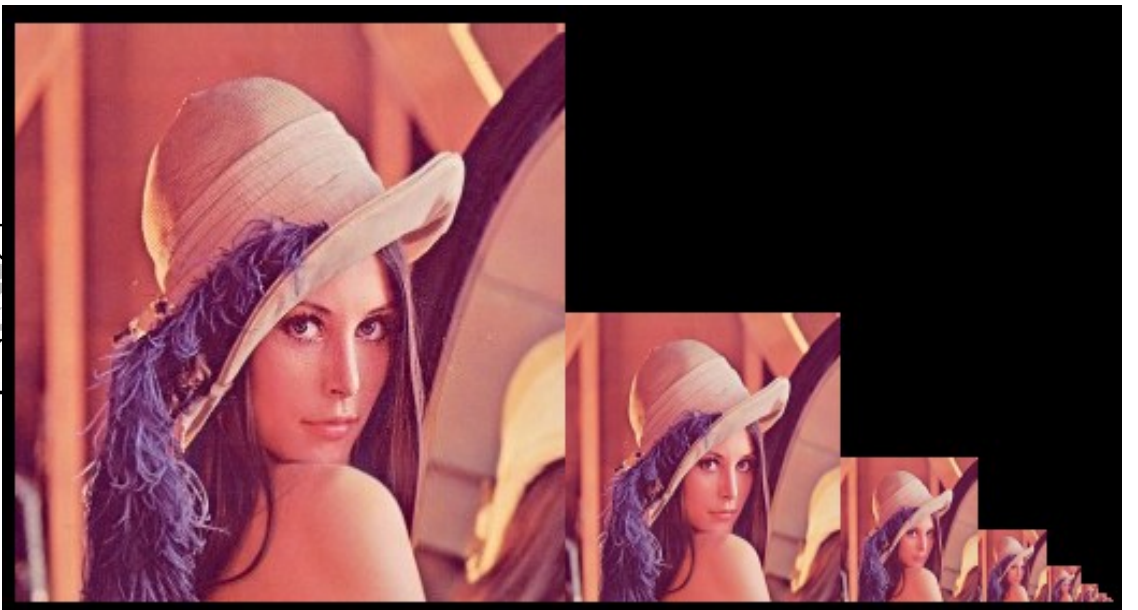
Nearest Linear Catmul-Rom CubicBSpline

Texture filtering (2)

- Mipmapping – minification
  - Down sampled textures to half
  - Memory requirements 133%
  - $d = \log_2(\mathrm{sqrt}(A))$
  - Trilinear filtering (interpolation)

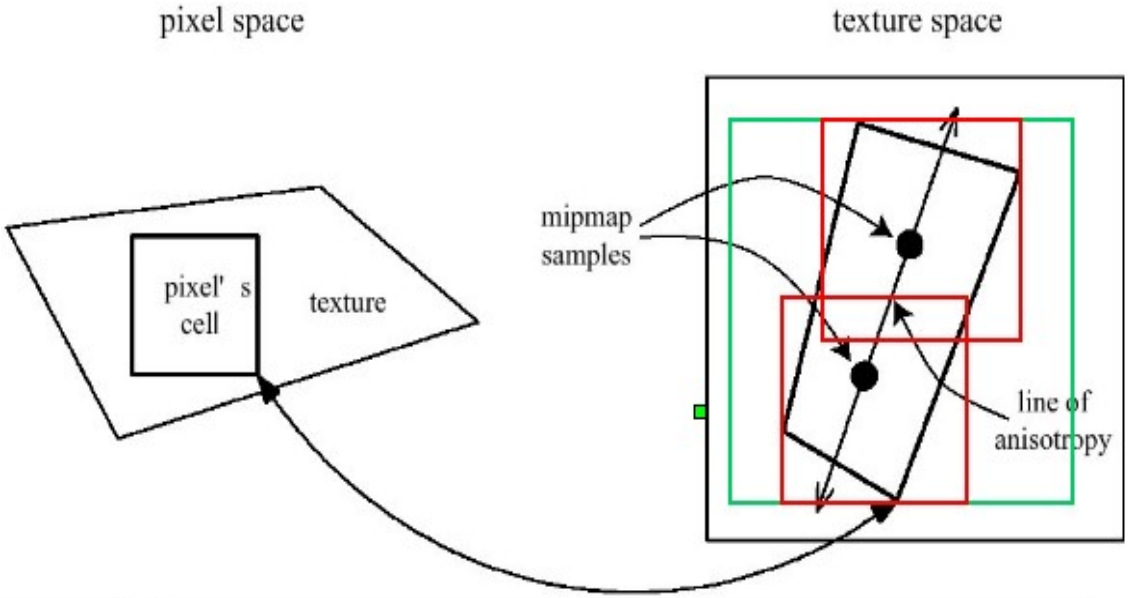


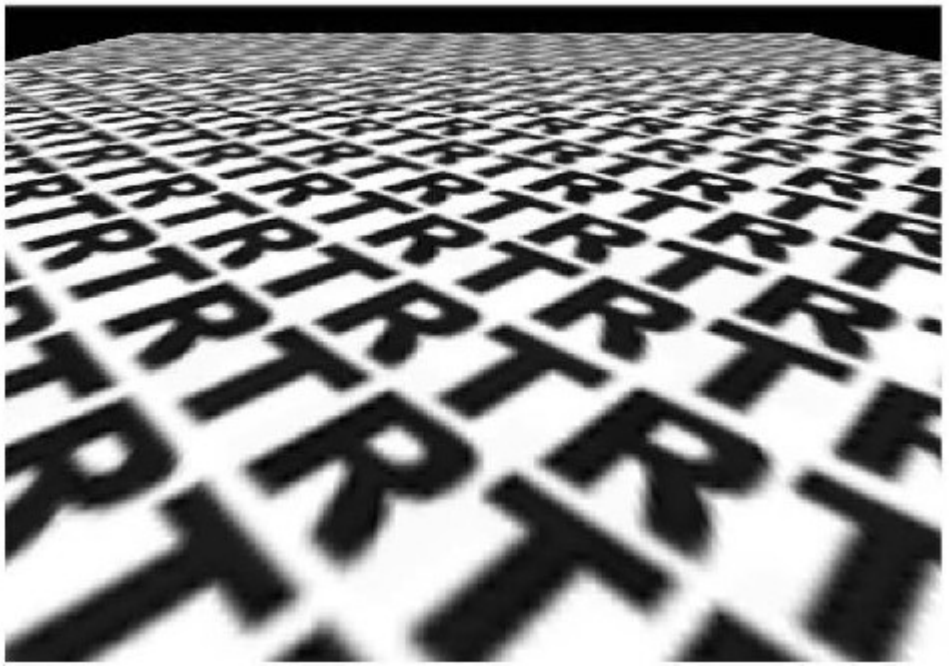


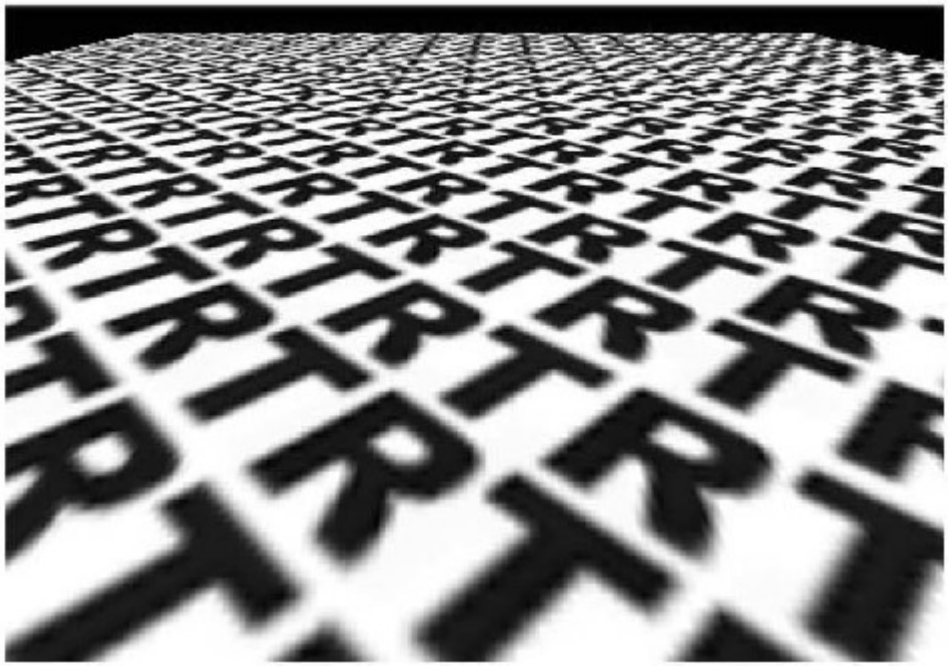


Texture filtering (3)

- Anisotropic
  - < 16 samples
  - Vertical, horizontal

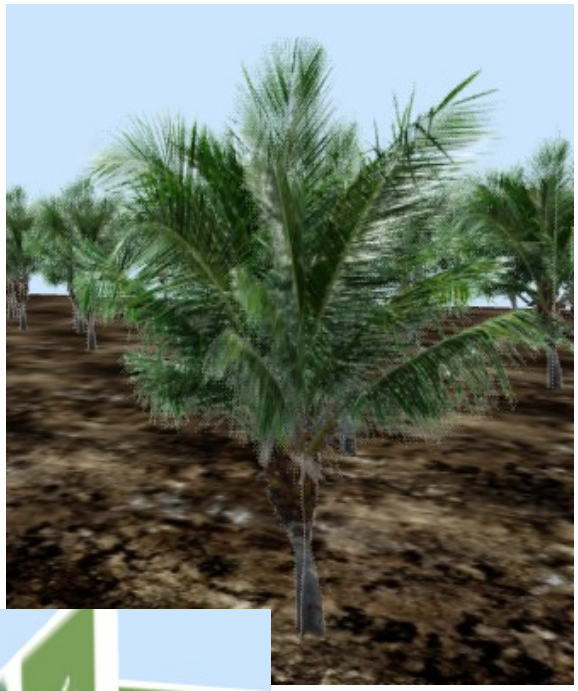






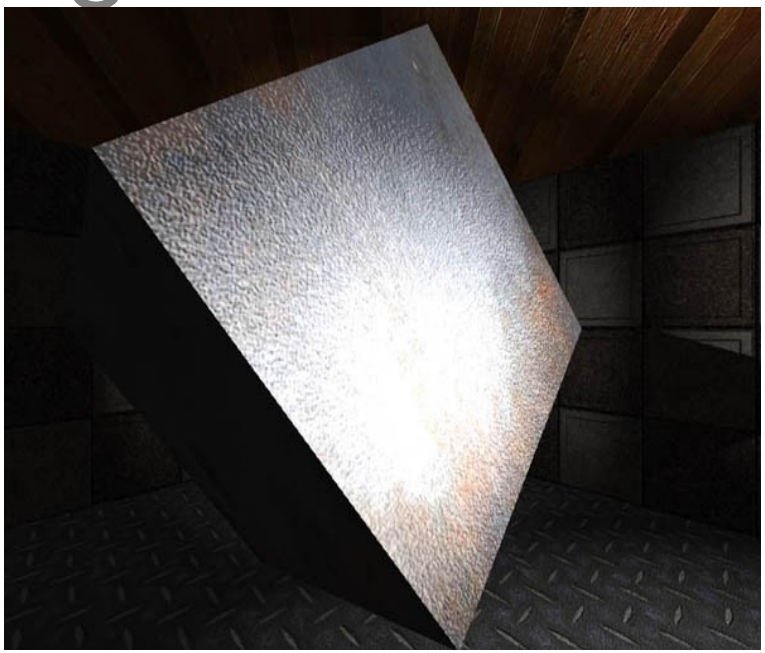
Alpha mapping

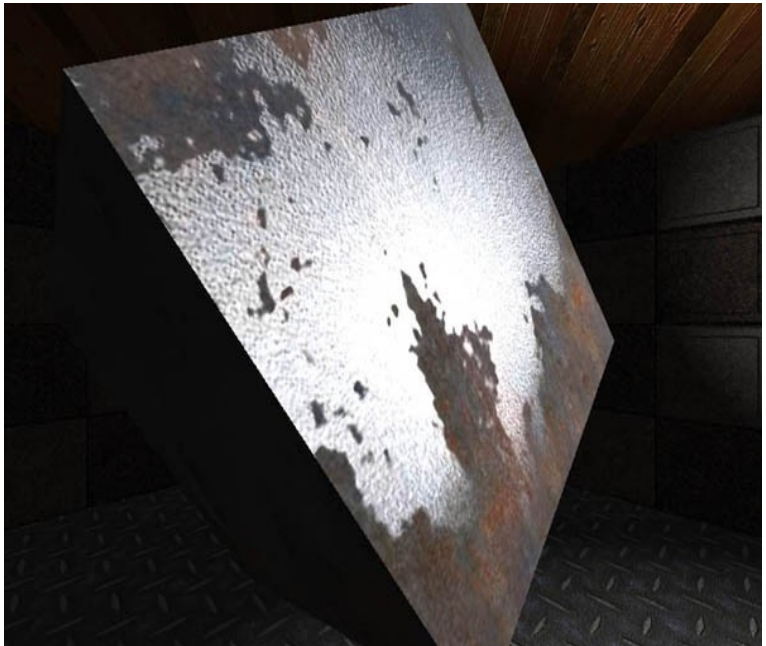
- Billboards
- Transp. Textures
  - trees,...
- Animated textures
  - fire, ...



Gloss mapping

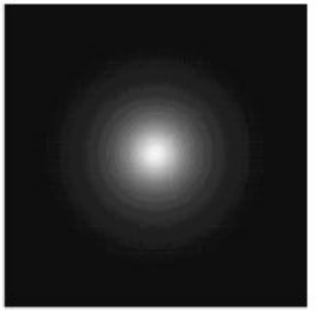
- Material properties in texture
- Used for specular

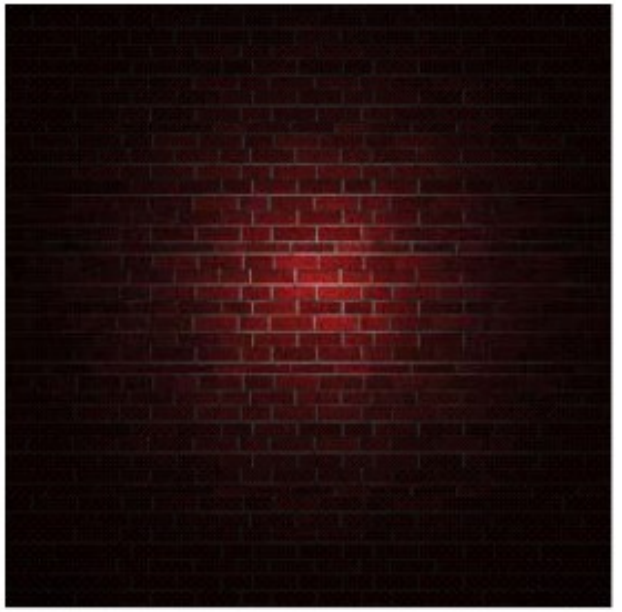




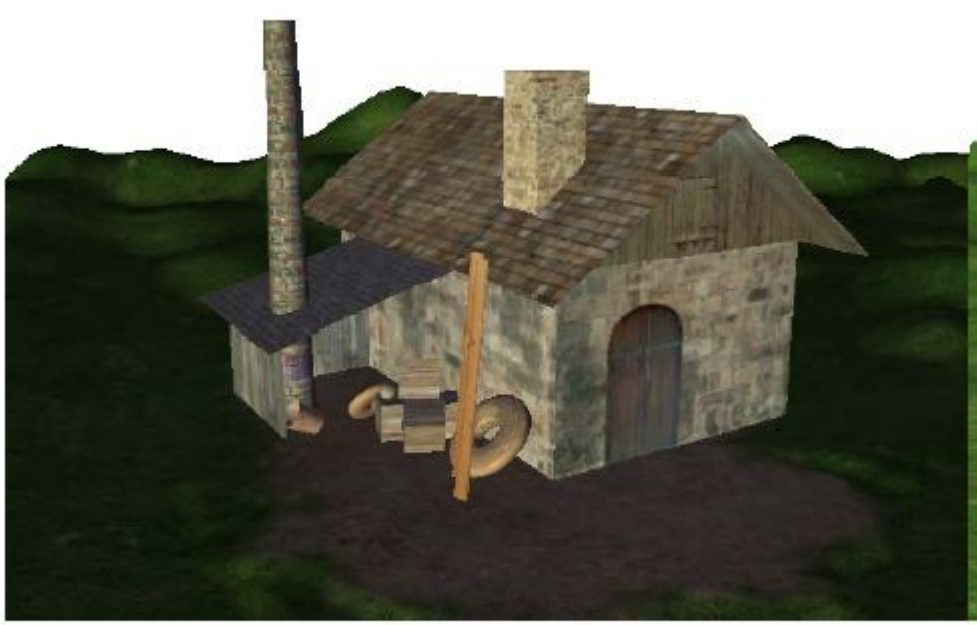
Light mapping

- Diffuse light view independent
- Precomputed light text.
  - Low resolution
  - Various approaches
- Combine with surface
- Shadows (static)
- Animated maps





Light mapping (2)

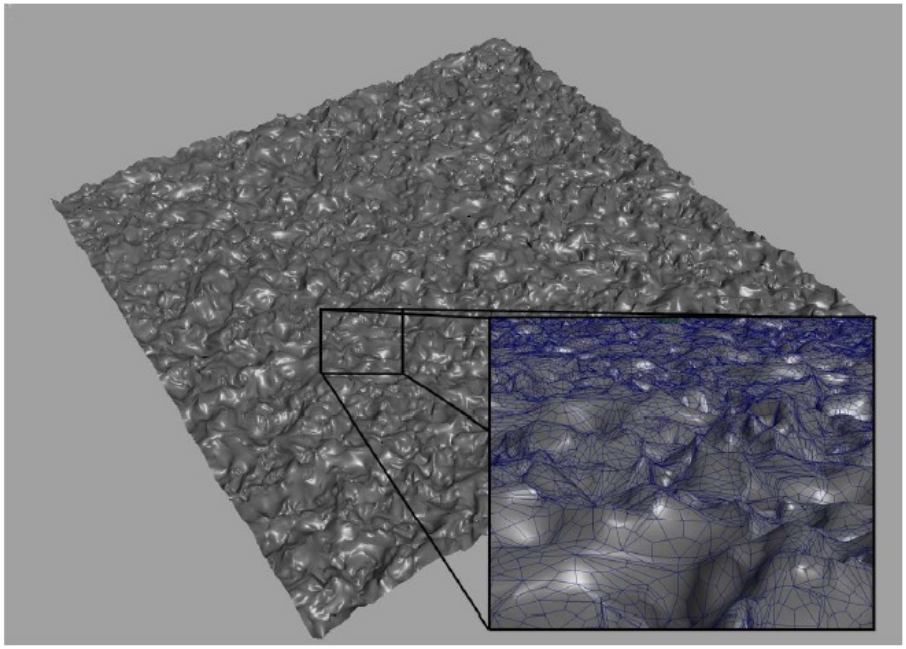


Original scene

Light-mapped

Rough surfaces

- ...
- Gloss Mapping
- Light Mapping
- Rough Surface
  - Bump mapping
  - Normal mapping
  - Displacement mapping
  - Parallax mapping
  - Relief mapping
  - Combinations
- Ambient Occlusion

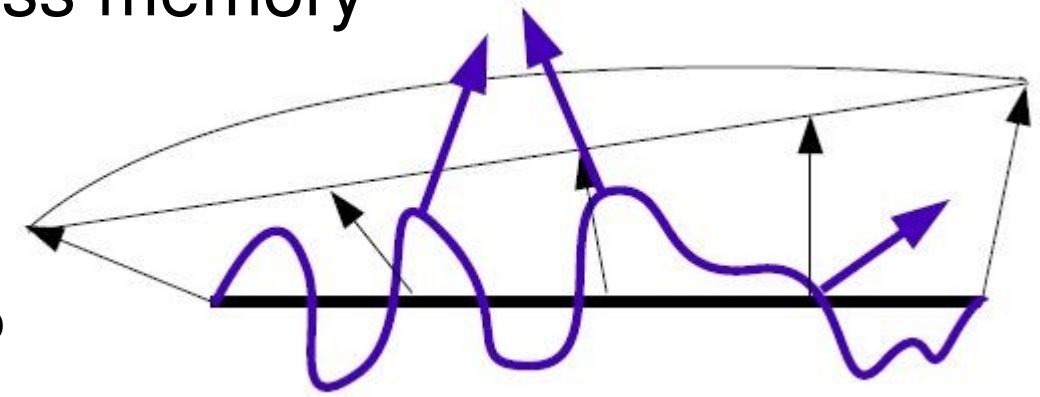


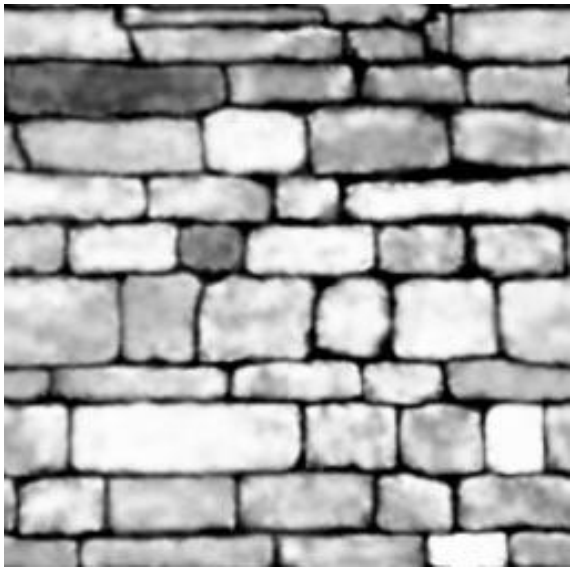
Bump mapping

- Rendering of structured surfaces
- Visual improvement without additional geometry
- Silhuette without change
- No shadows

Bump mapping (2)

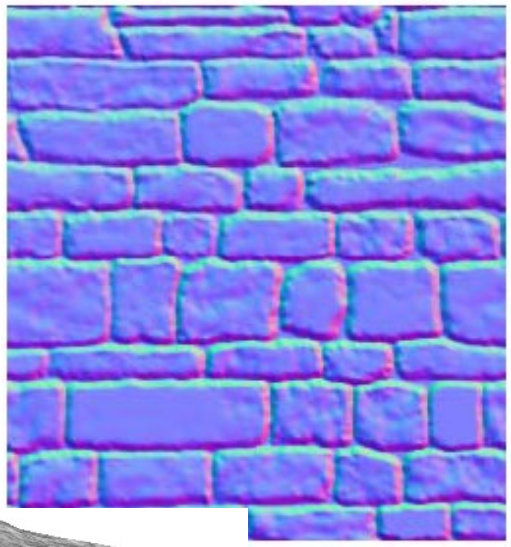
- Height map
  - Calculated normal
  - Central differences
  - uv space
- Perturbing surface normal by height map normal
- More computation
- Less memory



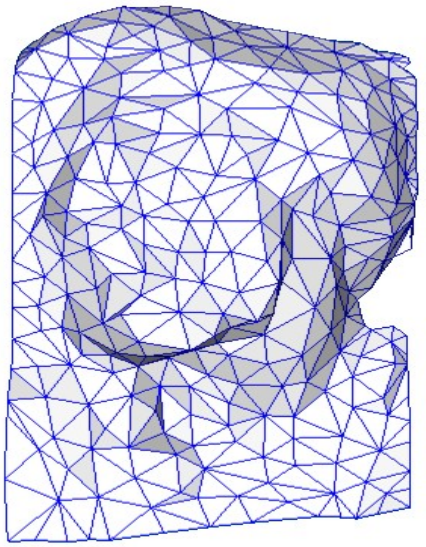


Normal mapping

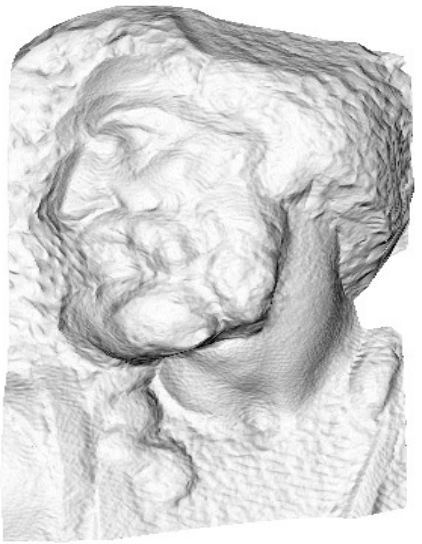
- Replaces surface normals from texture
- Normals in texture
  - Generated from high res. model
  - High resolution
  - Compressed [-1,1] → [0,1]
  - uv space



original mesh
4M triangles



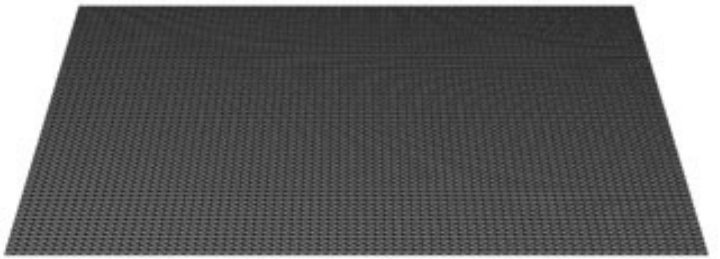
simplified mesh
500 triangles



simplified mesh
and normal mapping
500 triangles

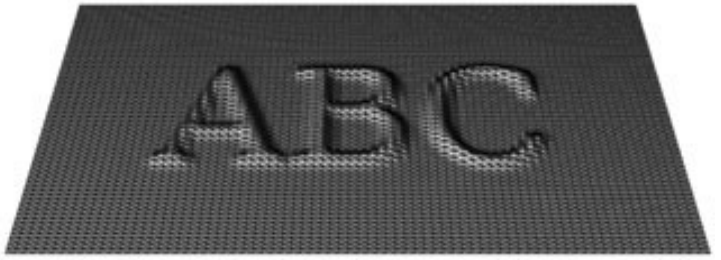
Displacement mapping

- Displacement along surface normal
- Applied to vertexes
  - Adaptive tessellation
- Costly technique
- New GPU (DX11)
  - Tesselator shader
  - Automatic LOD



ORIGINAL MESH

DISPLACEMENT MAP



MESH WITH DISPLACEMENT

Parallax mapping

- Approximation of original geometry
- More apparent depth
- Trace rays against height fields

Normal

Paralax

Relief

Parallax mapping

- Calculate offset
  - s,b (scale, bias) based on material
  - s=00.1, b=s*(-0.5)
  - $h_n=h*s-b$
  - $T_n = T_0+(h_n*V_{xy}/V_z)$
  - $V_z \rightarrow 0$
- Limited offset
- $T_n = T_0+(h_n*V_{xy})$

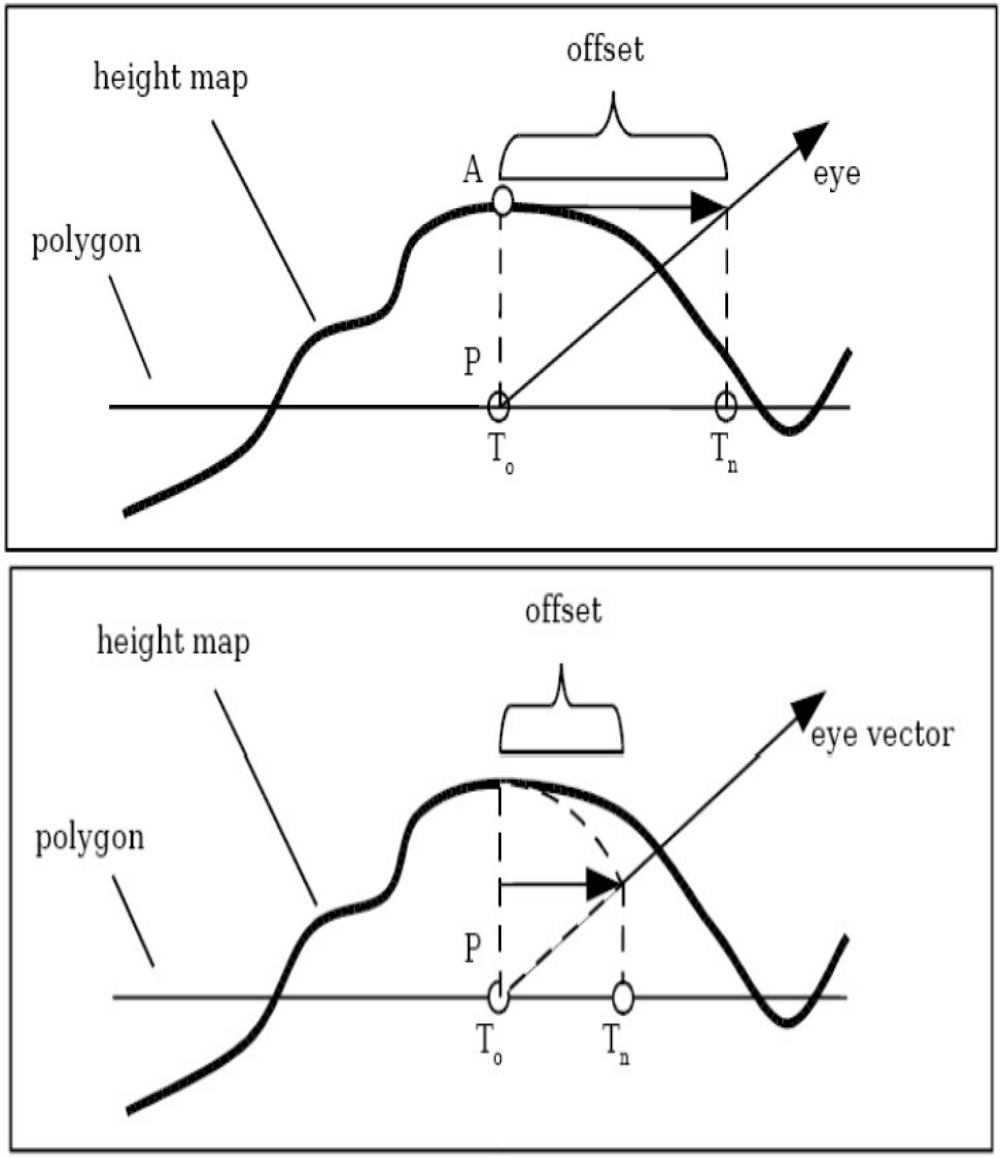
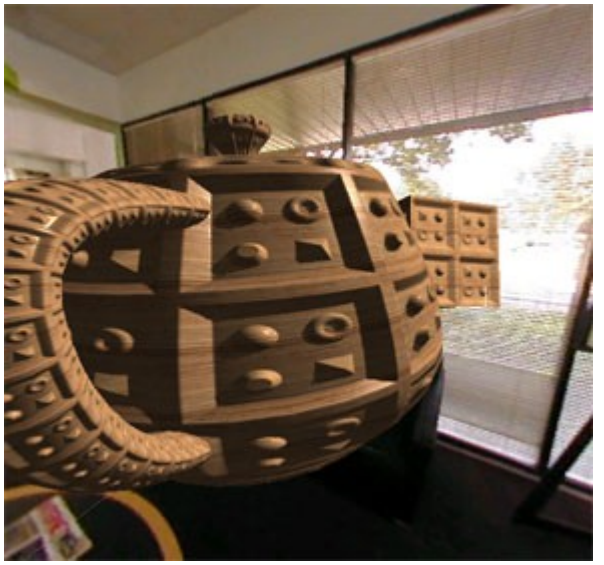
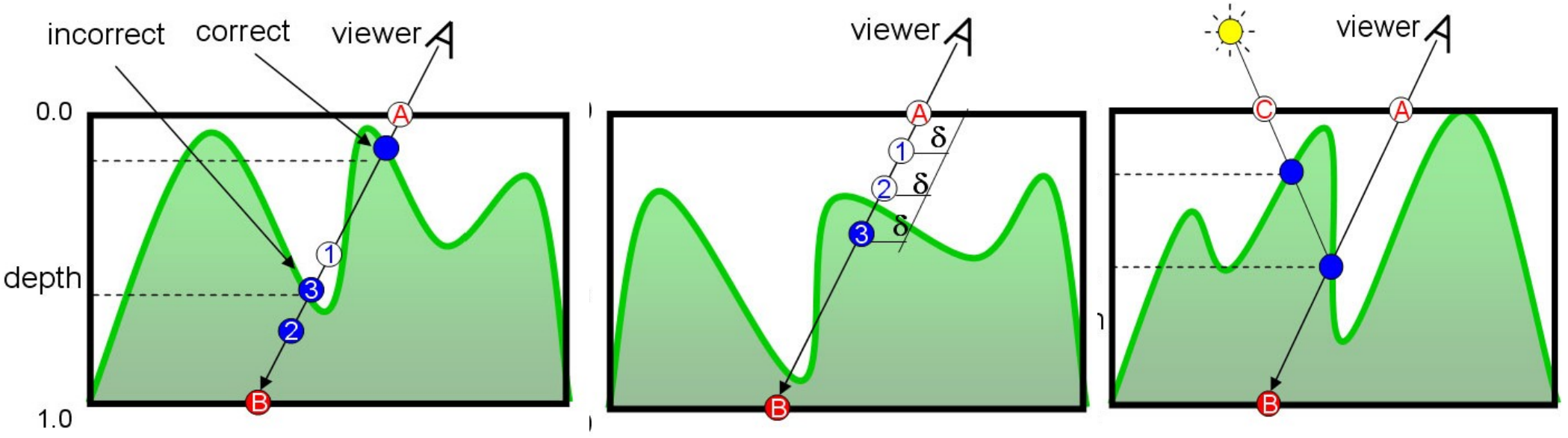


Image by Terry Welsh

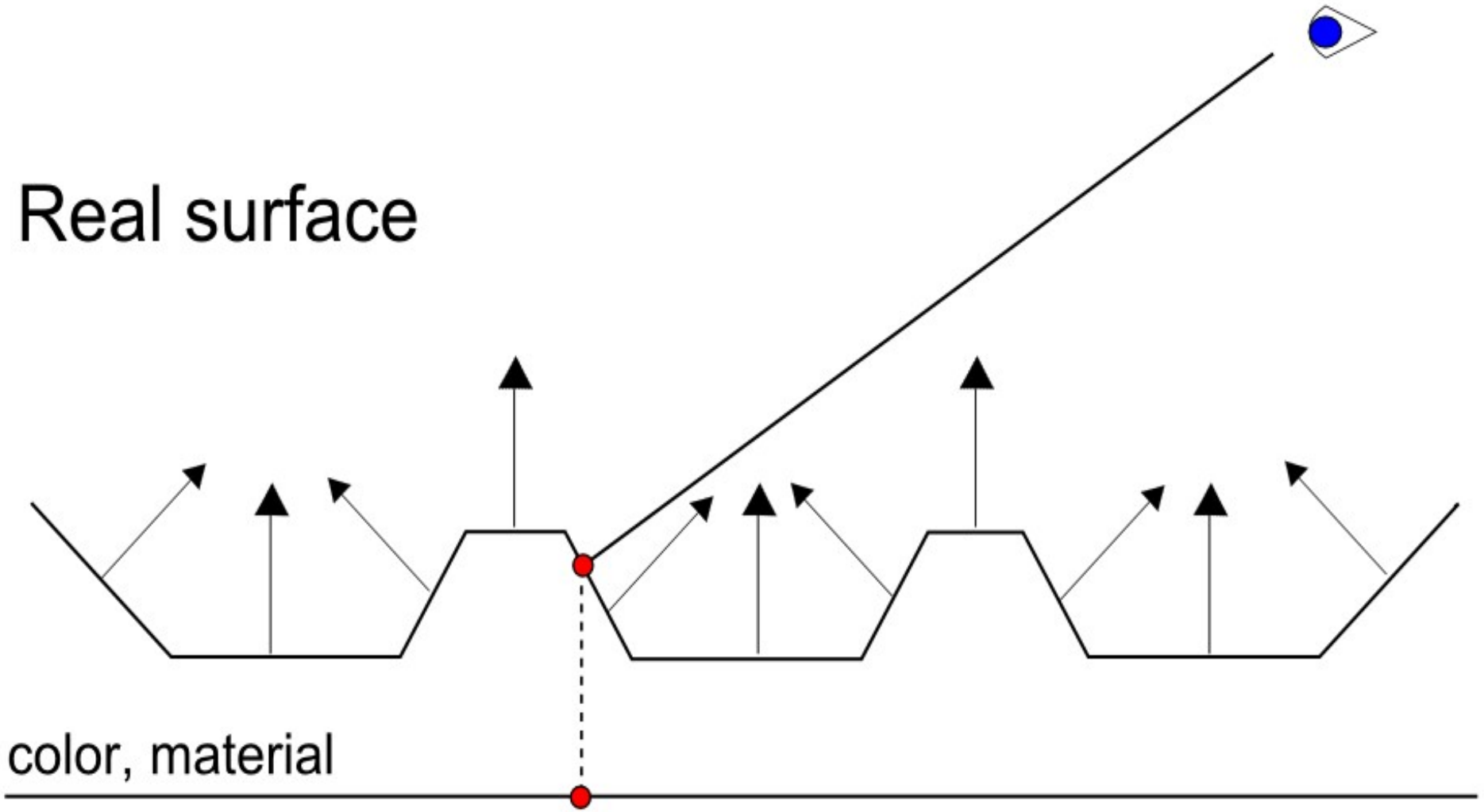
Relief mapping

- More accurate than parallax m.
- Self-shadowing, self-occlusion, silhouettes
- Based on ray-tracing
  - Various speed-up techniques





Comparison



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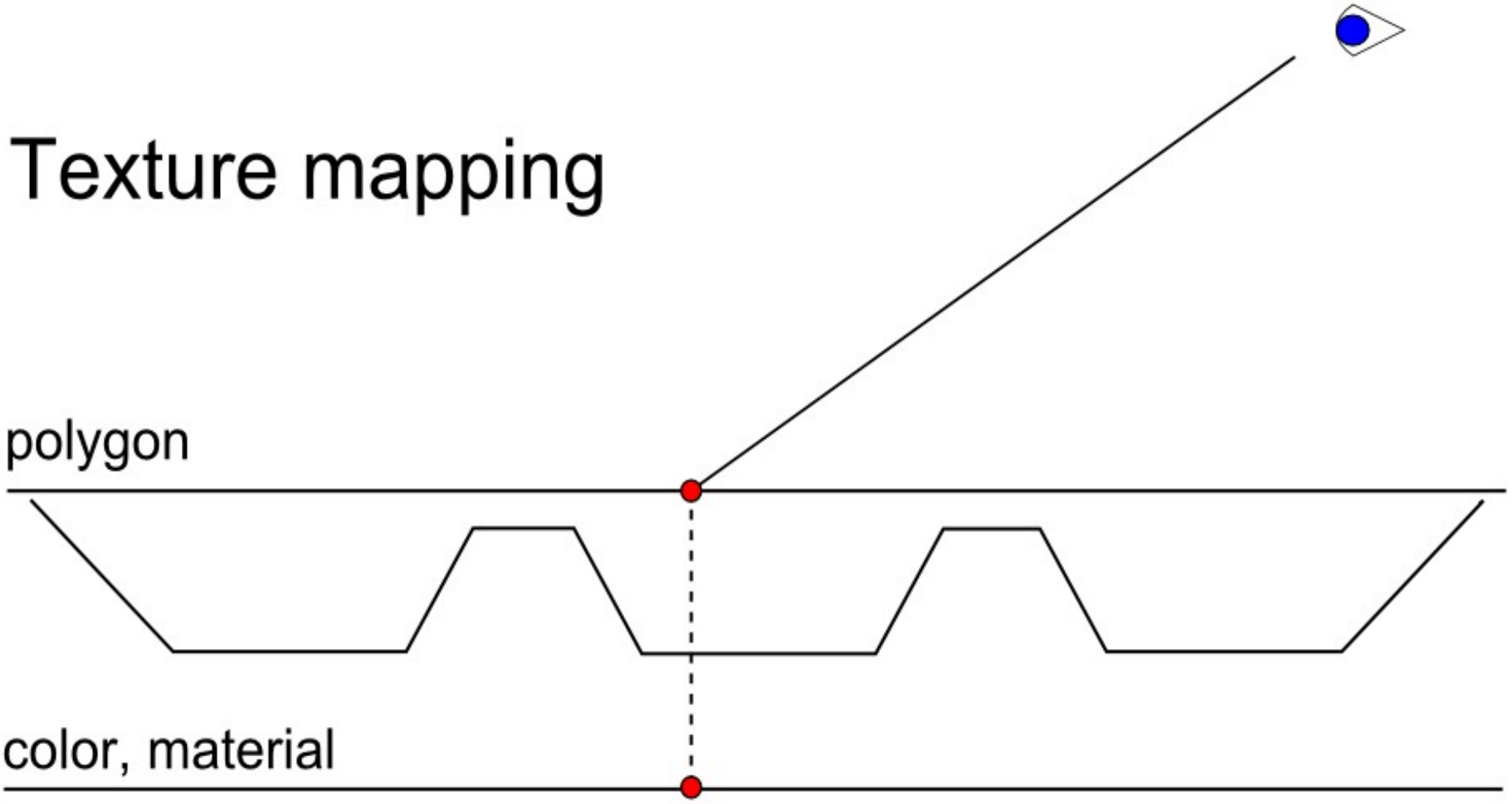
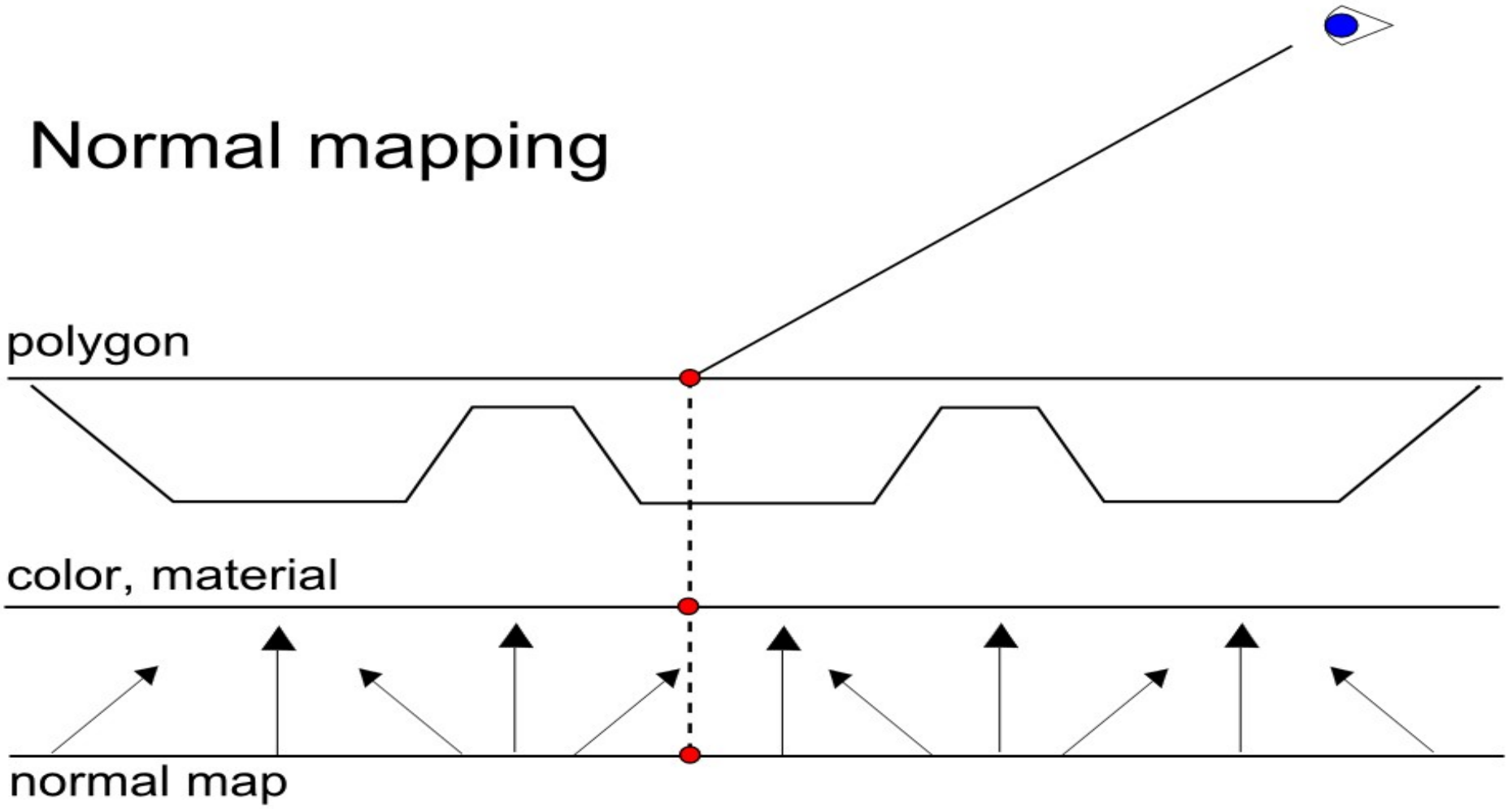
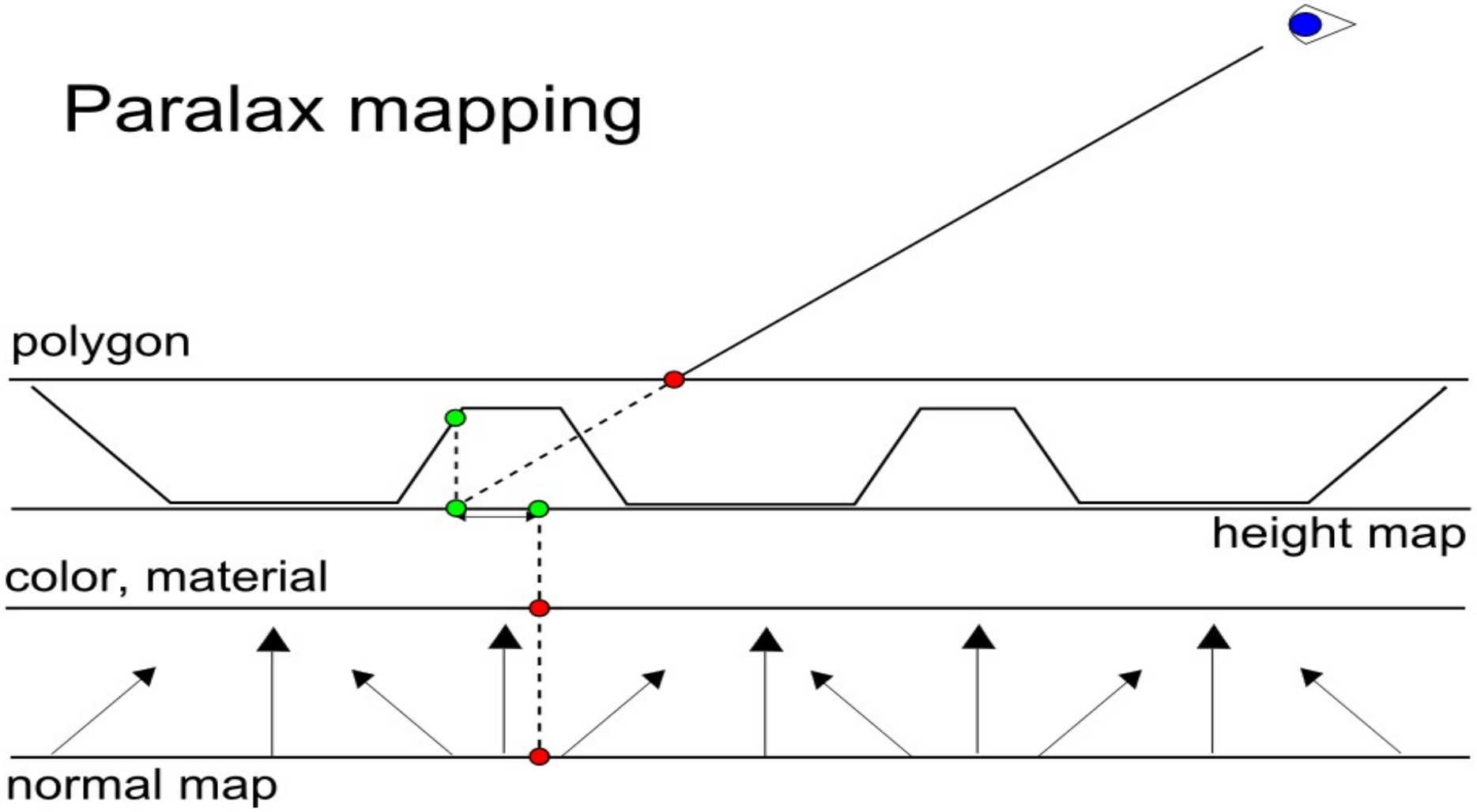


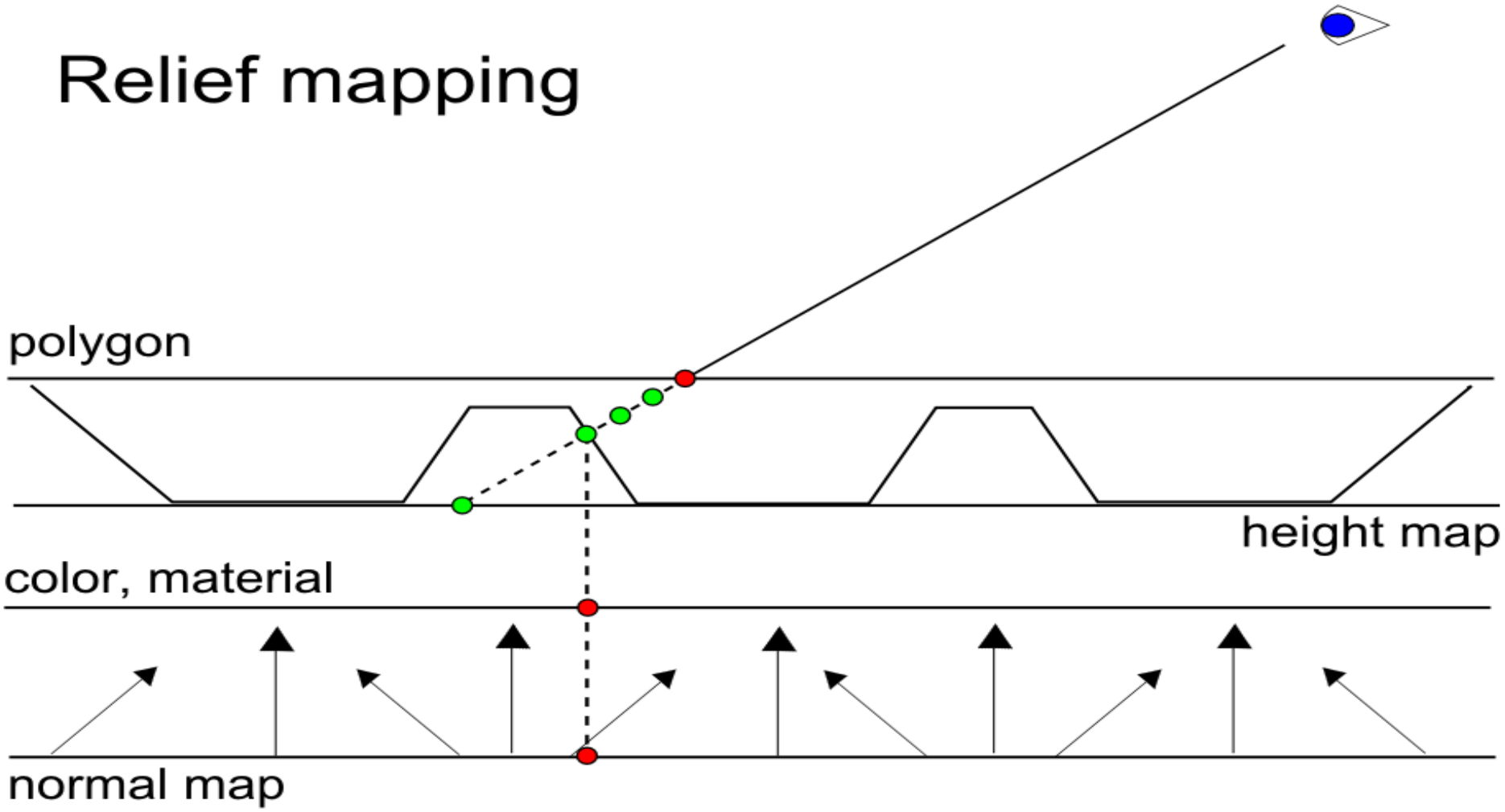
Comparison



Comparison


Paralax mapping
polygon
height map
color, material
normal map

Comparison


Relief mapping
polygon
height map
color, material
normal map

Comparison (2)

Texture mapping

Parallax mapping

Relief mapping

Combinations

- Steep Parallax Mapping
- Interval Mapping
- …

Texture Mapped

Normal Mapped

Parallax Mapped

Steep Parallax Mapped

References

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Questions ?