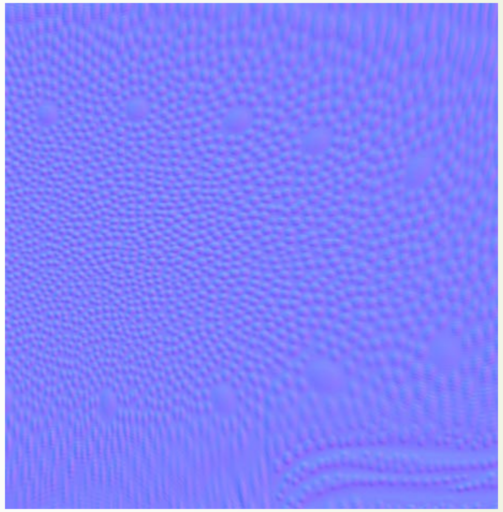
CS451 Texturing 4

Bump mapping continued



Jyh-Ming Lien

Department of Computer SCience

George Mason University

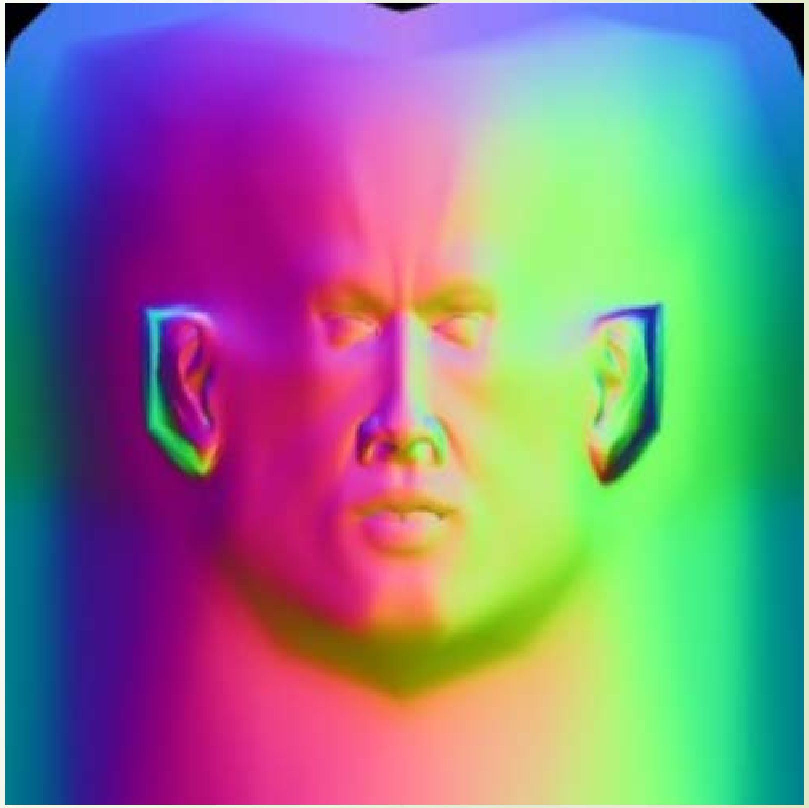
From Martin Mittring,

Spaces where your Normal map lives

- World space normal map
  - Each normal direction stored in texel is a world space vector
  - Usually applied to object using cube mapping
  - Rarely used for things that move
- Object space normal map
  - Each normal direction stored in texel is a vector in the space of the model
  - Each vertex must have unique (u,v) coordinates
- Tangent space normal map
  - Allow reuse of a normal map texture across multiple parts of the model

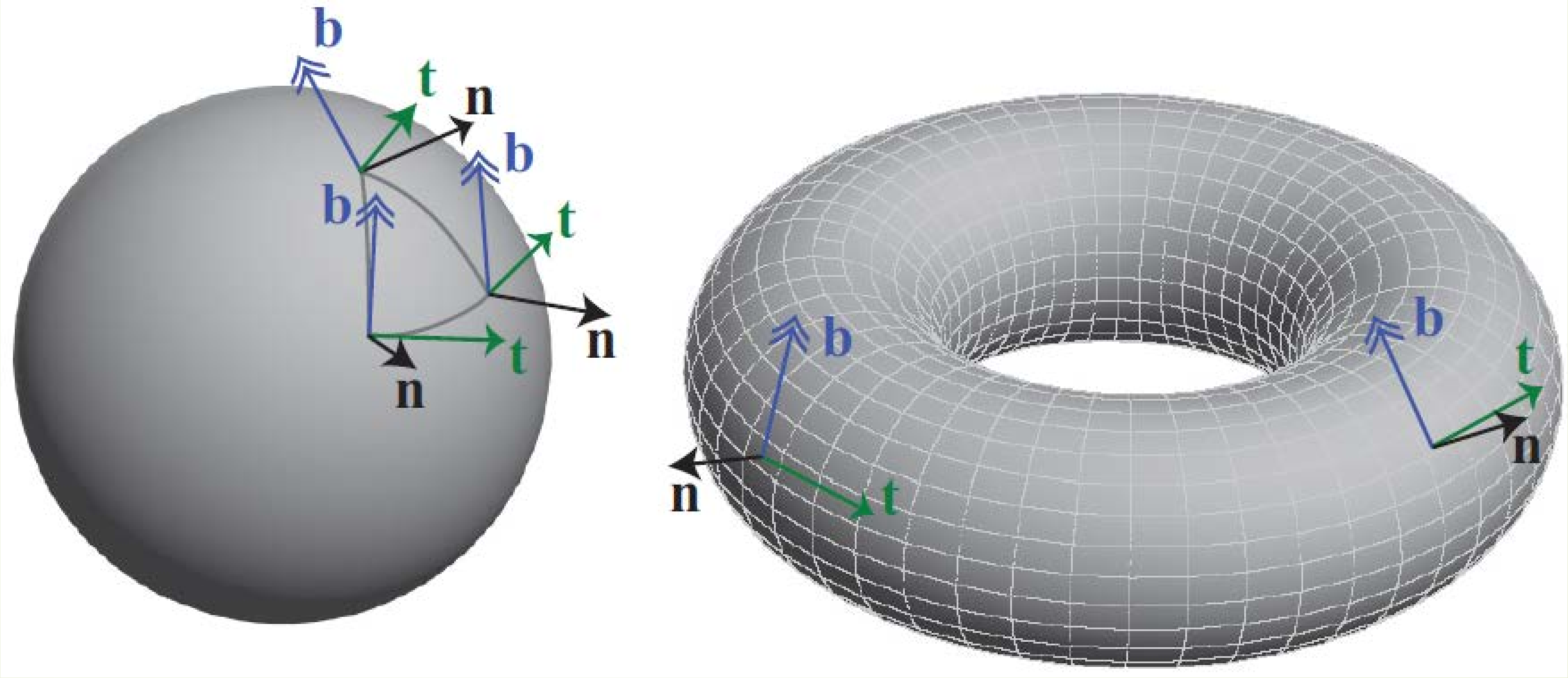
Object-Space Normal Mapping

- 3d vector encoded
- Simpler to implment
- Reuse limited to
  - translation
  - Scaling
  - Rotation



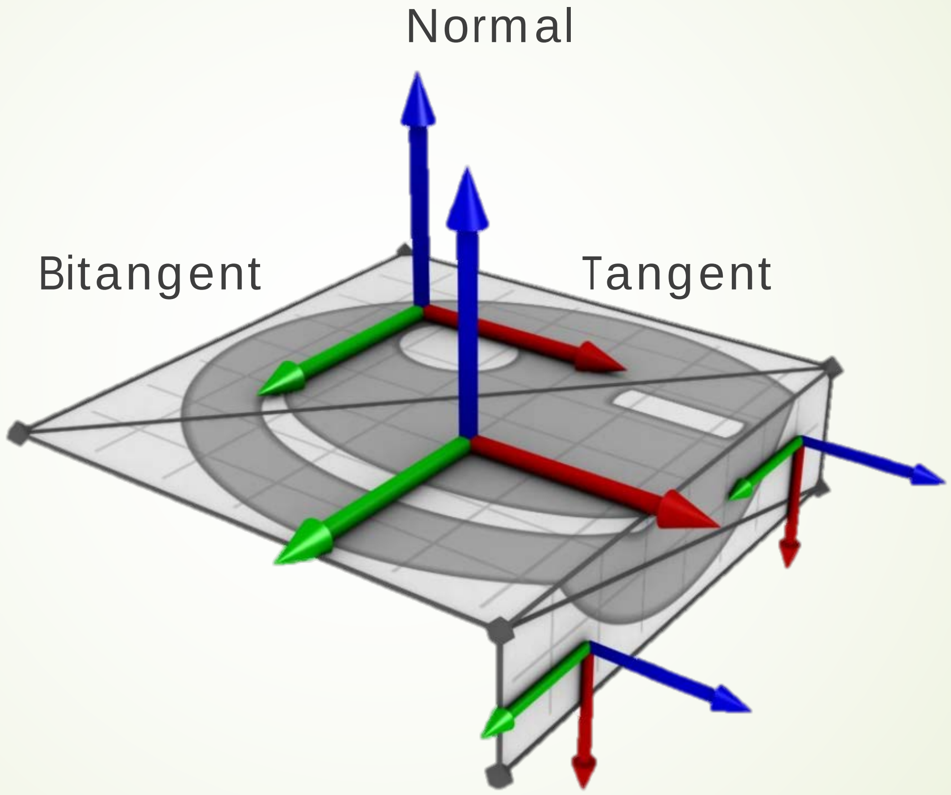
Tangent Space

- Normal, tangent, Bi-tangent



Tomas Akenine-Mől
ler © 2002

Tangent Space Per Triangle

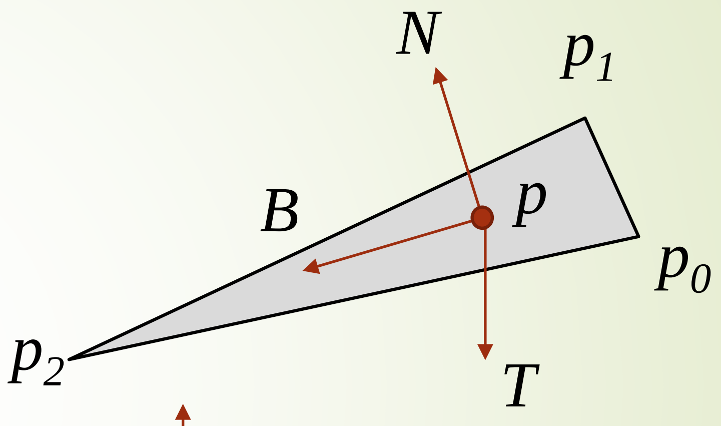


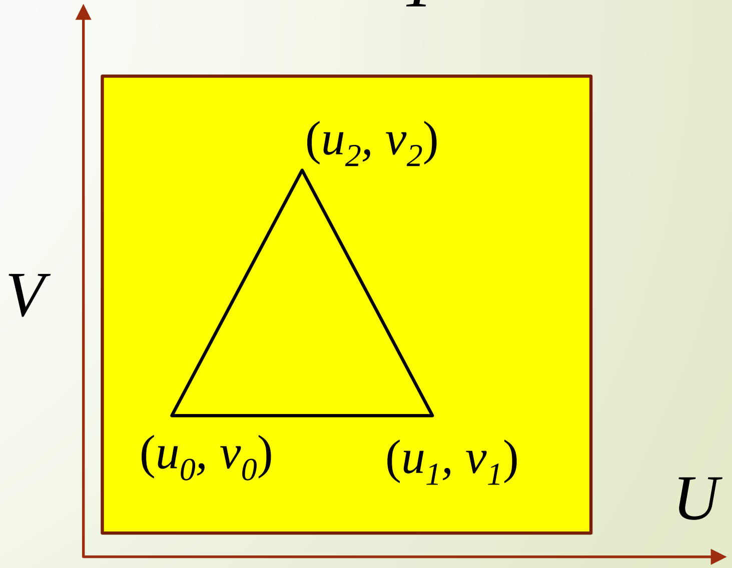
How is Tangent Space Computed?

- Normal : perpendicular to the plane
- Tangent and bitangent are parallel to the plane
  - Tangent and bitangent are perpendicular to the normal
  - There are many possible tangents and bitangents
  - Their direction is determined by the UV coordinates
    - one points in the direction of U-axis in 3d space
    - the other in the direction of the V-axis
  - tangent space normal map stores the length of each vector

How is Tangent Space Computed?

- Goal: $P - P_0 = (u - u_0)T + (v - v_0)B$

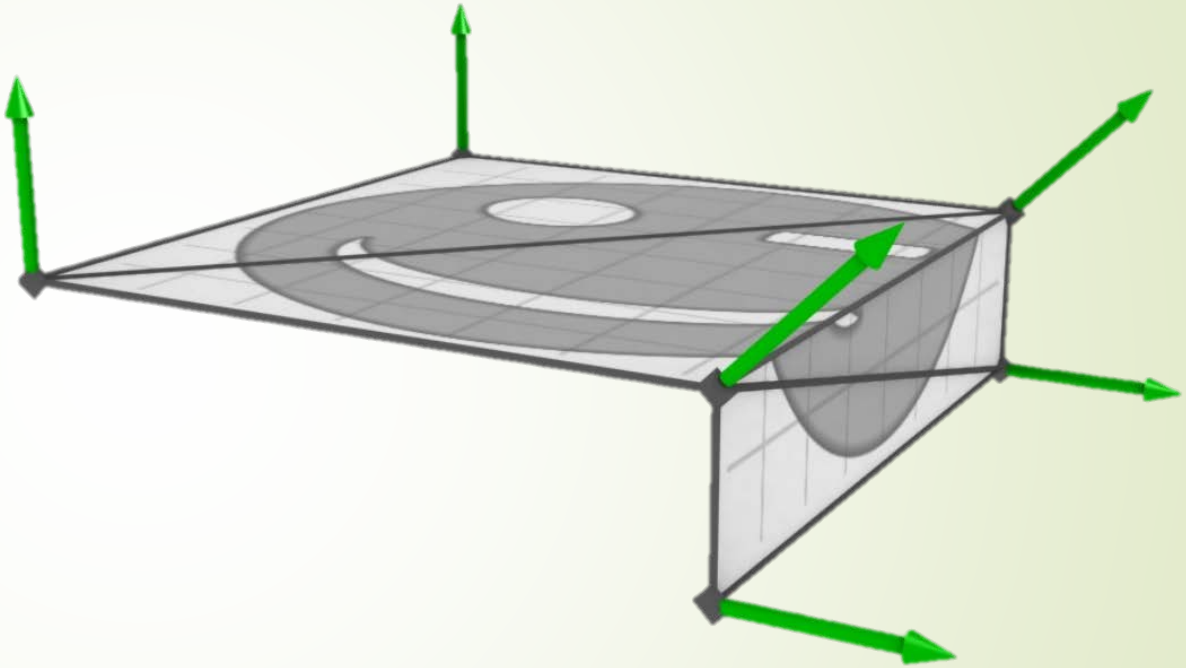




Note:

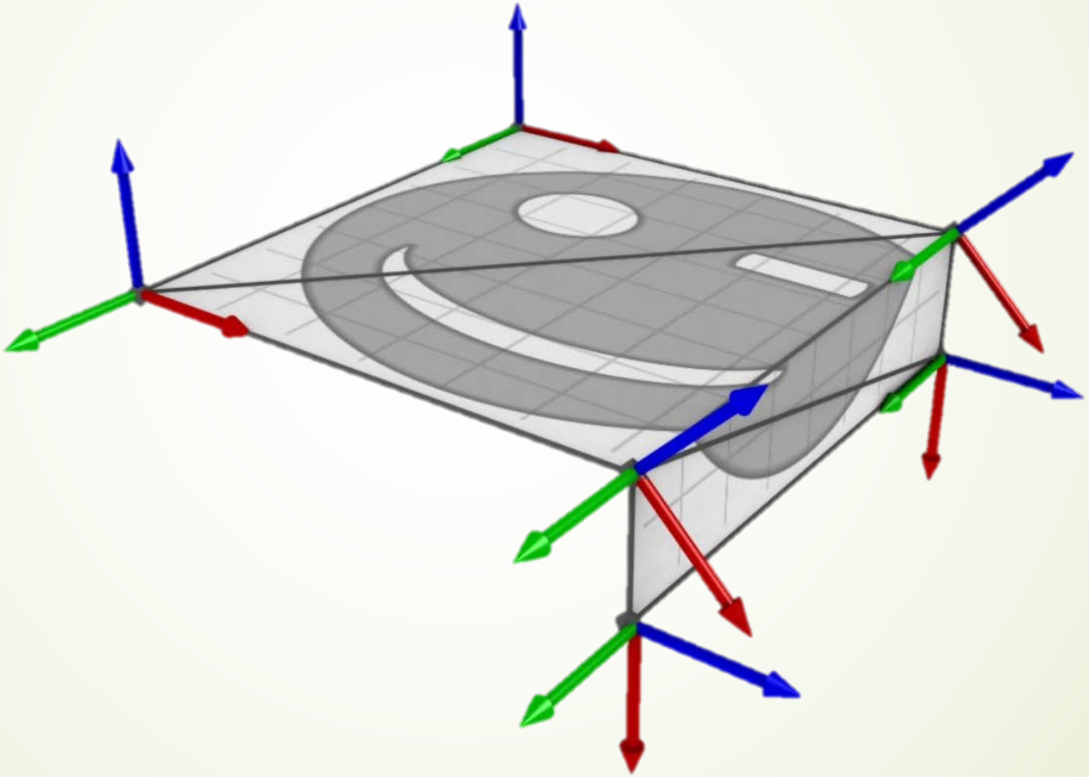
$$\begin{bmatrix} s_1 & t_1 \\ s_2 & t_2 \end{bmatrix}^{-1} = \frac{1}{s_1 t_2 - s_2 t_1} \begin{bmatrix} t_2 & -t_1 \\ -s_2 & s_1 \end{bmatrix}$$

Per Vertex Normal



- How do you compute per vertex normal?
- Is the normal affected by tessellation?

Per Vertex Tangent Space



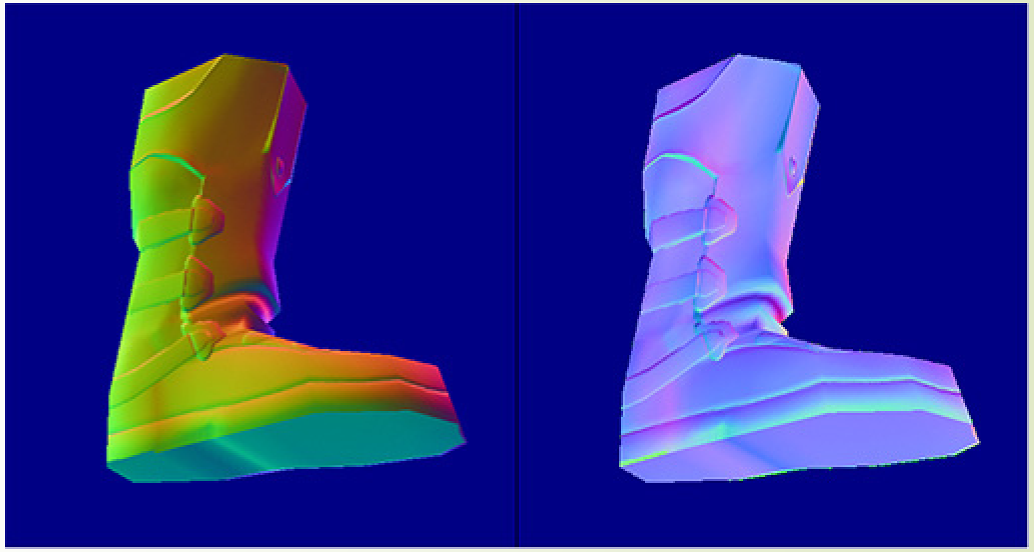
tangent space

$$\begin{bmatrix} T_1 & B_1 & N_1 \\ T_2 & B_2 & N_2 \\ T_3 & B_3 & N_3 \end{bmatrix}$$

How do you convert a light source to tangent space?

Advantages of Tangent Space

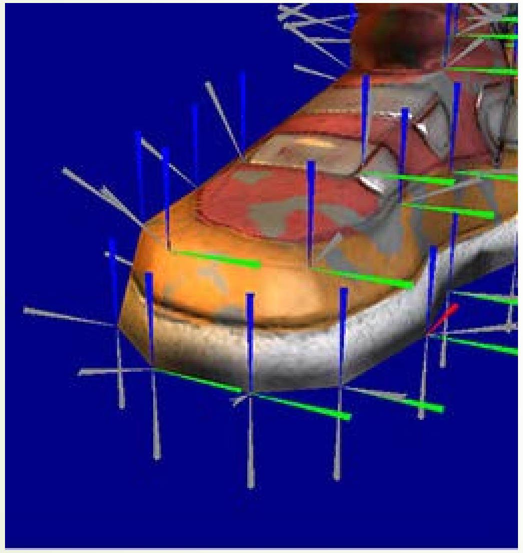
- Efficient
- Support for mirroring
- Tiling textures
- Higher image compression rate



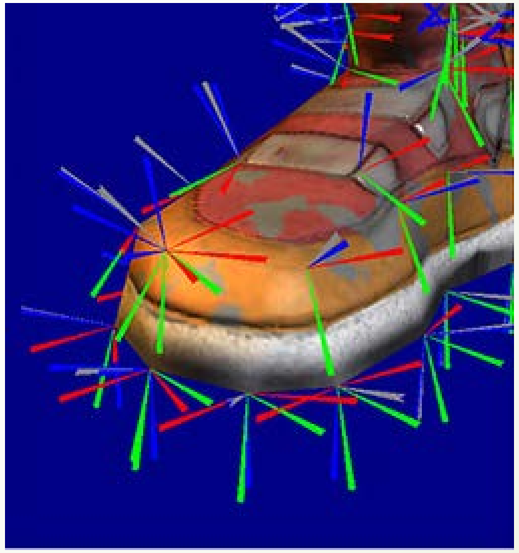
object space Tangent space

Comparison

- The spaces defined by each vertex

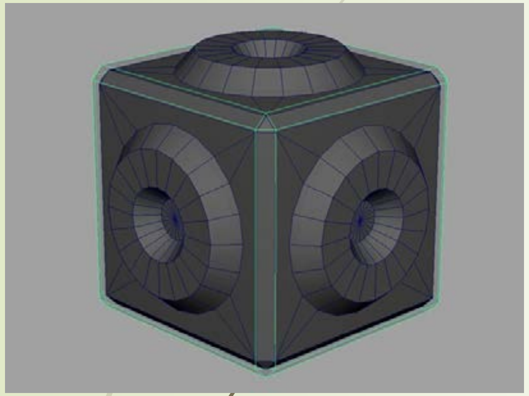


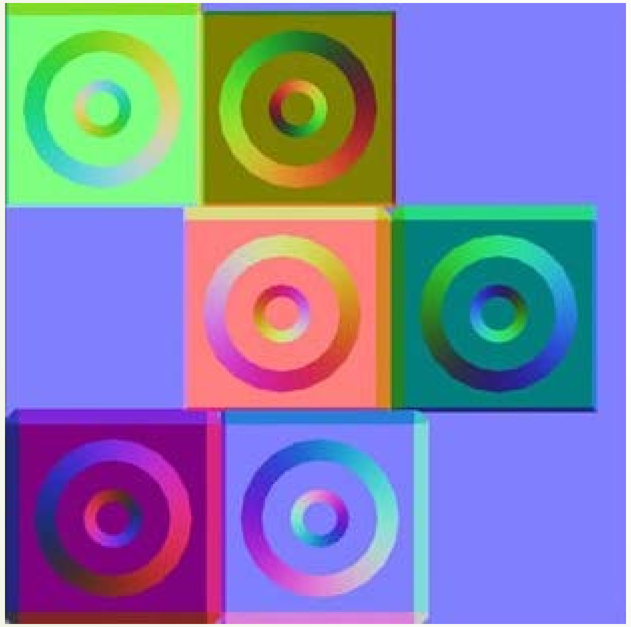
object space



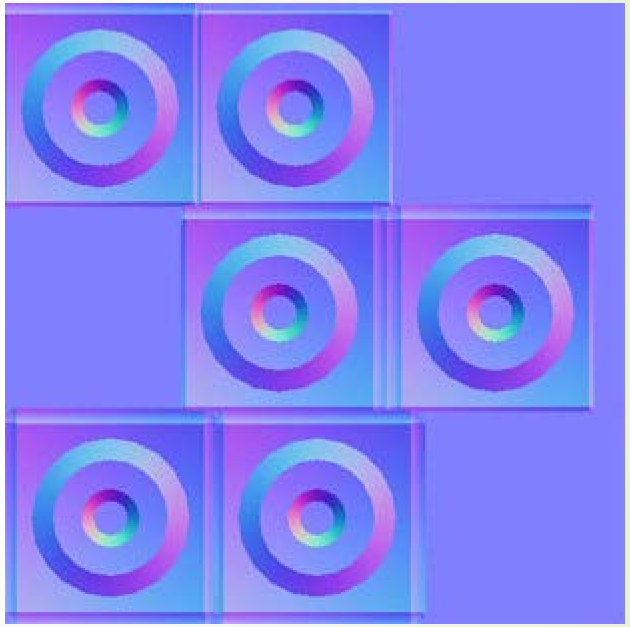
Tangent space

Comparison





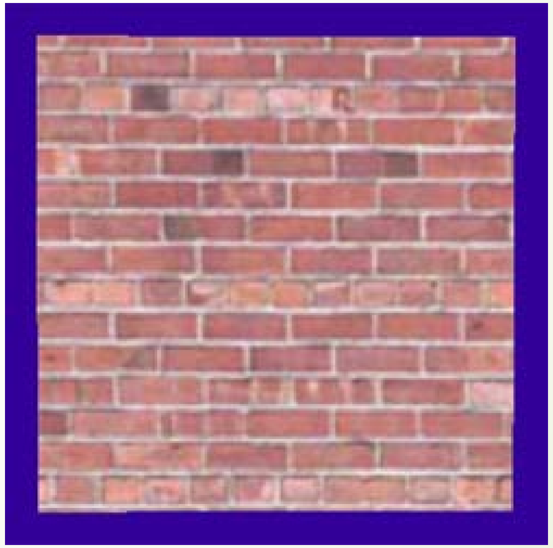
Object space

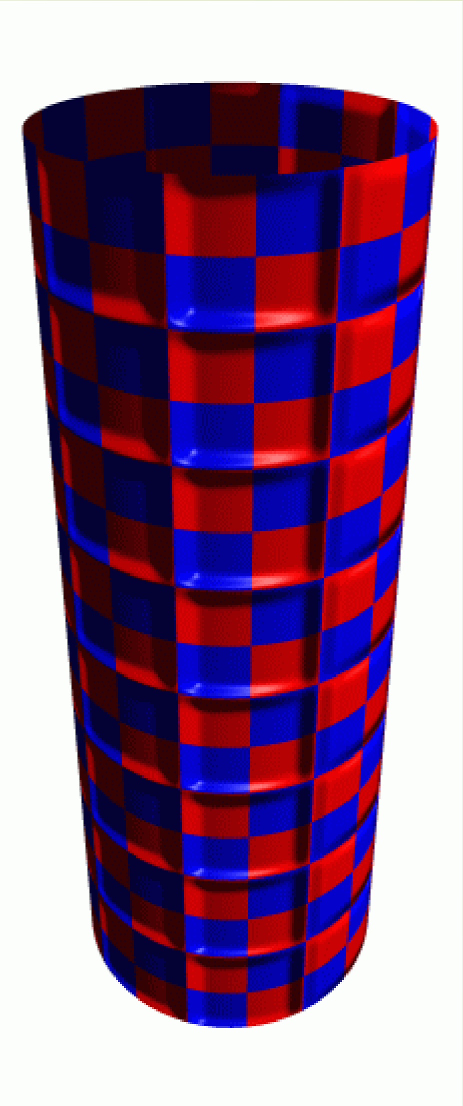


Tangent space

What's Missing?

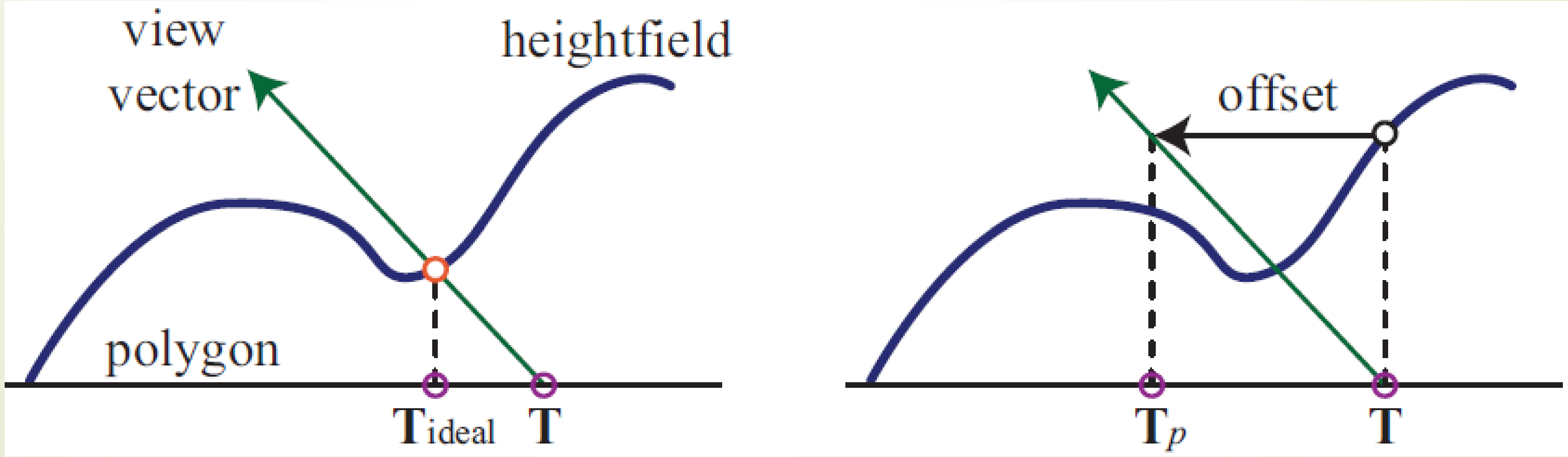
- There are no bumps on the silhouette of a bump-mapped object
- Bump maps don’t allow self-occlusion or self-shadowing





Parallax Mapping

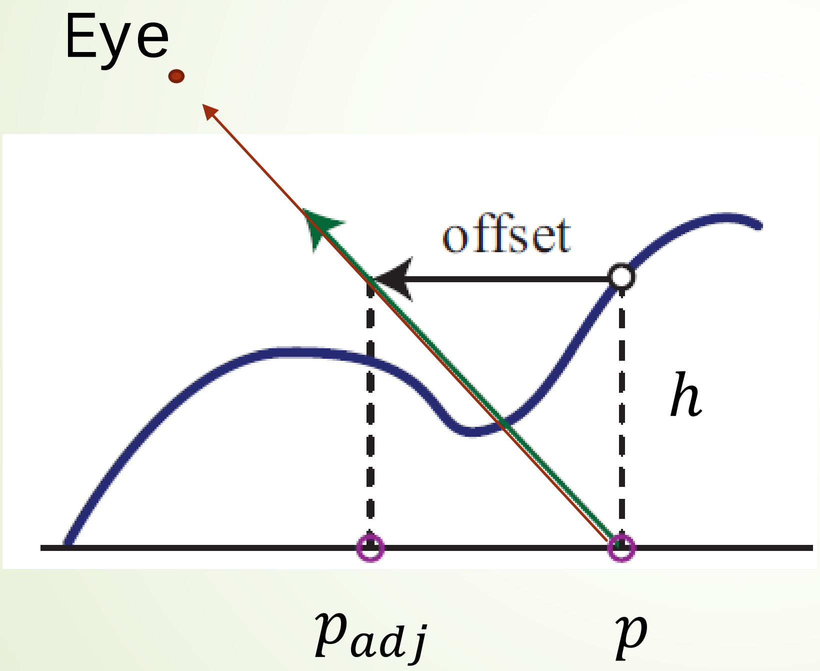
- A.k.a. Offset mapping, visual displacement mapping
- Using height field instead of normal map
- Example: What is the elevation and color for the green ray below



Parallax Mapping

Vector from eye to p

$v = (v_x, v_y, v_z)$

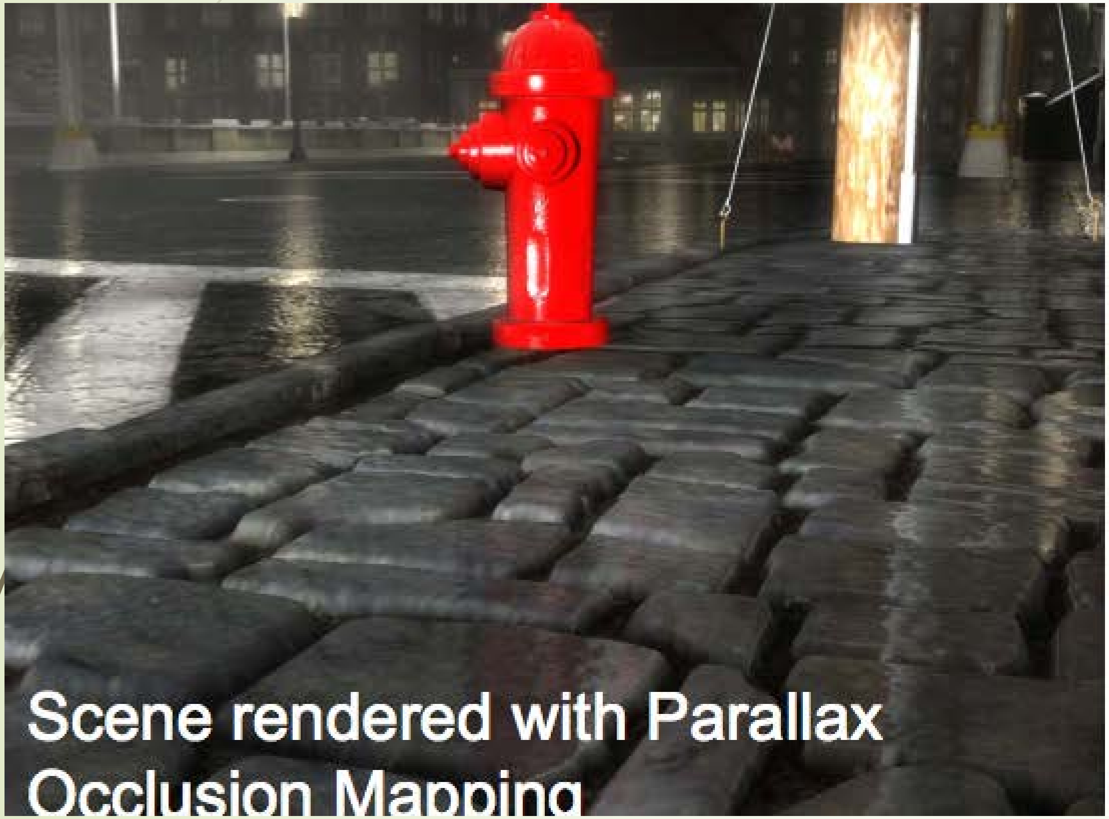


Solve p_{adj}

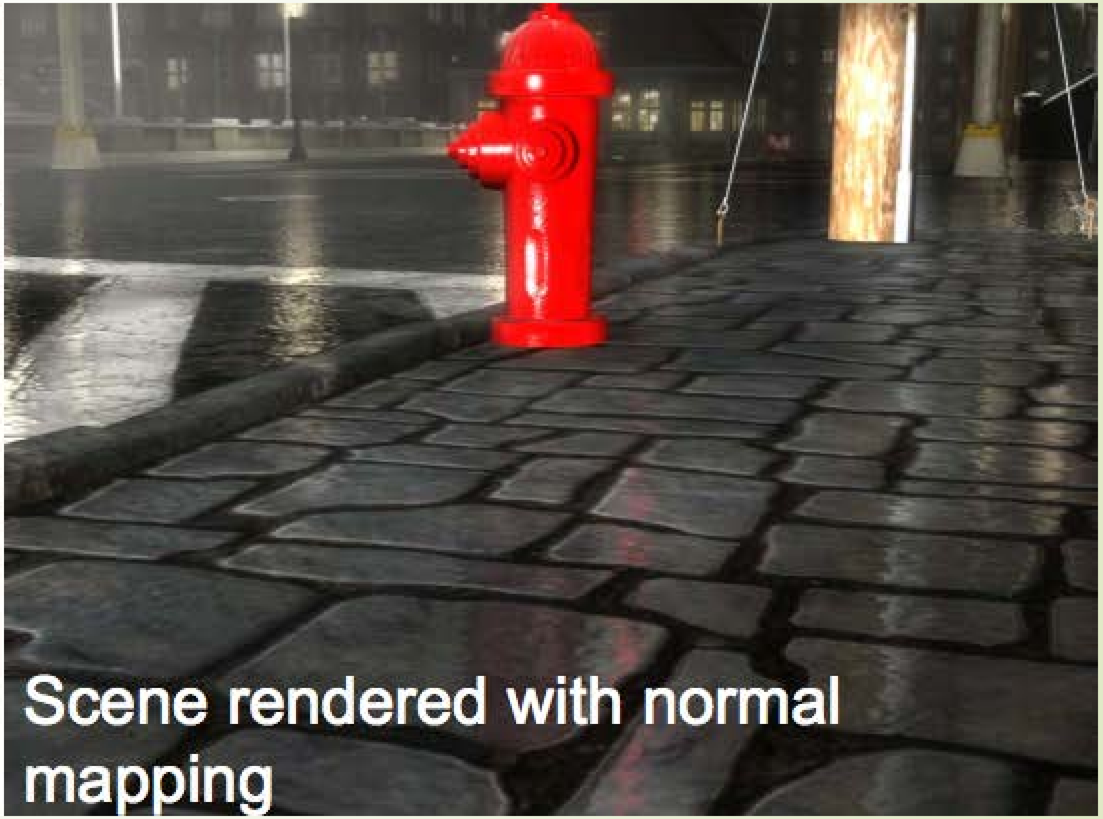
Then the color of this ray is computed using color, normal defined at p_{adj} instead of those at p

Parallax Mapping

- Parallax provides much better visualization of “occlusion”



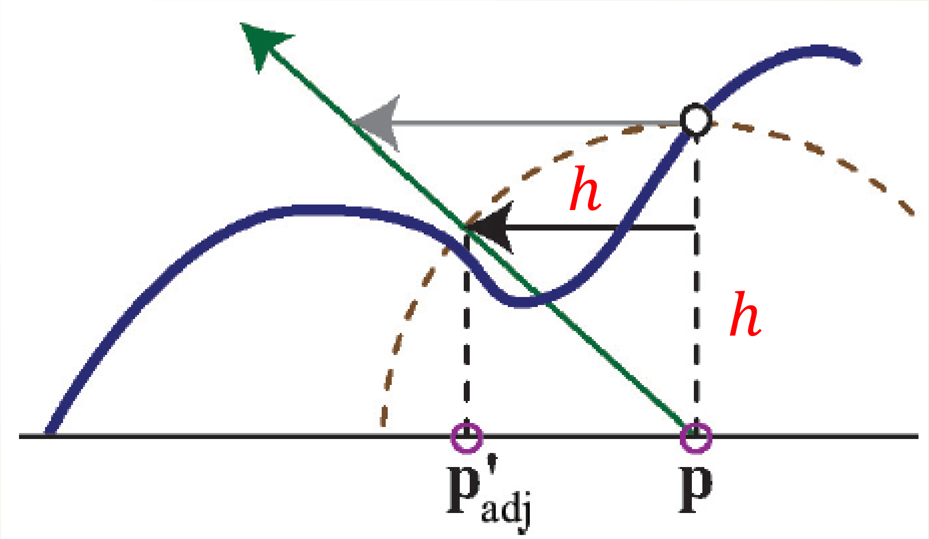
Scene rendered with Parallax Occlusion Mapping



Scene rendered with normal mapping

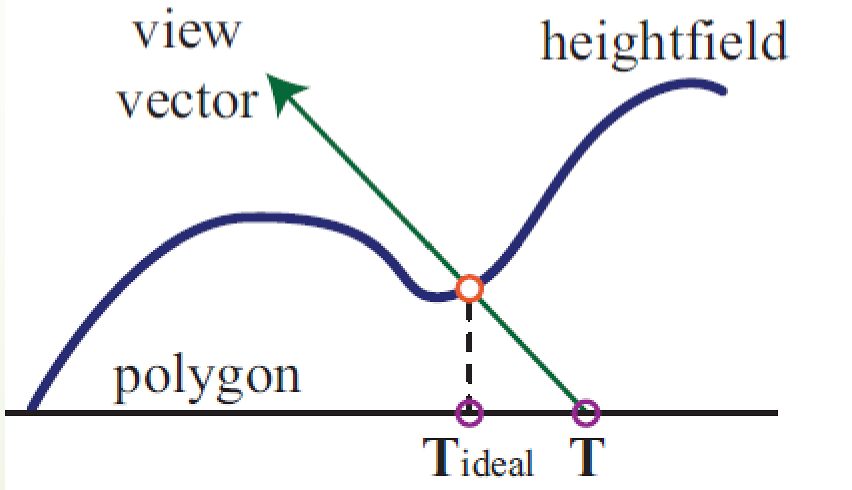
Parallax Offset Limiting

- Parallax fails if the neighboring heights are very different
- Solution: limit the amount of offset
- $p'_{adj} = p + h \cdot \boldsymbol{v}_{xy}$



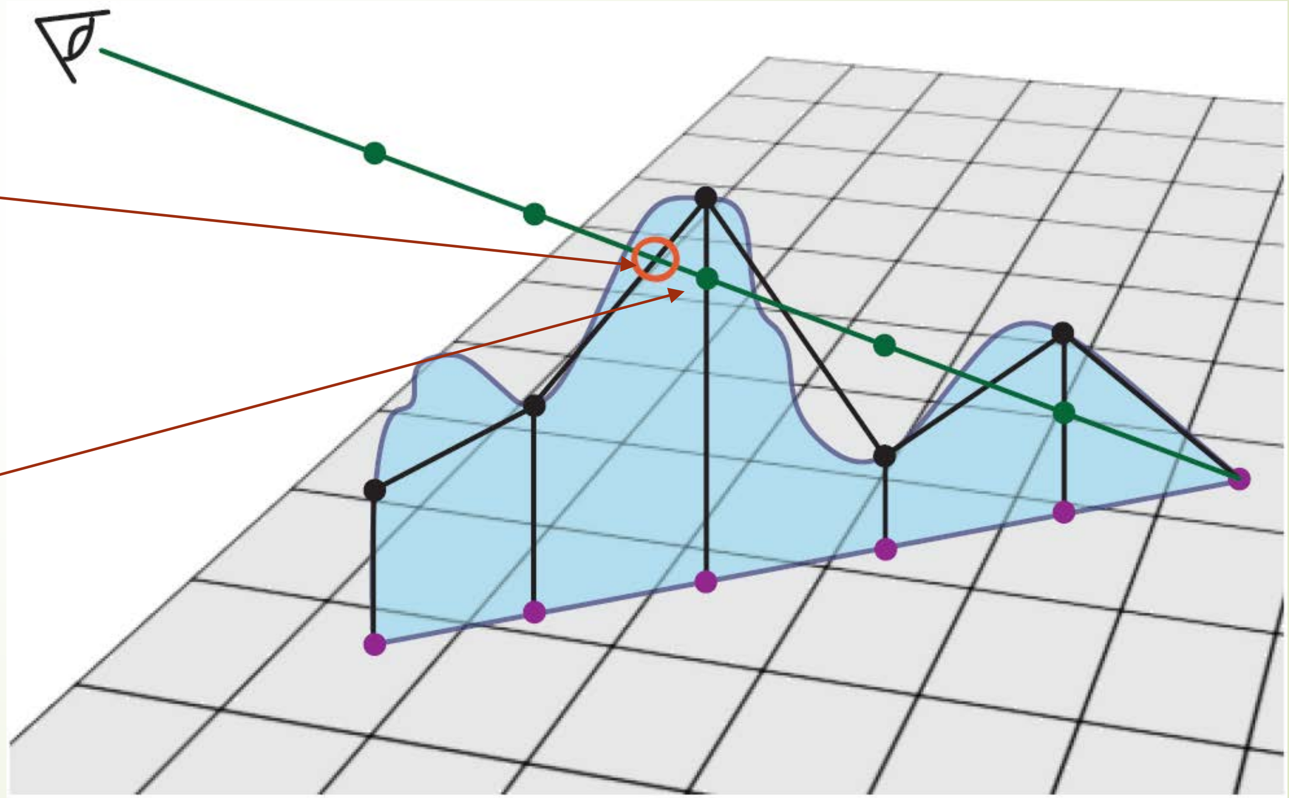
Relief Mapping

- Relief mapping (a.k.a. Steep parallax mapping or parallax occlusion mapping)
- Compute the first intersection between the ray and the height field via Sampling
- Still an approximation



Relief Mapping

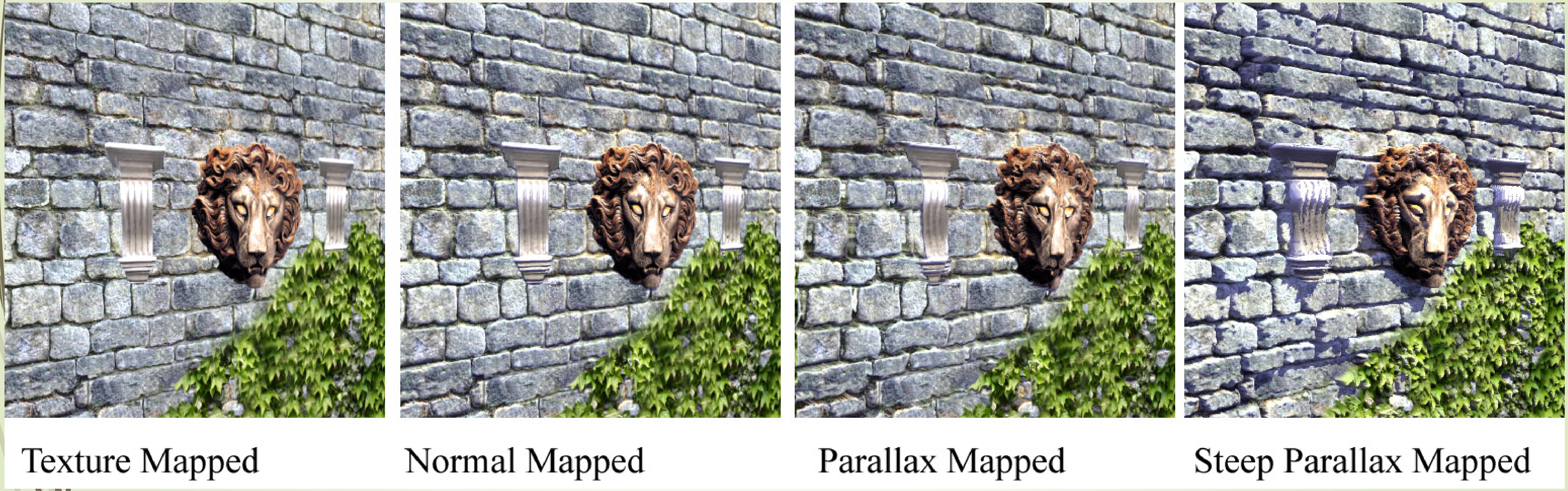
- Sample along the viewing ray



Goal: compute this point

First sample lower than the height map

Comparison



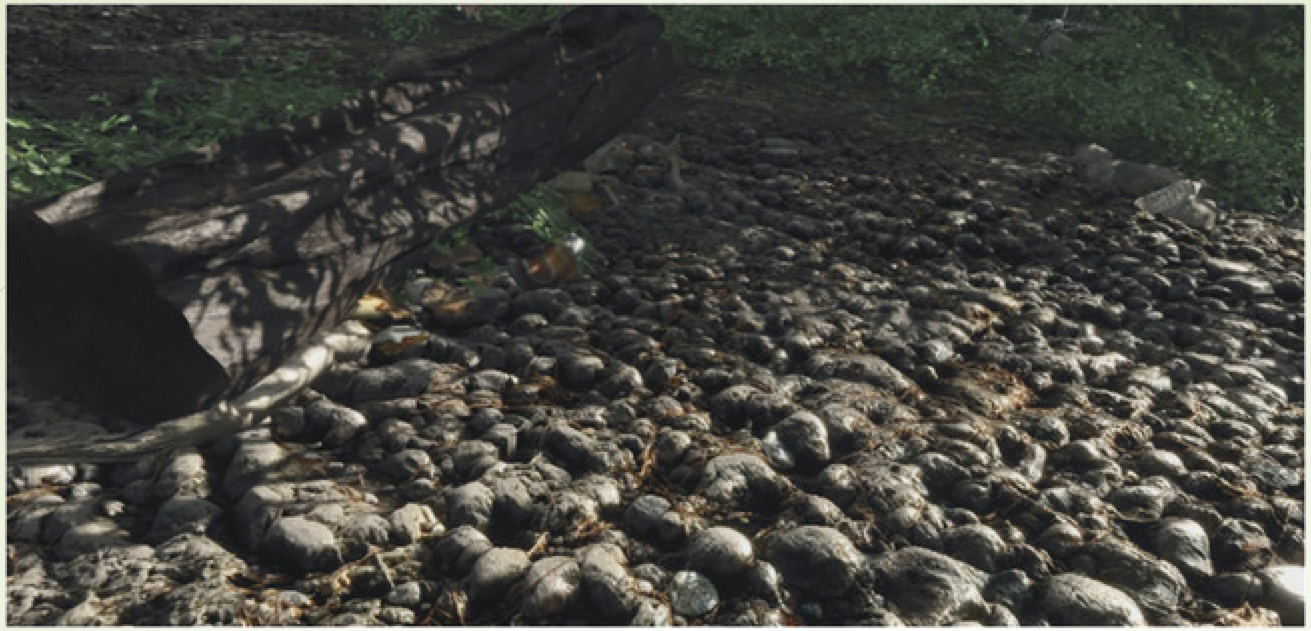
Texture Mapped

Normal Mapped

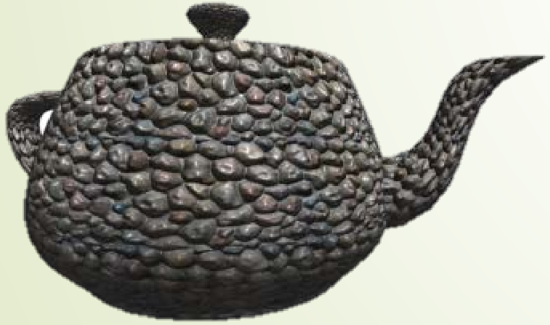
Parallax Mapped

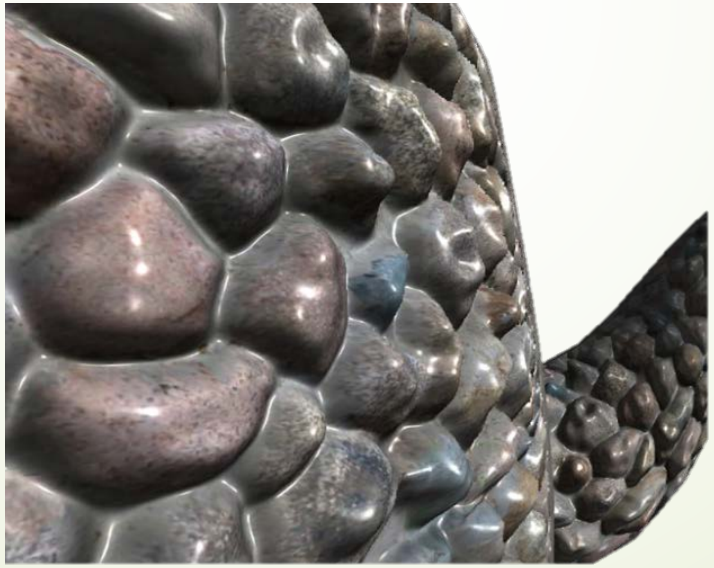
Steep Parallax Mapped

Image by Morgan McGuire and Max McGuire



Great visual effect

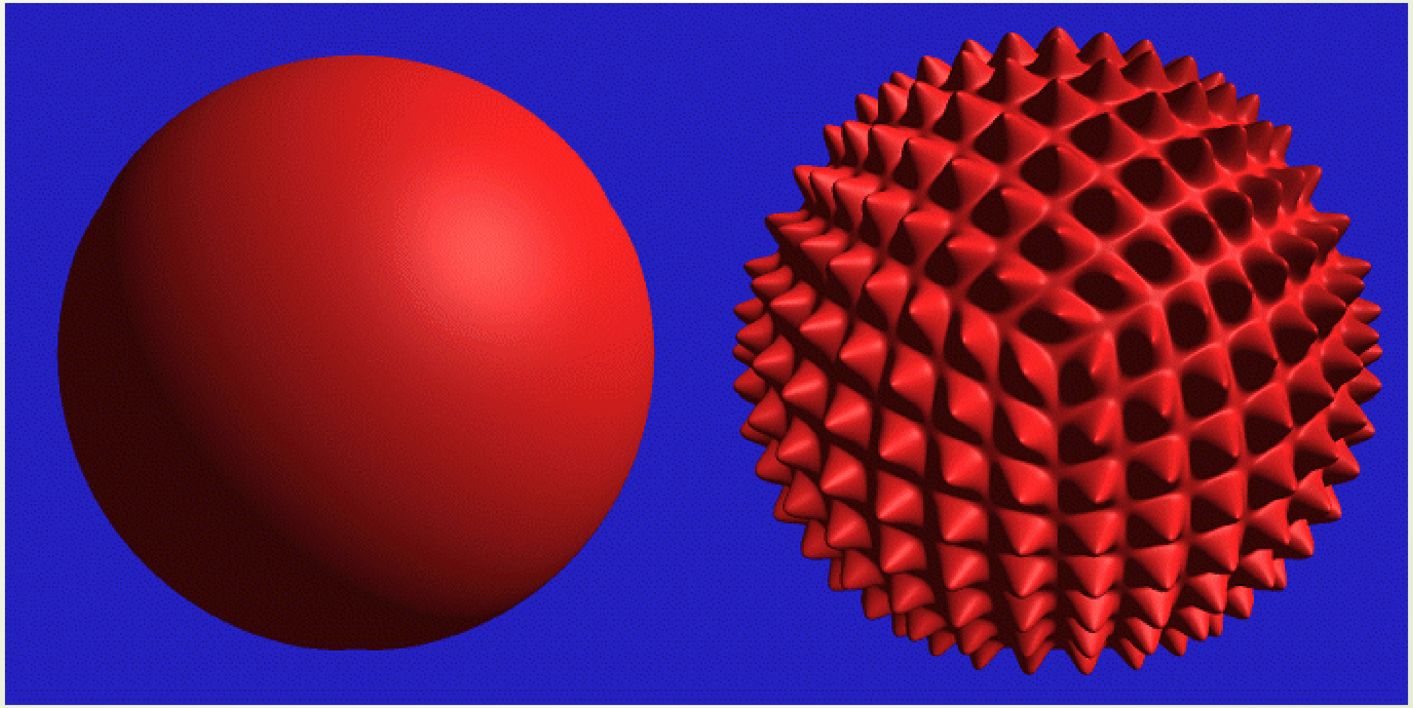




Not so much if the silhouette is revealed

Displacement Mapping

- Use the texture map to actually move the surface point
- The geometry must be displaced before visibility is determined



Displacement Mapping

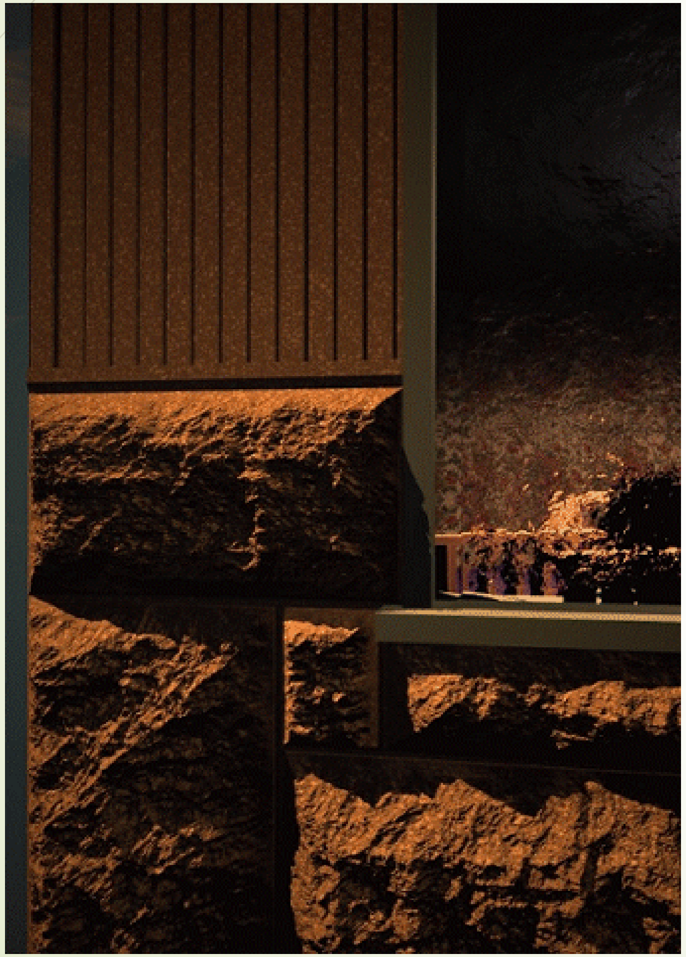


Image from:

Geometry Caching for
Ray-Tracing Displacement Maps

by Matt Pharr and Pat Hanrahan.

note the detailed shadows
cast by the stones

Displacement Mapping

By Ken Musgrave

Summary

- **Bump** mapping (using normal map, or height field)
  - Pro: Provide the illusion of local wrinkles
  - Con: No self-occlusion
- **Parallax** mapping
  - Pro: Provide self-occlusion
  - Con: The elevation cannot vary too much
- **Relief** mapping
  - Pro: Works with varying heights, can even provides shadow
  - Con: Bad visual effect on the silhouette
- **Displacement** mapping
  - Pro: bumps on silhouette
  - Con: Consume much more resources (CPU, GPU, memory)