CPSC 314
TEXTURE MAPPING

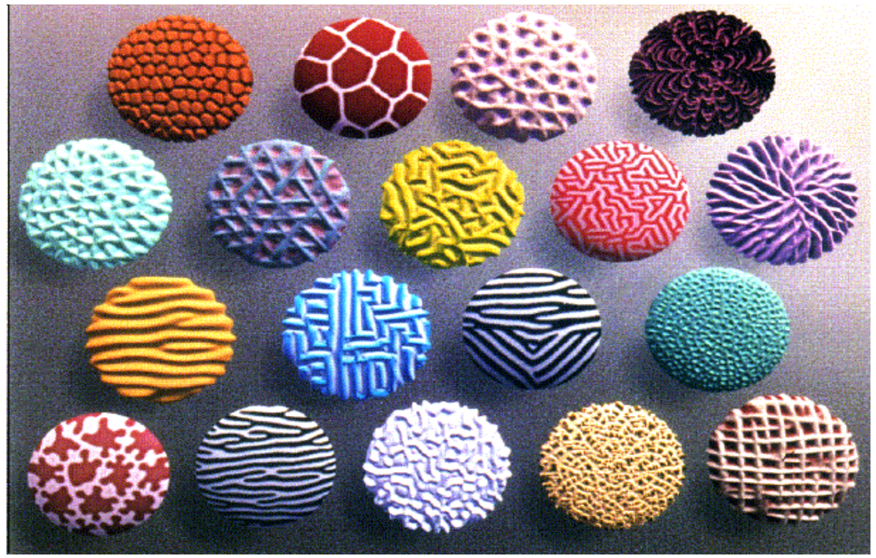
UGRAD.CS.UBC.CA/~cs314

Glen Berseth (Based of Mikhail Bessmeltsev and Dinesh Pai)

WHY IS TEXTURE IMPORTANT?

TEXTURE MAPPING

- real life objects have nonuniform colors, normals
- to generate realistic objects, reproduce coloring &normal variations = **texture**
- can often replace complex geometric details



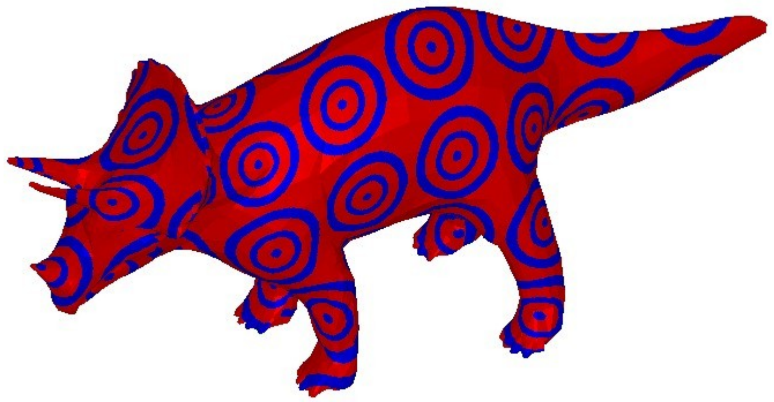
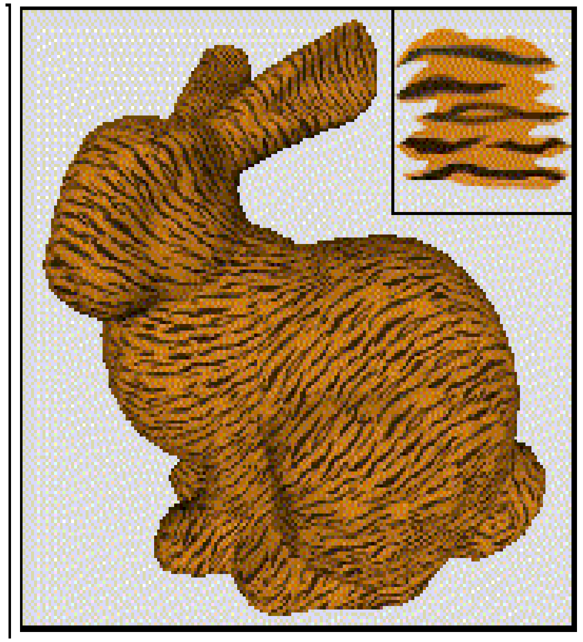
TEXTURE MAPPING

- hide geometric simplicity
  - images convey illusion of geometry
  - map a brick wall texture on a flat polygon
  - create bumpy effect on surface

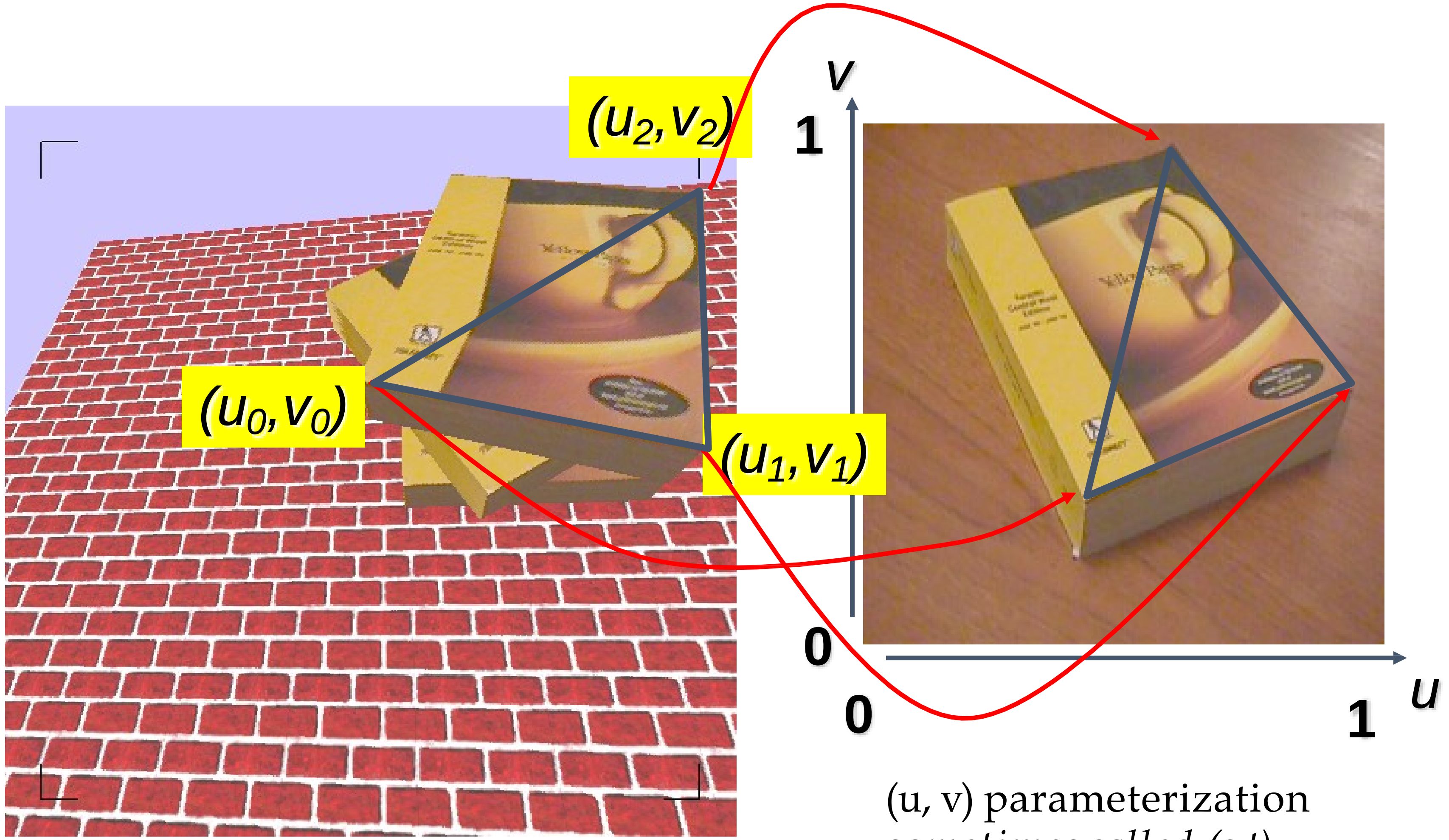
- usually:
  associate 2D information with a surface in 3D
  - point on surface ↔ point in texture
  - “paint” image onto polygon

COLOR TEXTURE MAPPING

- define color (RGB) for each point on object surface
- other:
  - volumetric texture
  - procedural texture

TEXTURE MAPPING

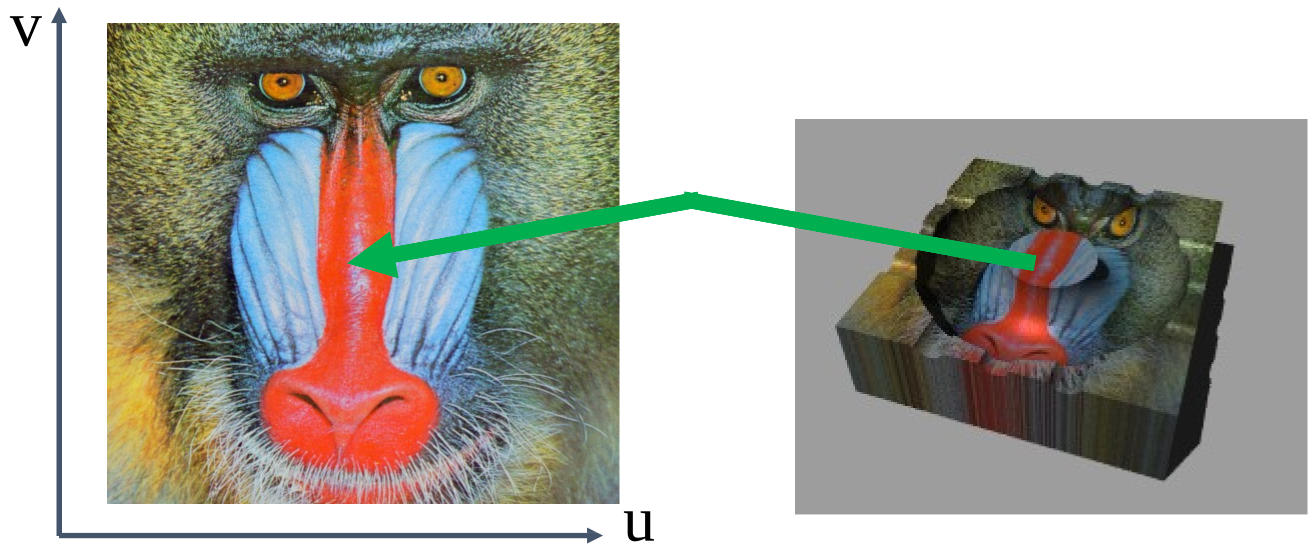


(u, v) parameterization
sometimes called (s,t)

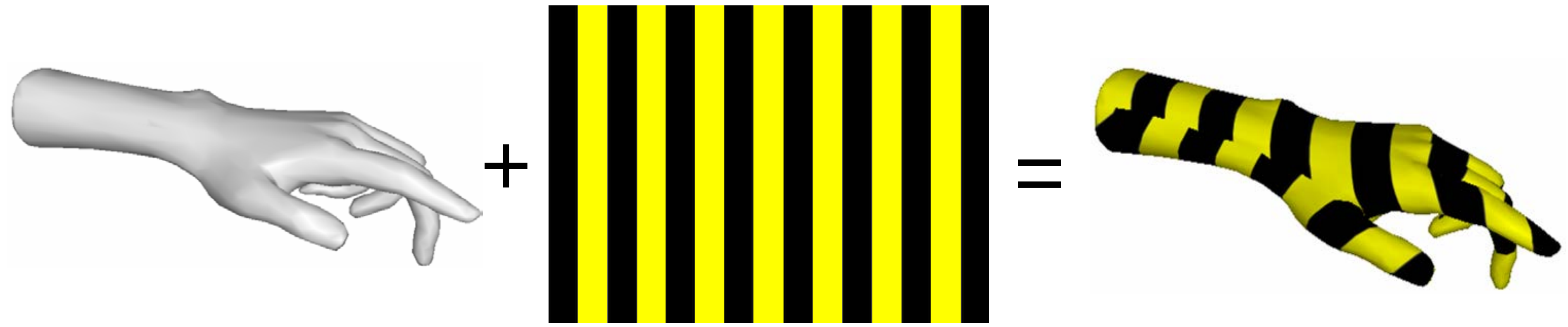
TEXTURE MAPPING – Questions?

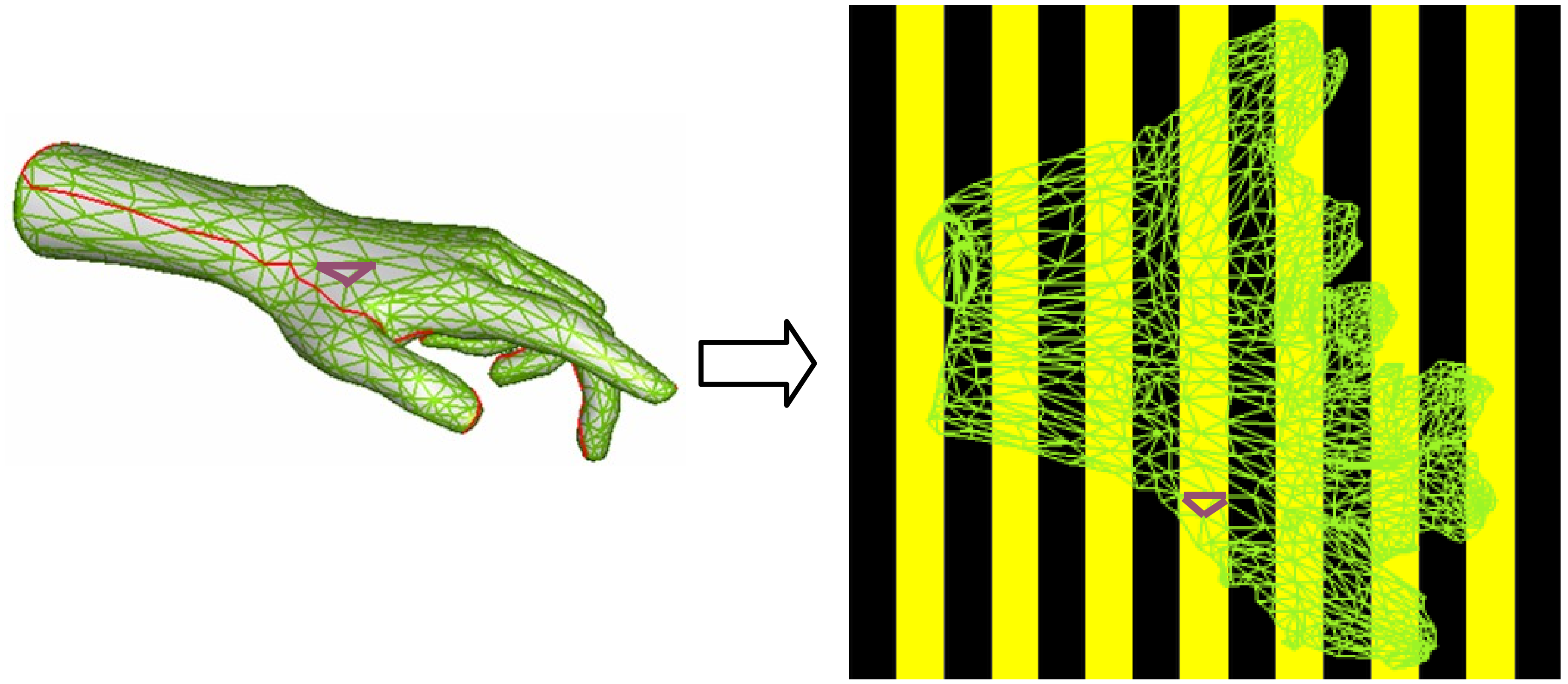
SURFACE TEXTURE

- Define texture pattern over (u,v) domain (Image)
  - Image – 2D array of "texels"
- Assign (u,v) coordinates to each point on object surface
  - How: depends on surface type
- For polygons (triangle)
  - Inside – use barycentric coordinates
  - For vertices need mapping function (artist/programmer)

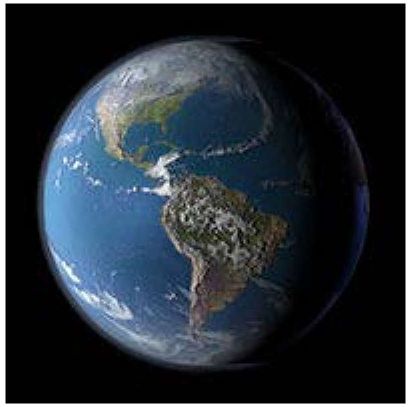


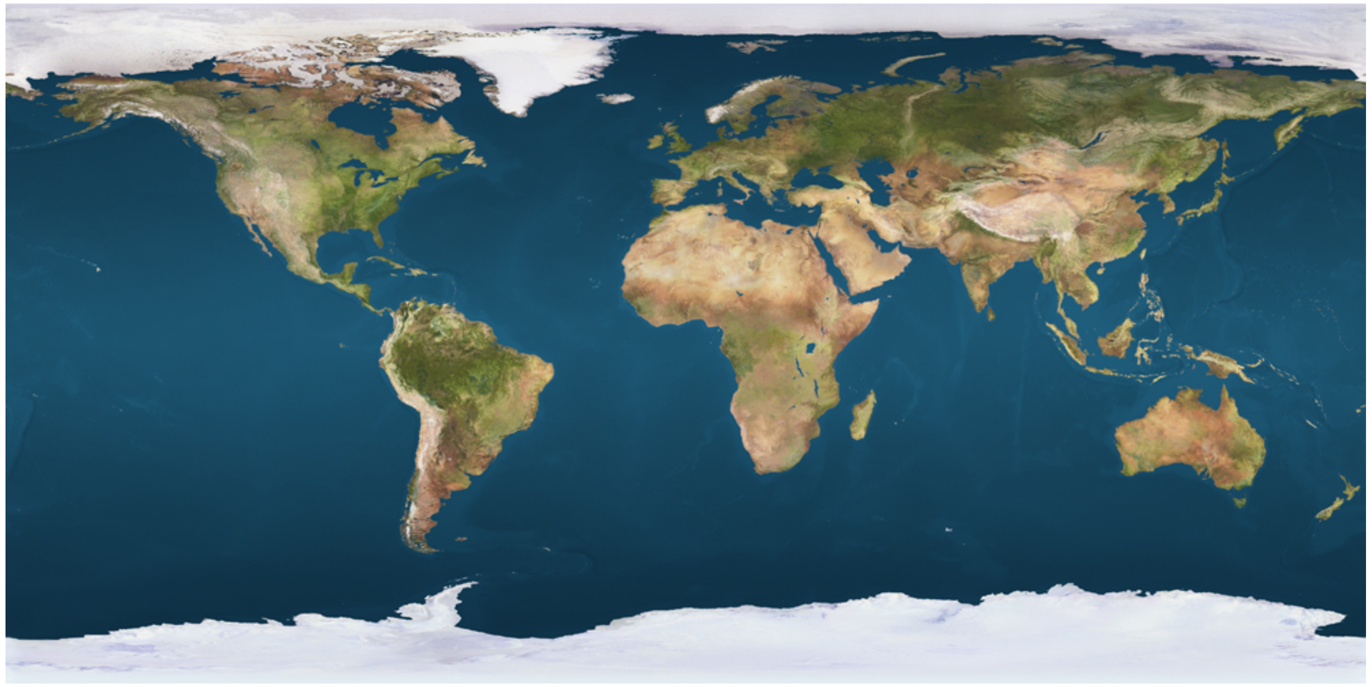
TEXTURE MAPPING EXAMPLE





TEXTURE MAPPING EXAMPLE





TEXTURE MAPPING EXAMPLE

Pause …. --> Math Example

THREE.JS

- pass texture as a uniform:

```
var uniforms = {
    texture1: { type: "t", value:  THREE.ImageUtils.loadTexture( "texture.jpg" ) }};
var material = new THREE.ShaderMaterial( { uniforms,  …});
```

- uv will be passed on to the vertex shader *(no need to write this)*:

```
attribute vec2  uv;
```

- use it, e.g., in Fragment Shader:

```
uniform sampler2D  texture1;
varying vec2  texCoord;
vec4 texColor =  texture2D(texture1,  texCoord);
```

HOW TO USE COLOR TEXTURES

- Replace
  - Set fragment color to texture color

```
gl_FragColor = texColor;
```

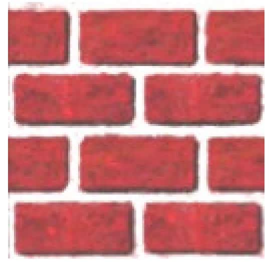
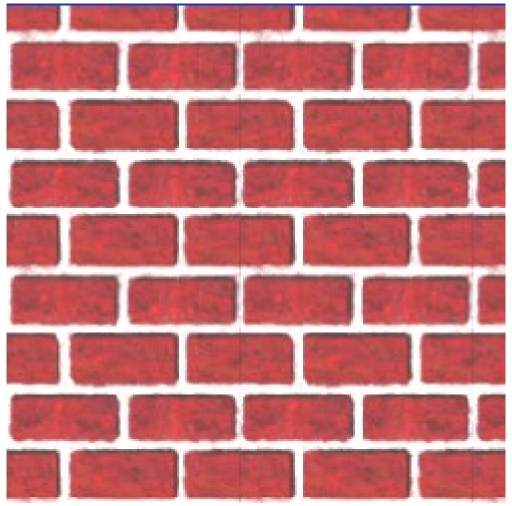
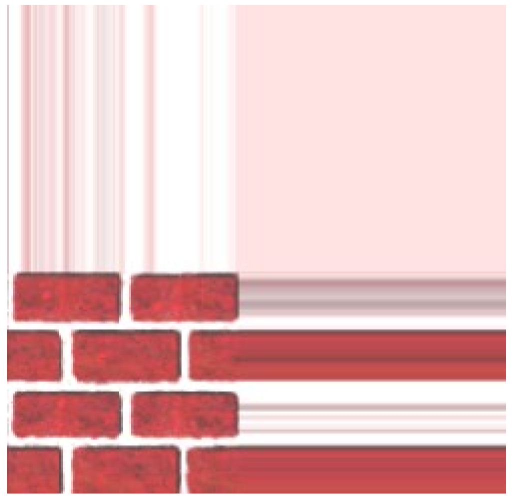
- Modulate
  - Use texture color as reflection color in illumination equation

```
kd = texColor; ka = texColor;
gl_FragColor = ka*ia + kd*id*dotProduct + …;
```

TEXTURE LOOKUP: TILING AND CLAMPING

- What if s or t is outside [0…1] ?
- Multiple choices
  - Use fractional part of texture coordinates
    - Cyclic repetition (*repeat*)

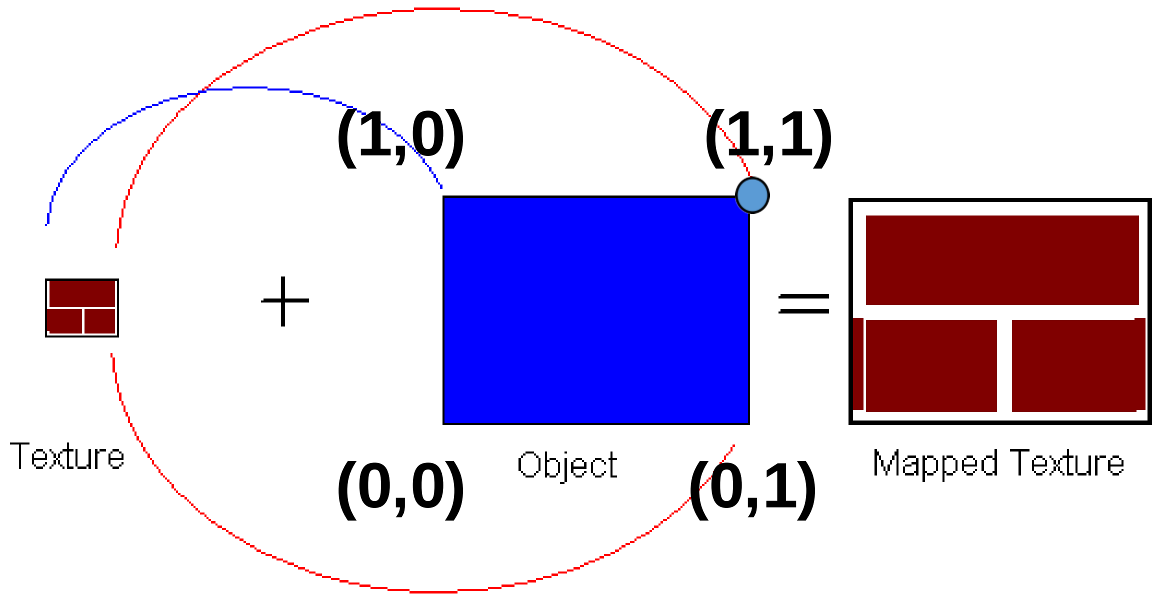
  - Clamp every component to range [0…1]
    - Re-use color values from texture image border

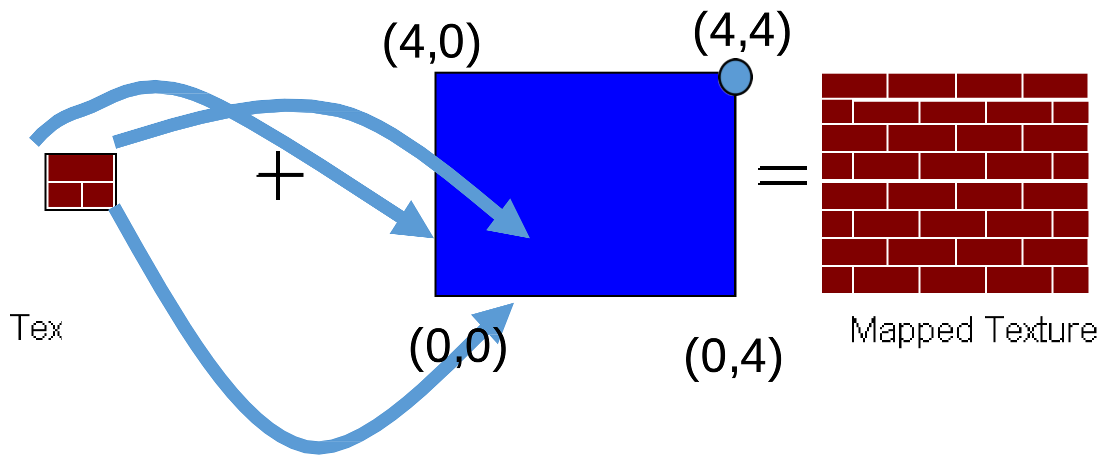




IN THREE.JS

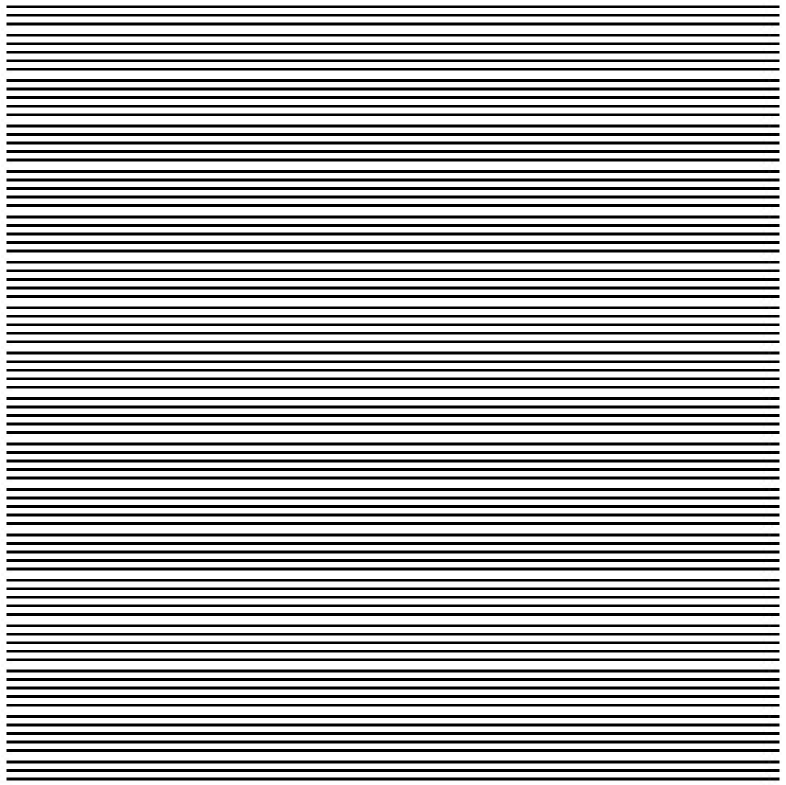
```
var texture = THREE.ImageUtils.loadTexture(
"textures/water.jpg" );
texture.wrapS = THREE.RepeatWrapping;
texture.wrapT = THREE.ClampToEdgeWrapping;
texture.repeat.set( 4, 4 );
```

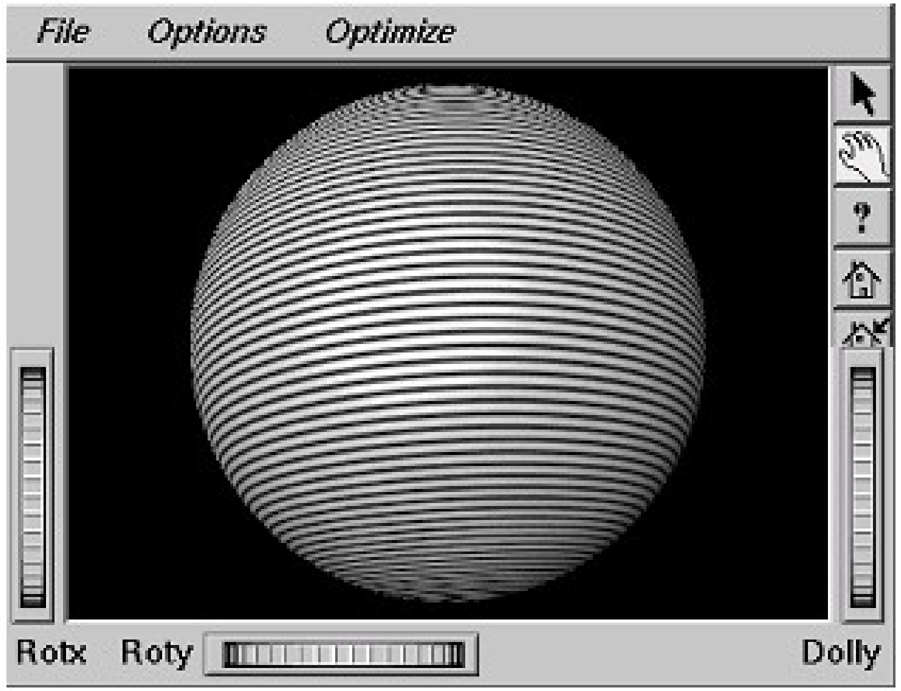
TILED TEXTURE MAP





RECONSTRUCTION

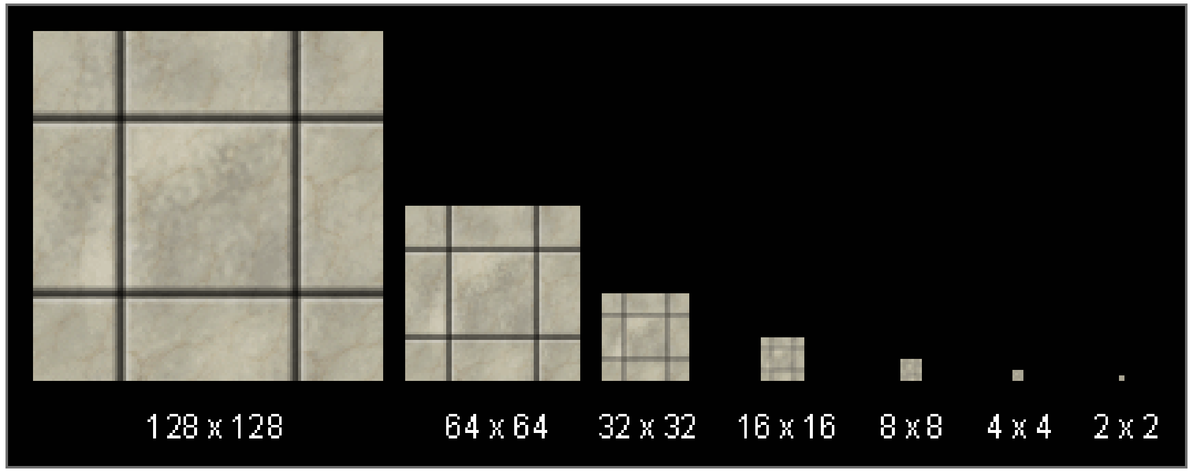




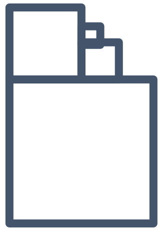
(image courtesy of Kiriakos Kutulakos, U Rochester)

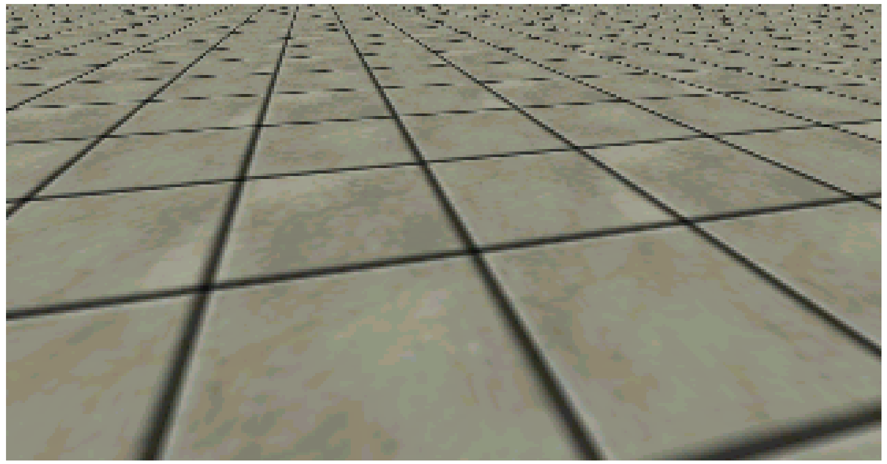
MIPMAPPING

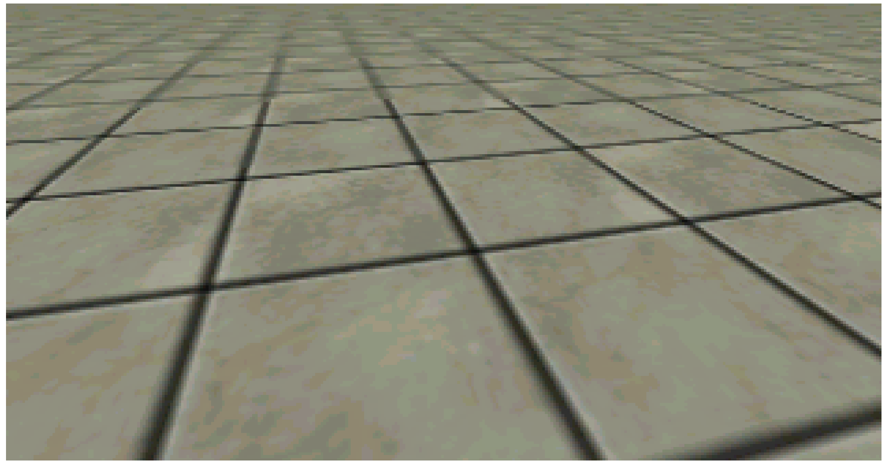
use “image pyramid” to precompute averaged versions of the texture



store whole pyramid in single block of memory



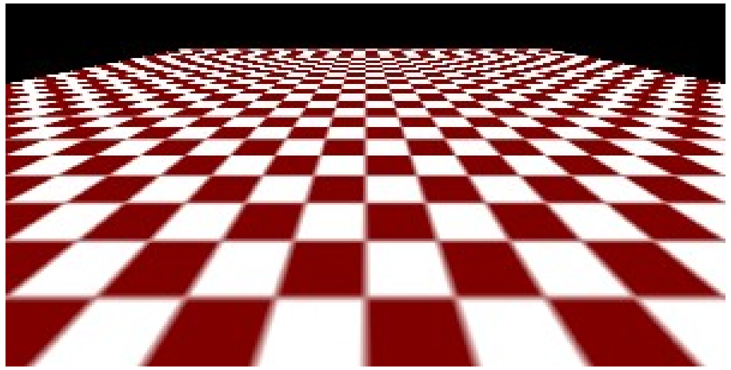

Without MIP-mapping


With MIP-mapping

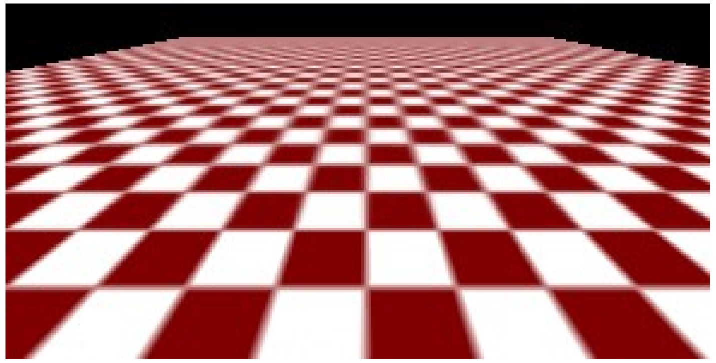
MIPMAPS

- **multum in parvo** -- many things in a small place
  - prespecify a series of prefiltered texture maps of decreasing resolutions
  - requires more texture storage
  - avoid shimmering and flashing as objects move
- `texture.generateMipmaps = true`
  - automatically constructs a family of textures from original texture size down to 1x1
- `texture.mipmaps[…]`

without

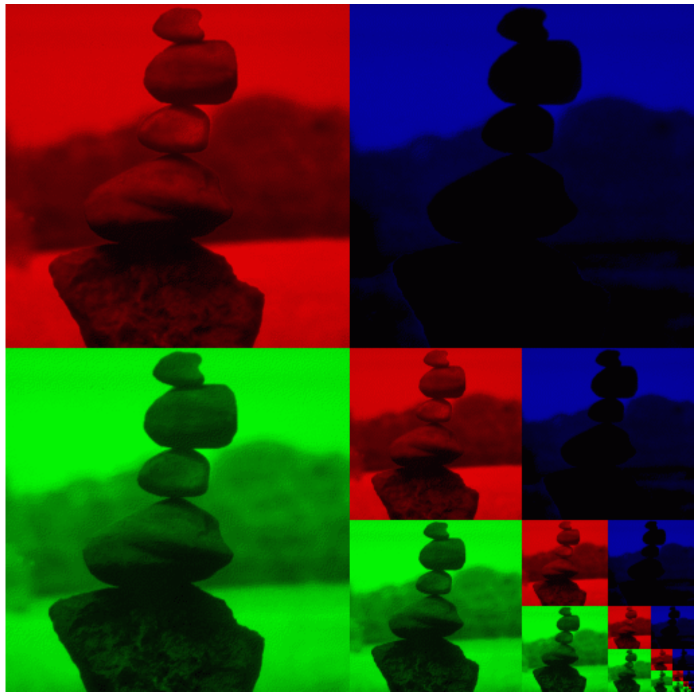


with



MIPMAP STORAGE

- only 1/3 more space required

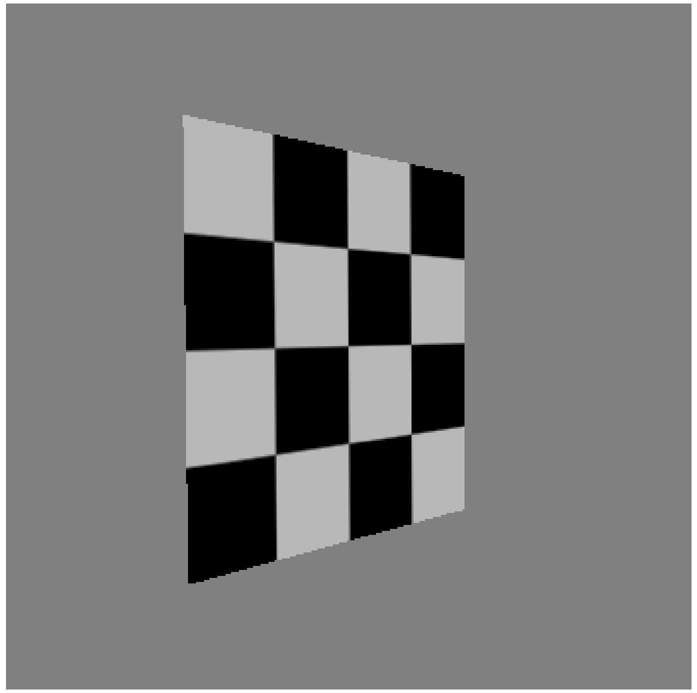
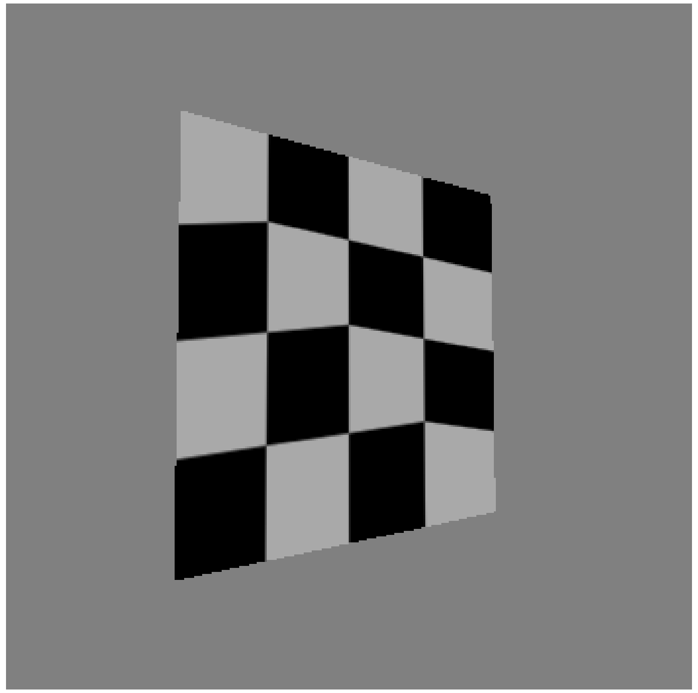


HOW TO INTERPOLATE S,T?

TEXTURE MAPPING

Texture coordinate interpolation

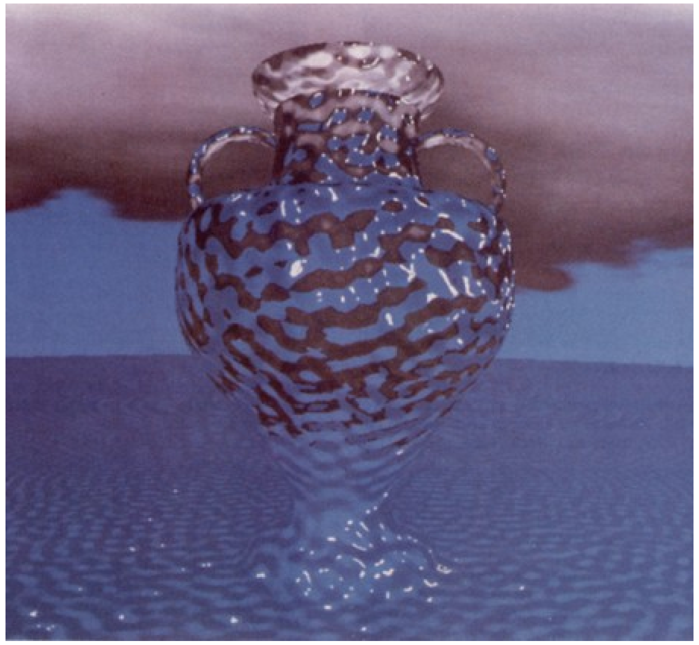
- Perspective foreshortening problem
- Also problematic for color interpolation, etc.

OTHER USES FOR TEXTURES

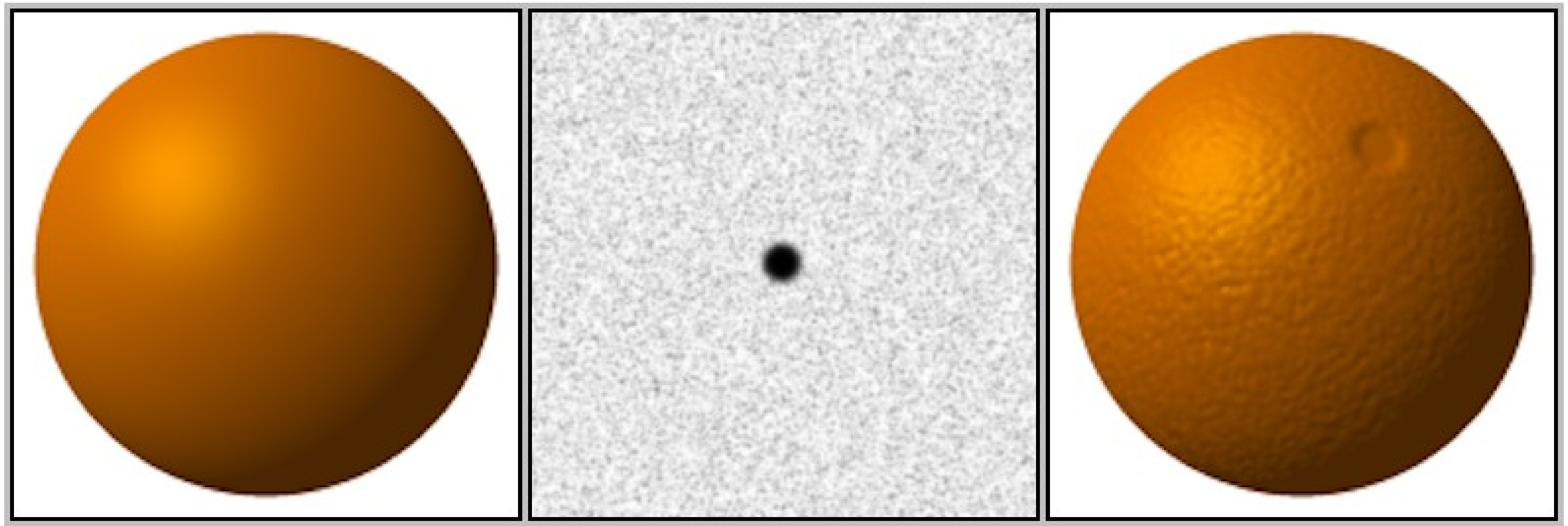
OTHER USES FOR TEXTURES

- usually provides colour, but …
- can also use to control other material/object properties
  - surface normal (bump mapping)
  - reflected color (environment mapping)

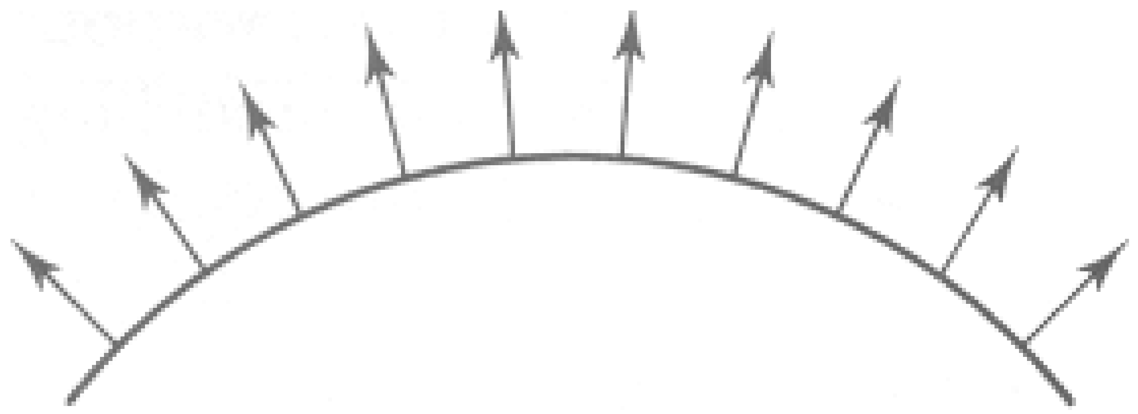


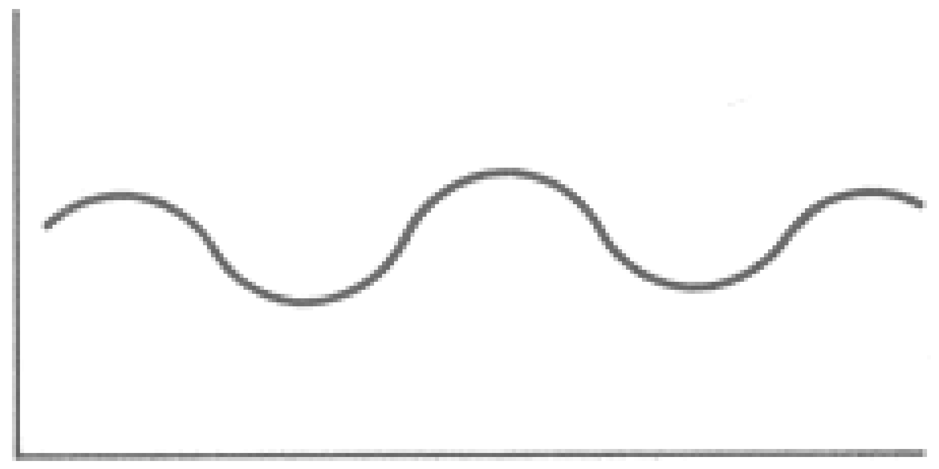
BUMP MAPPING: NORMALS AS TEXTURE

- object surface often not smooth – to recreate correctly need complex geometry model
- can control shape "effect" by locally perturbing surface normal
  - random perturbation
  - directional change over region

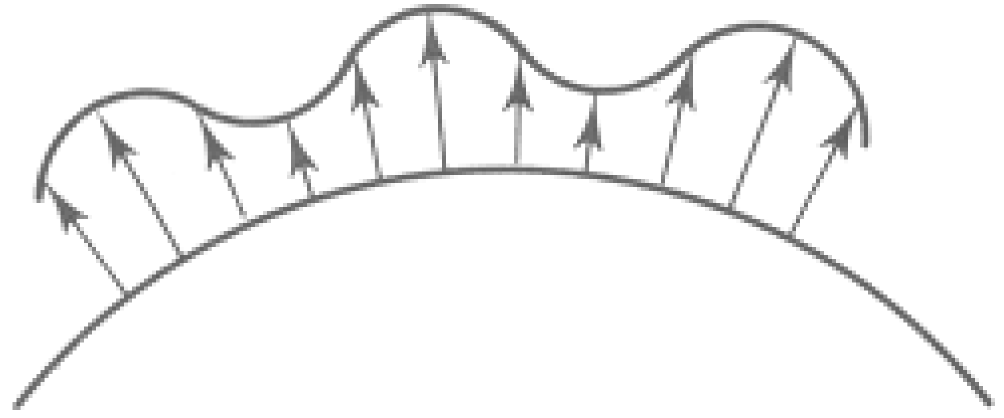


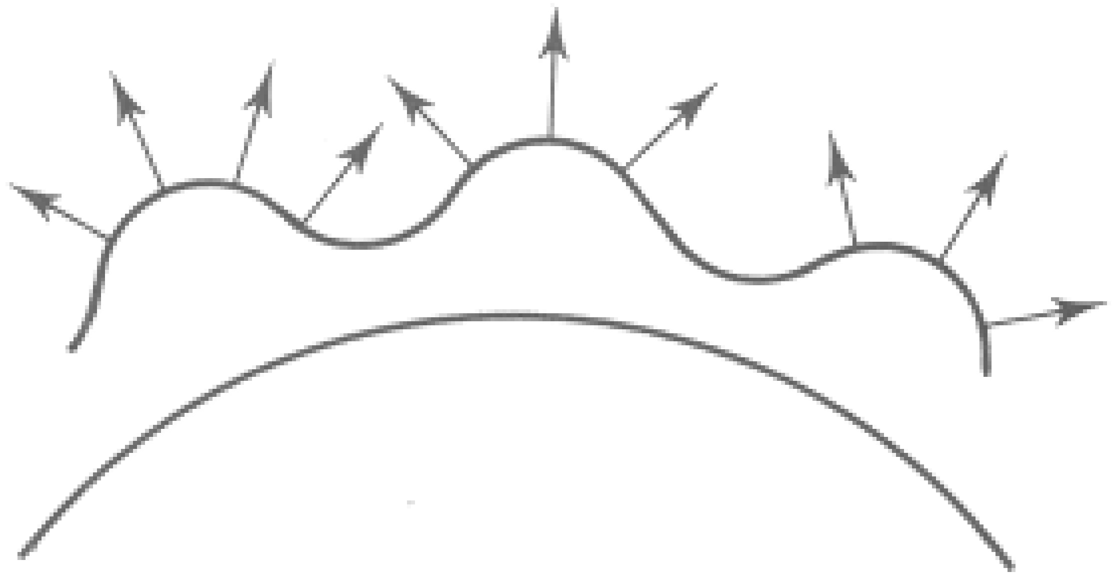
BUMP MAPPING





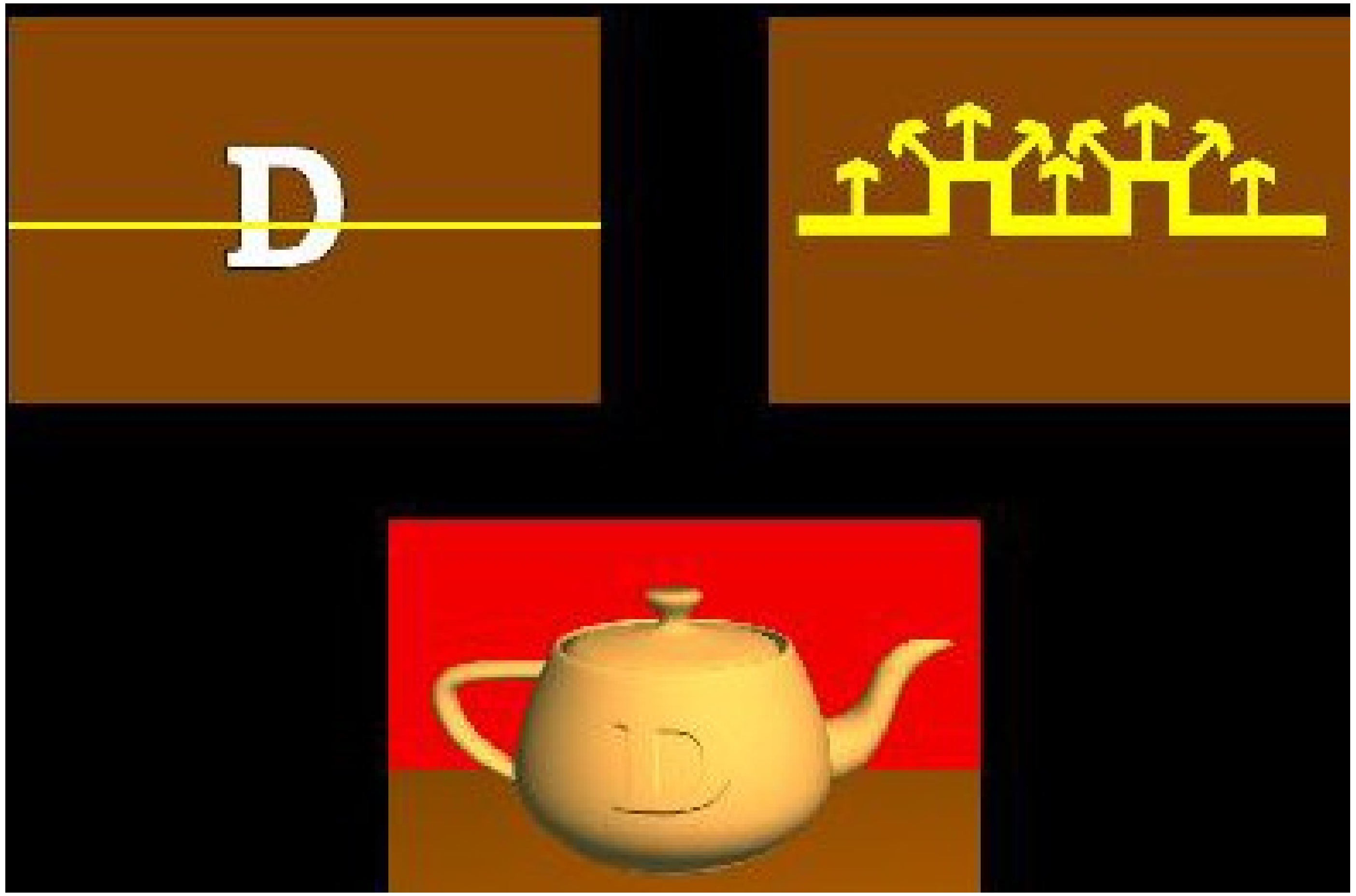
BUMP MAPPING



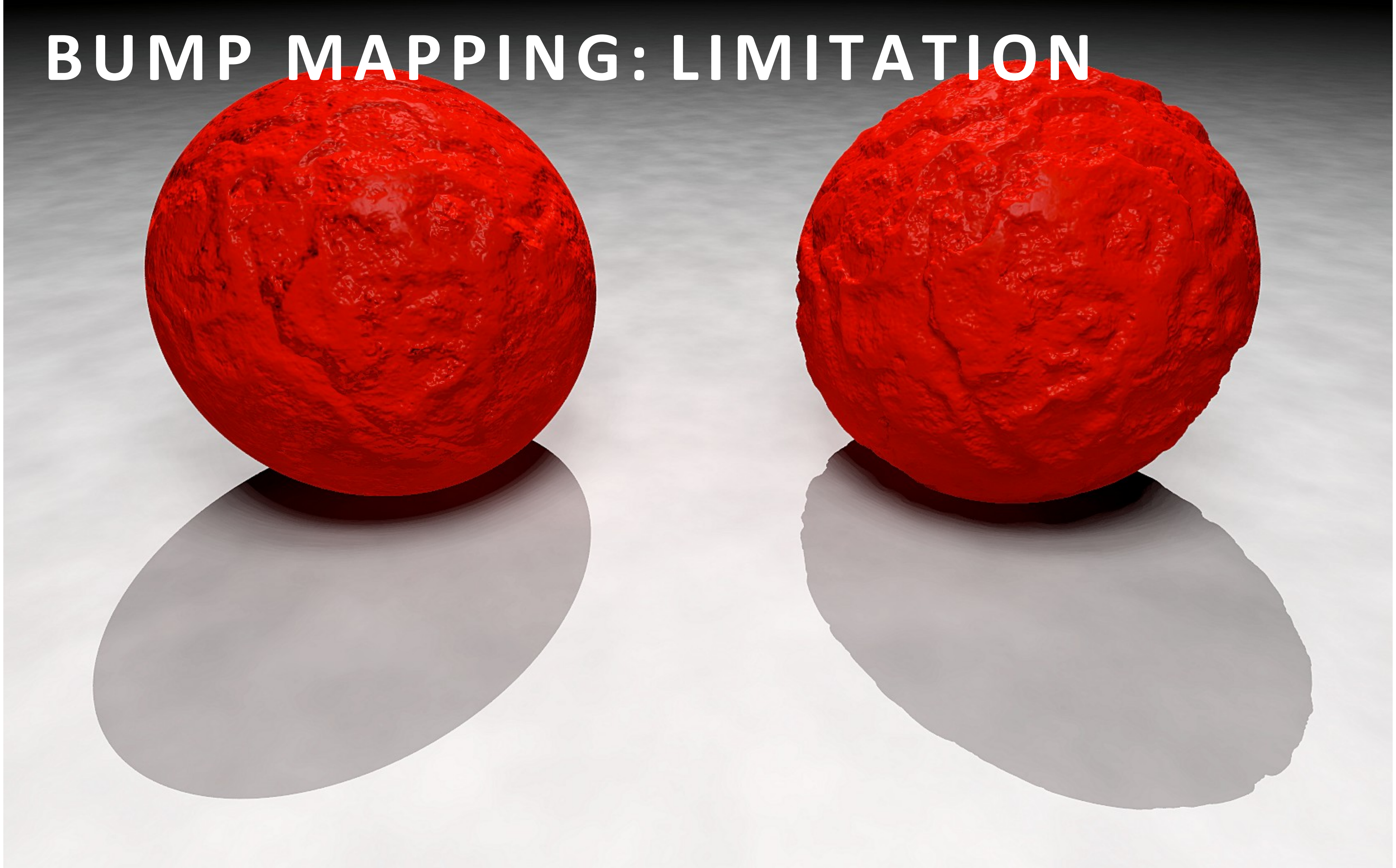


EMBOSSING

- at transitions
  - rotate point's surface normal by ϑ or - ϑ

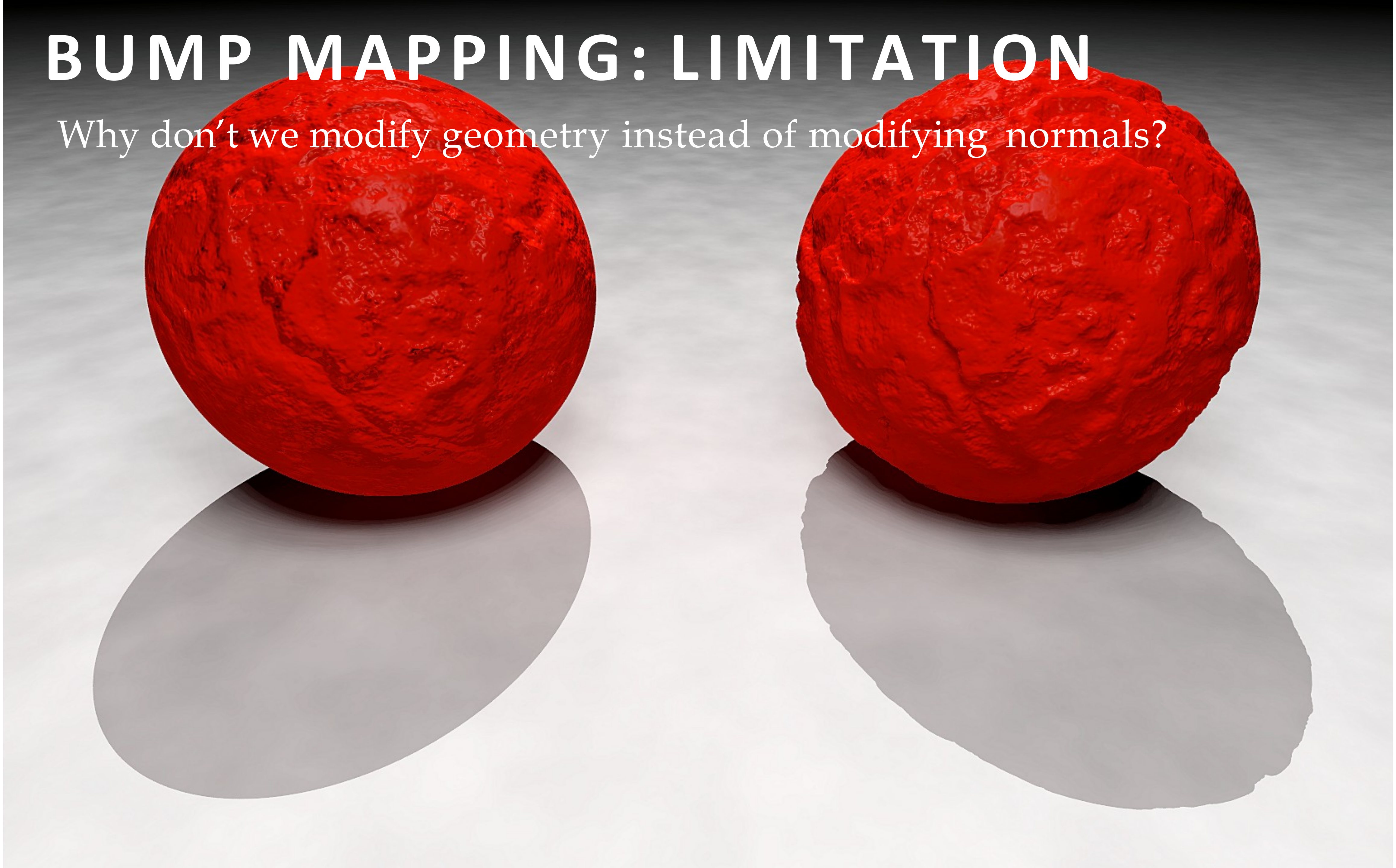


BUMP MAPPING: LIMITATION



BUMP MAPPING: LIMITATION

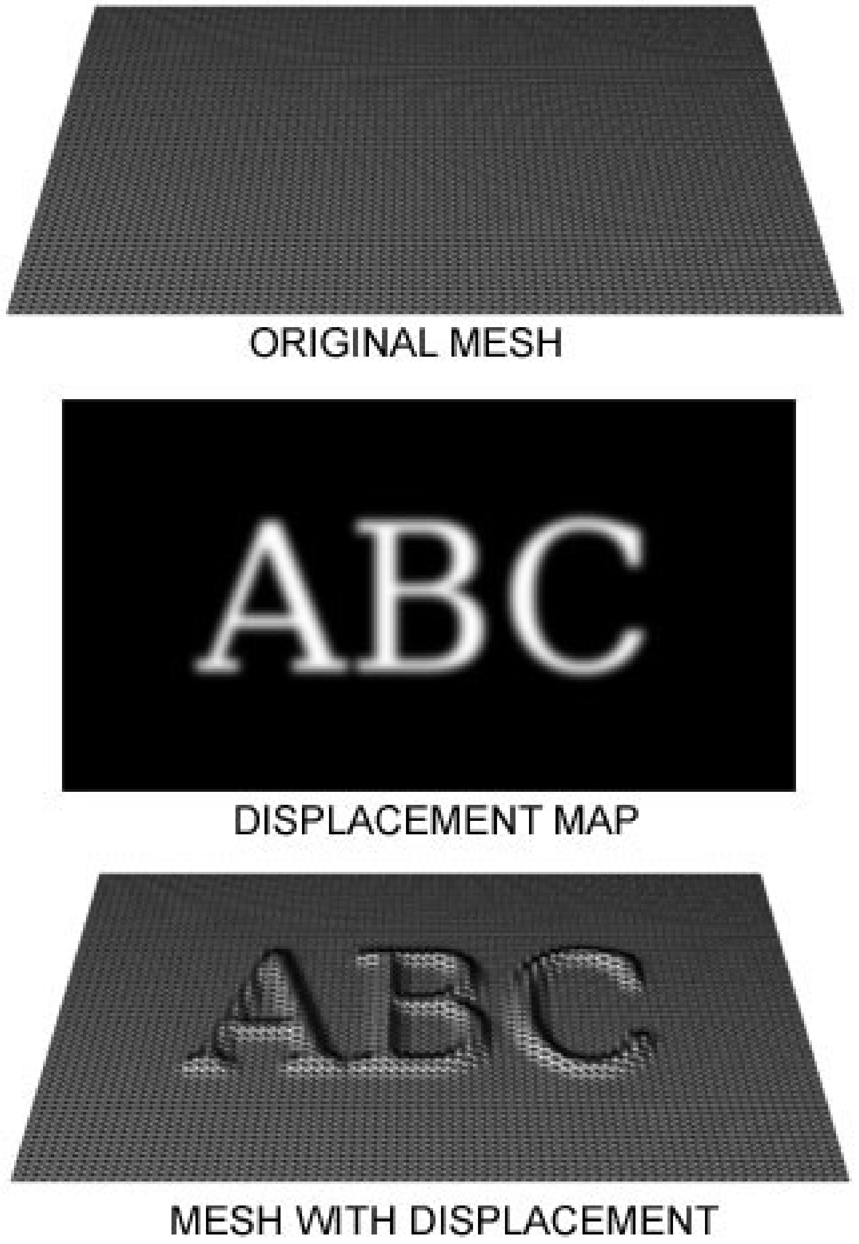
Why don’t we modify geometry instead of modifying normals?



DISPLACEMENT MAPPING

- bump mapping gets silhouettes wrong
    - shadows wrong too

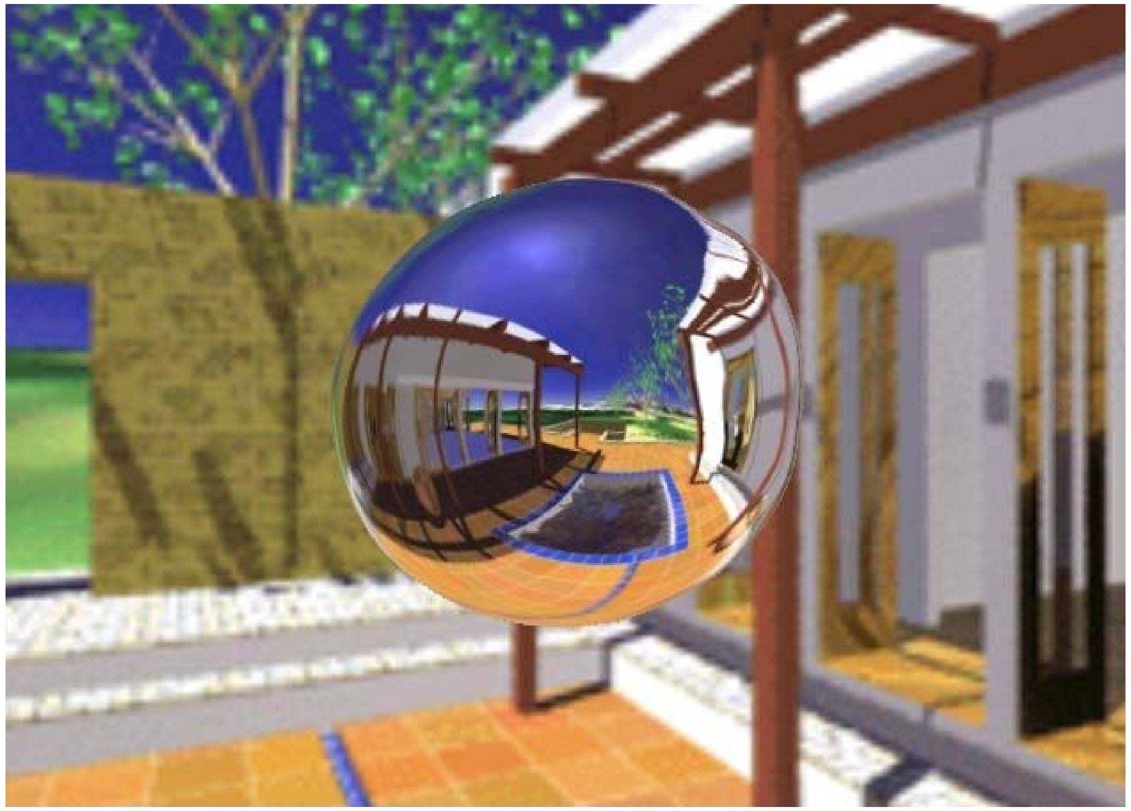
- change surface geometry instead
    - only recently available with realtime graphics
    - need to subdivide surface



https://en.wikipedia.org/wiki/Displacement_mapping#/media/File:Displacement.jpg

ENVIRONMENT MAPPING

- cheap way to achieve reflective effect
  - generate image of surrounding
  - map to object as texture

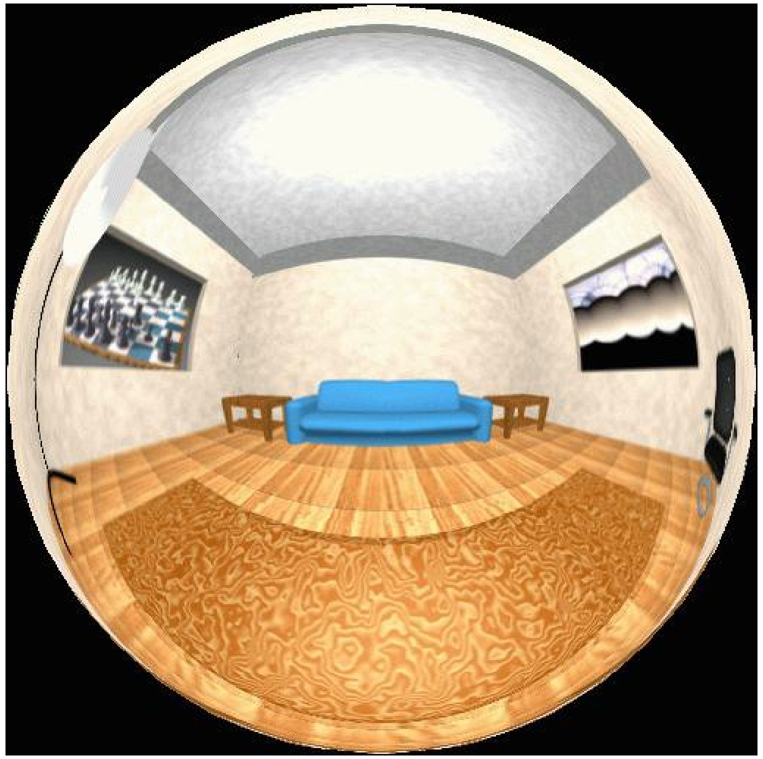


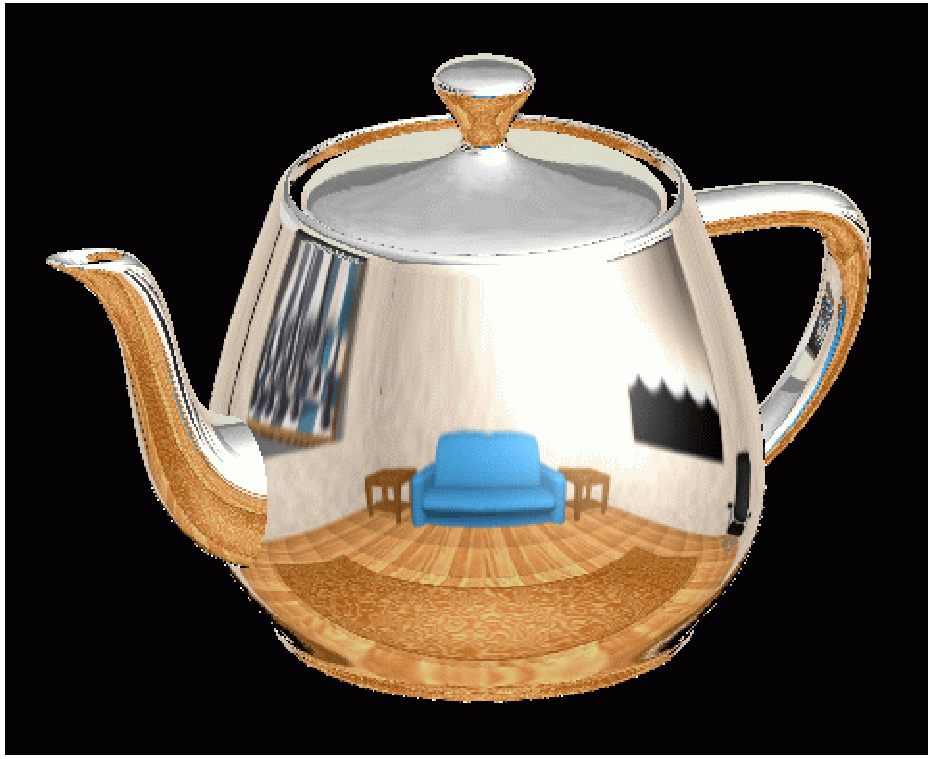
ENVIRONMENT MAPPING

- used to model object that reflects surrounding textures to the eye
  - movie example: cyborg in Terminator 2
- different approaches
  - sphere, cube most popular
  - others possible too

SPHERE MAPPING

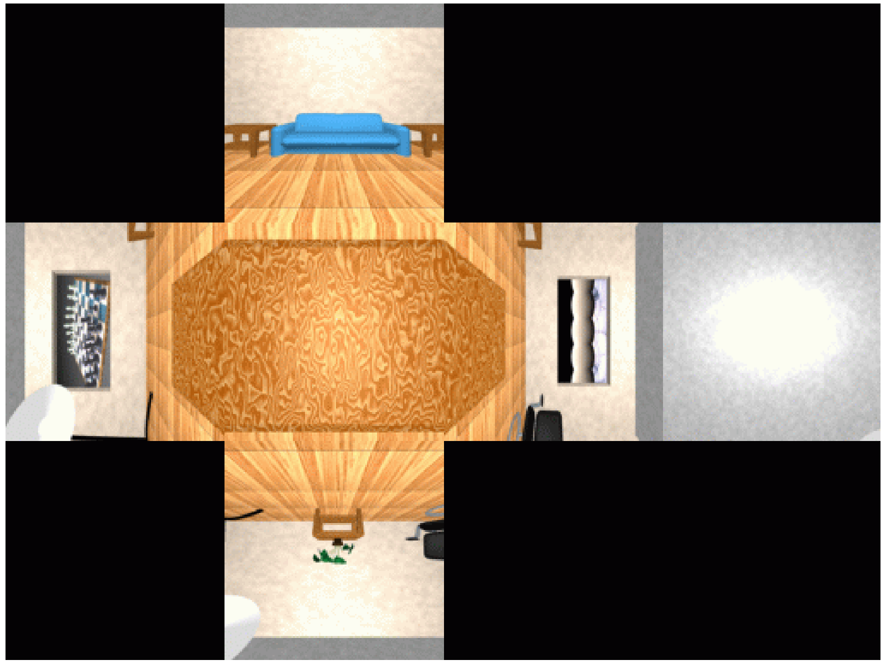
- texture is distorted fish-eye view
  - point camera at mirrored sphere
  - spherical texture mapping creates texture coordinates that correctly index into this texture map

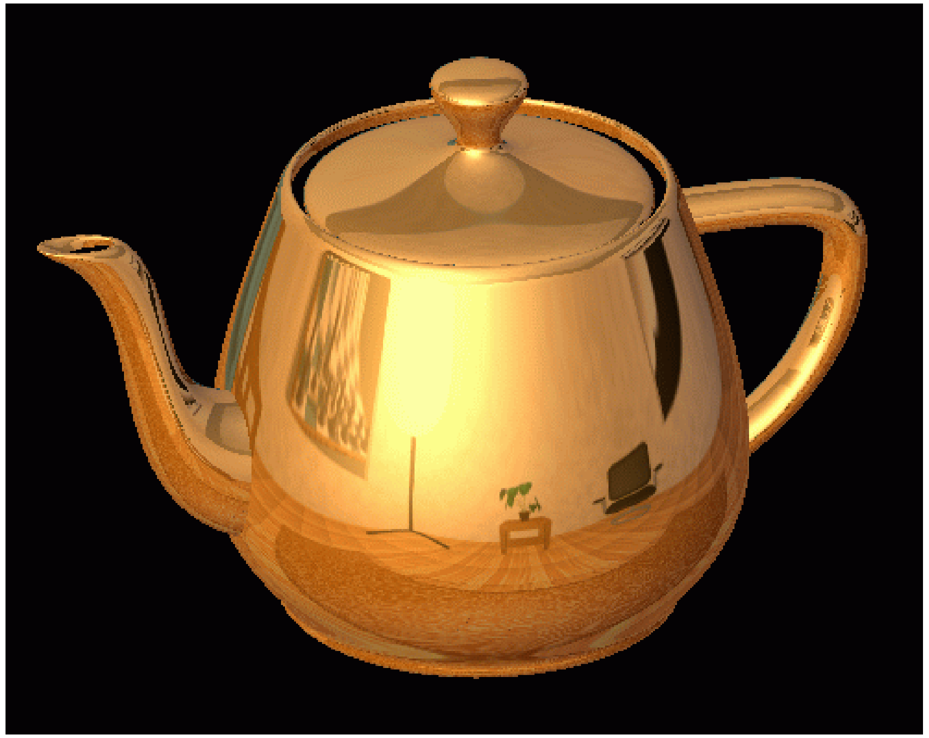




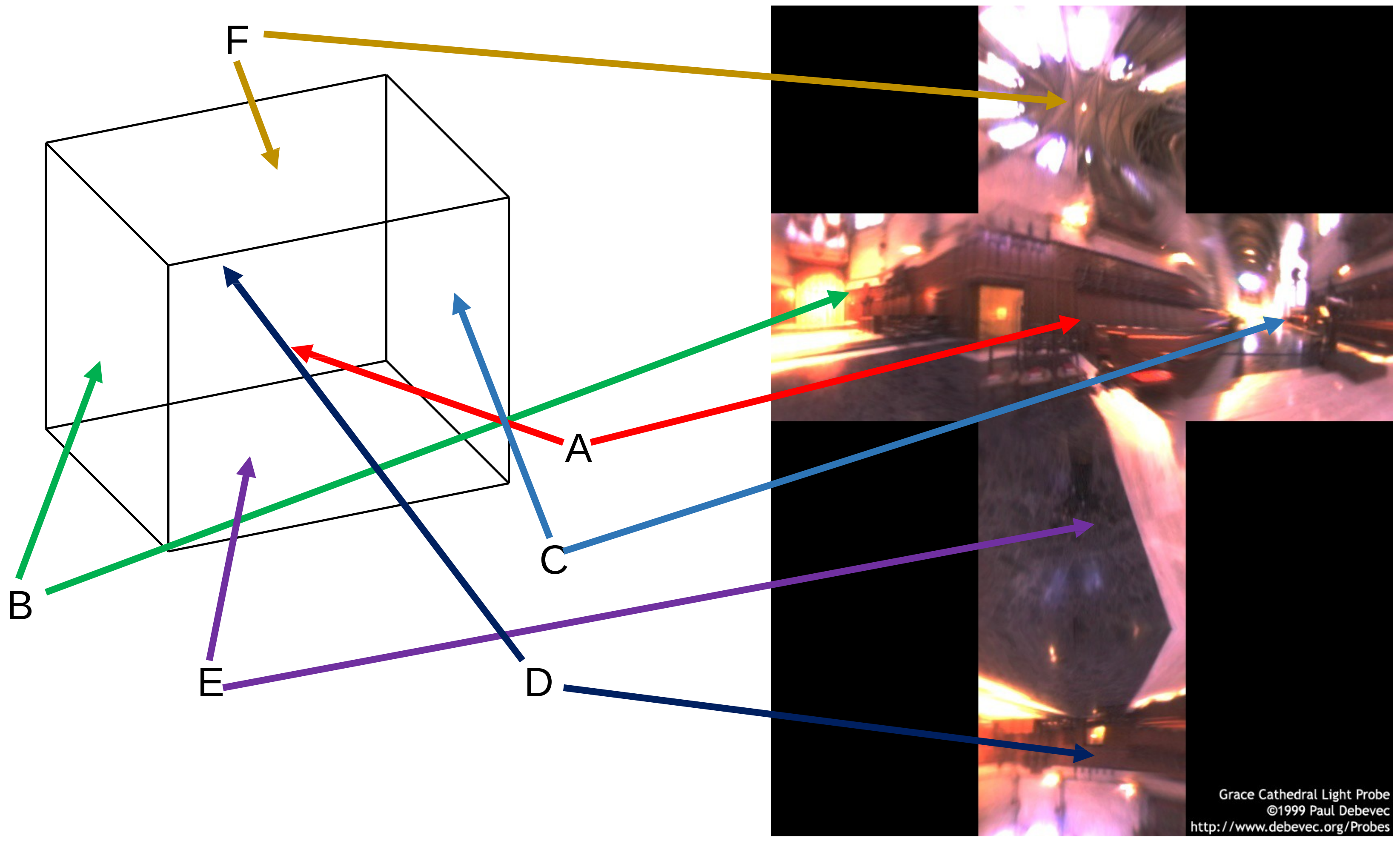
CUBE MAPPING

- 6 planar textures, sides of cube
  - point camera in 6 different directions, facing out from origin





CUBE MAPPING



CUBE MAPPING

- direction of reflection vector *r* selects the face of the cube to be indexed
    - co-ordinate with largest magnitude
        - e.g., the vector (-0.2, 0.5, -0.84) selects the –Z face

    - remaining two coordinates select the pixel from the face.

- difficulty in interpolating across faces

CUBE MAPPING

how to calculate?

- direction of reflection vector *r* selects the face of the cube to be indexed
  - co-ordinate with largest magnitude
    - e.g., the vector (-0.2, 0.5, -0.84) selects the –Z face
  - remaining two coordinates select the pixel from the face.
- difficulty in interpolating across faces

ENVIRONMENT MAPS (EM)

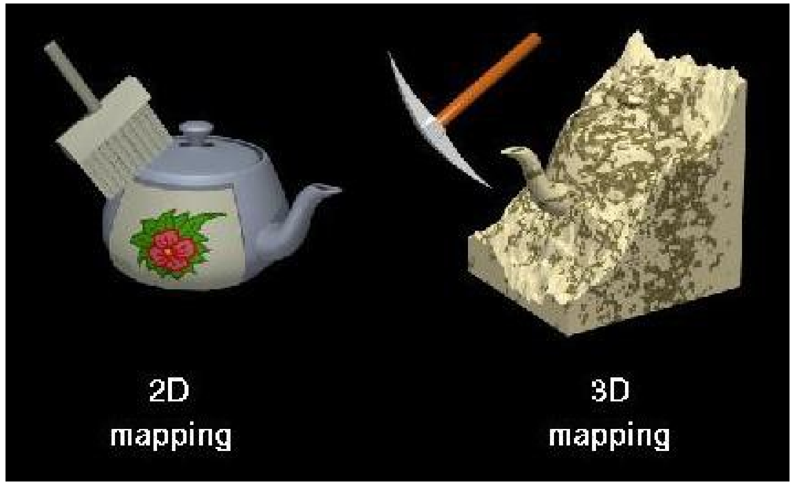
- in theory, every object should have a separate EM
- in theory, every time something moves, you should re-compute EM
- “you’ll be surprised at what you can get away with”

VOLUMETRIC TEXTURE

- define texture pattern over 3D domain - 3D space containing the object
- texture function can be digitized or procedural
- for each point on object compute texture from point location in space
- e.g., ShaderToy

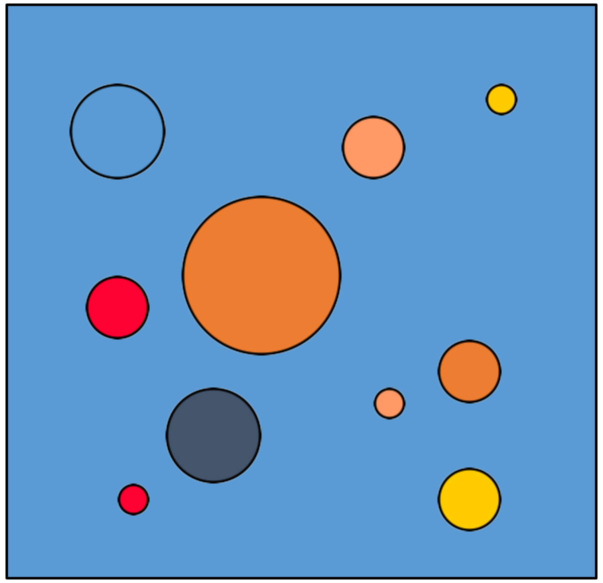
- computing is cheap,

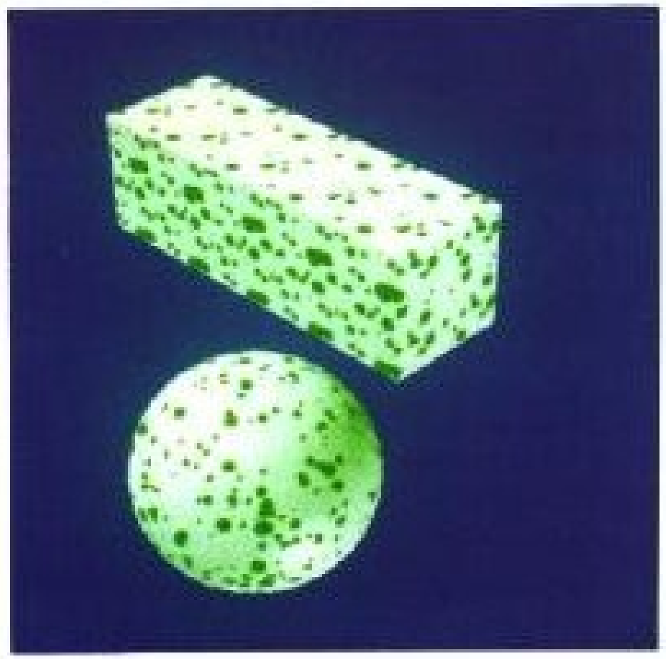
  memory access is expensive !



PROCEDURAL TEXTURE EFFECTS: BOMBING

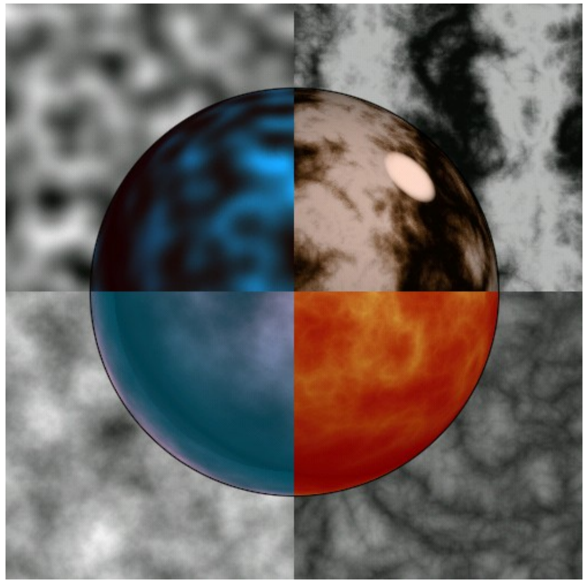
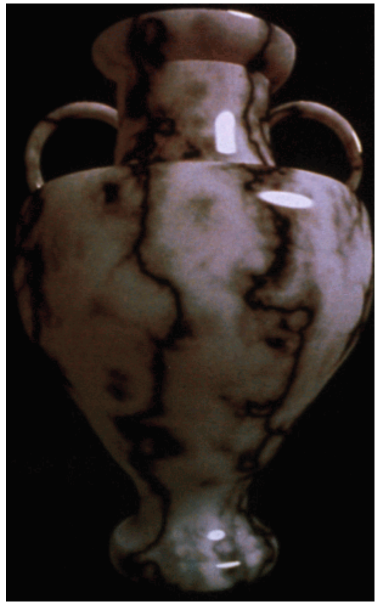
- randomly drop bombs of various shapes, sizes and orientation into texture space (store data in table)
    - for point P search table and determine if inside shape
        - if so, color by shape's color
        - otherwise, color by object's color





PERLIN NOISE: PROCEDURAL TEXTURES

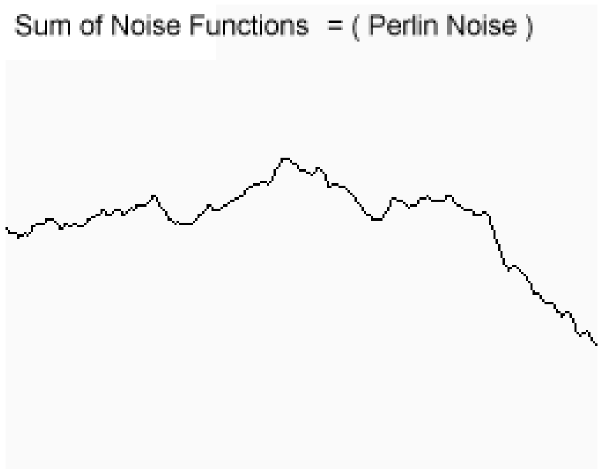
- several good explanations
  - http://www.noisemachine.com/talk1
  - http://freespace.virgin.net/hugo.elias/models/m_perlin.htm
  - http://www.robo-murito.net/code/perlin-noise-math-faq.html

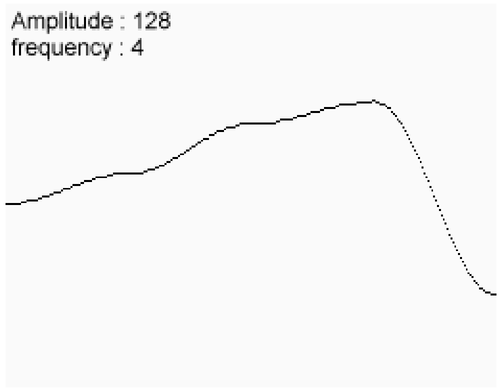



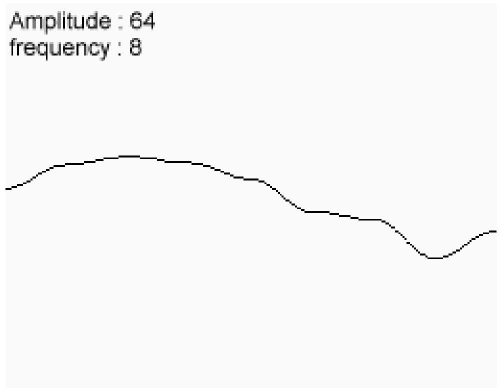
http://mrl.nyu.edu/~perlin/planet/

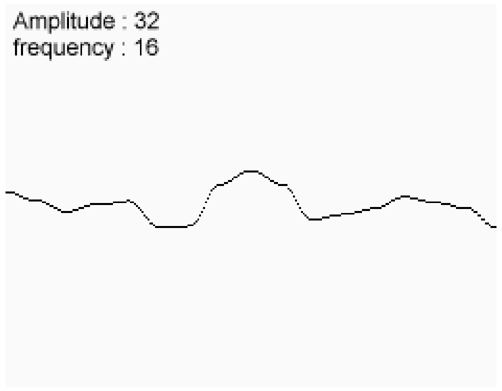
PERLIN NOISE: TURBULENCE

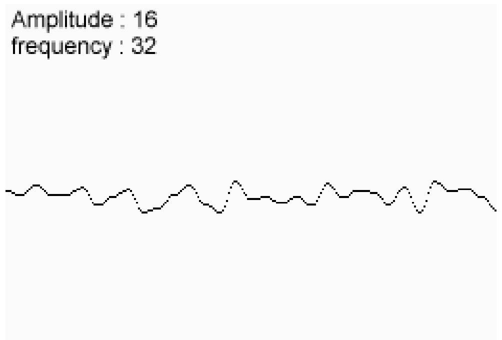
- multiple feature sizes
  - add scaled copies of noise

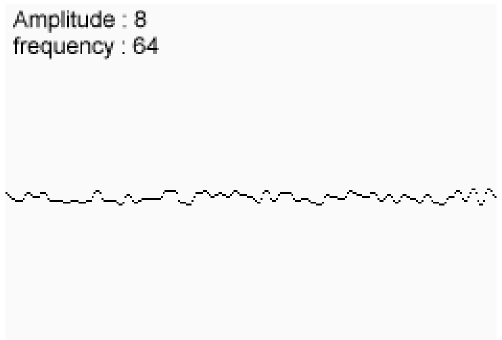


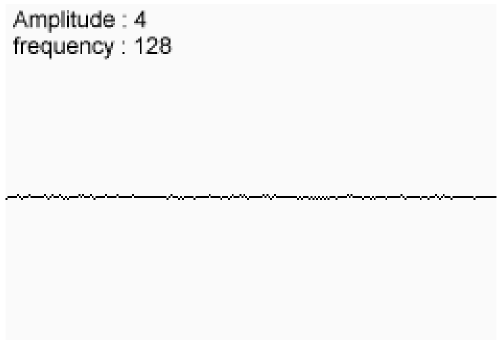












PERLIN NOISE: TURBULENCE

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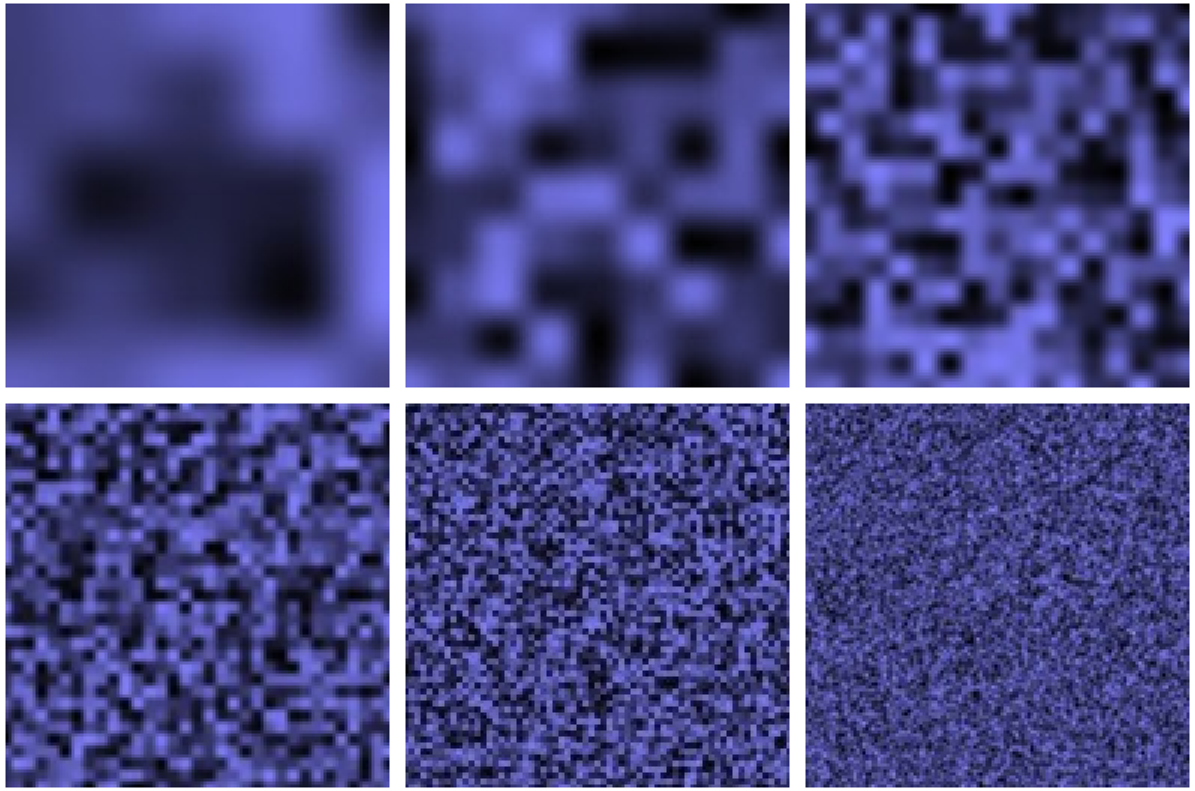
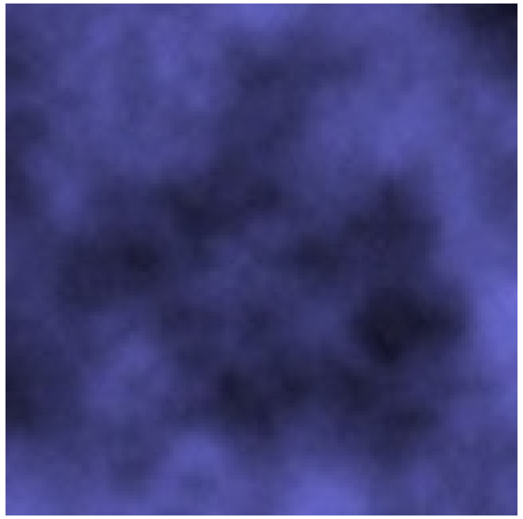
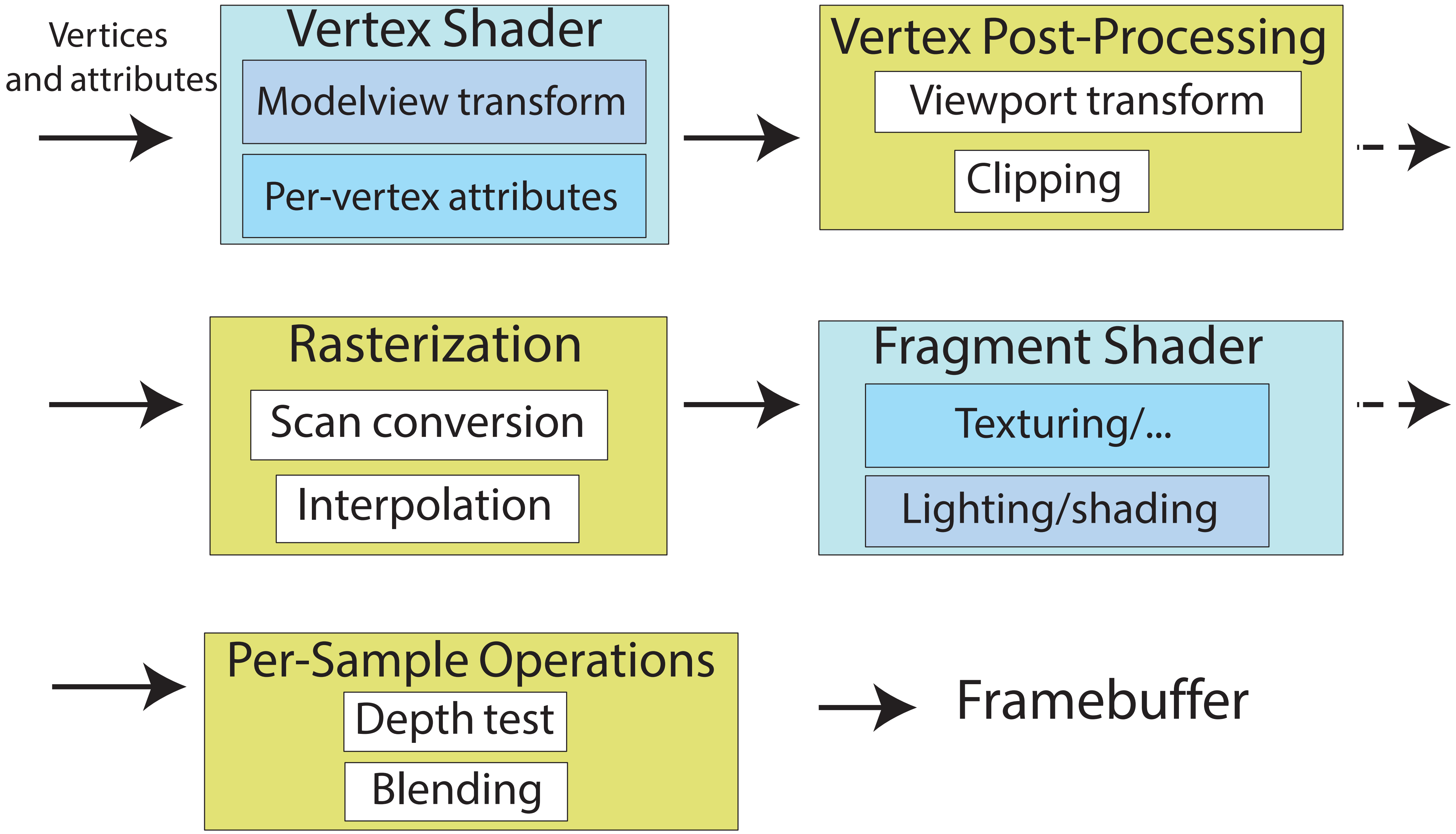




THE RENDERING PIPELINE



Vertices and attributes
Vertex Shader
Modelview transform
Per-vertex attributes
Vertex Post-Processing
Viewport transform
Clipping
Rasterization
Scan conversion
Interpolation
Fragment Shader
Texturing/...
Lighting/shading
Per-Sample Operations
Depth test
Blending
Framebuffer