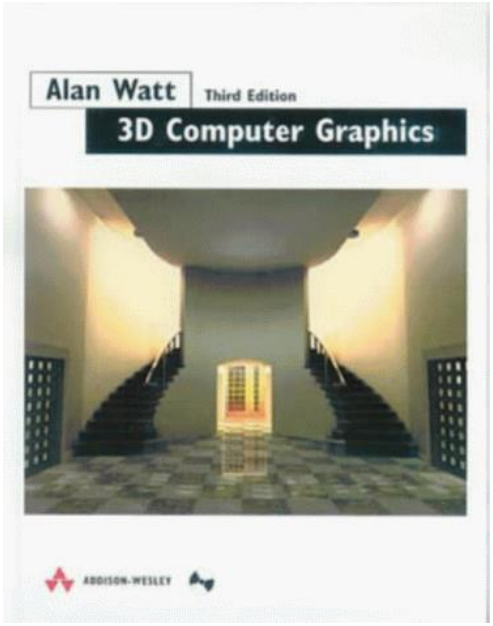
The University Of Sheffield.

COM3503/4503/6503: 3D Computer Graphics

Lecture 12: Texture: part 2



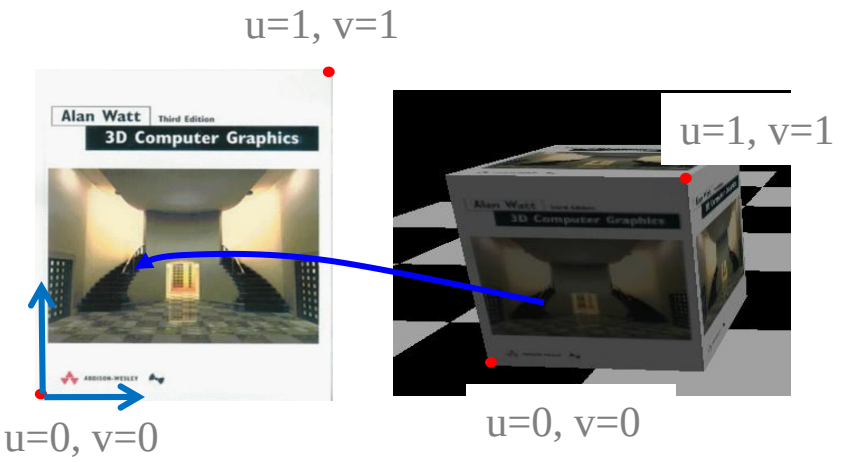
Dr. Steve Maddock
Room G011, Regent Court
s.maddock@sheffield.ac.uk

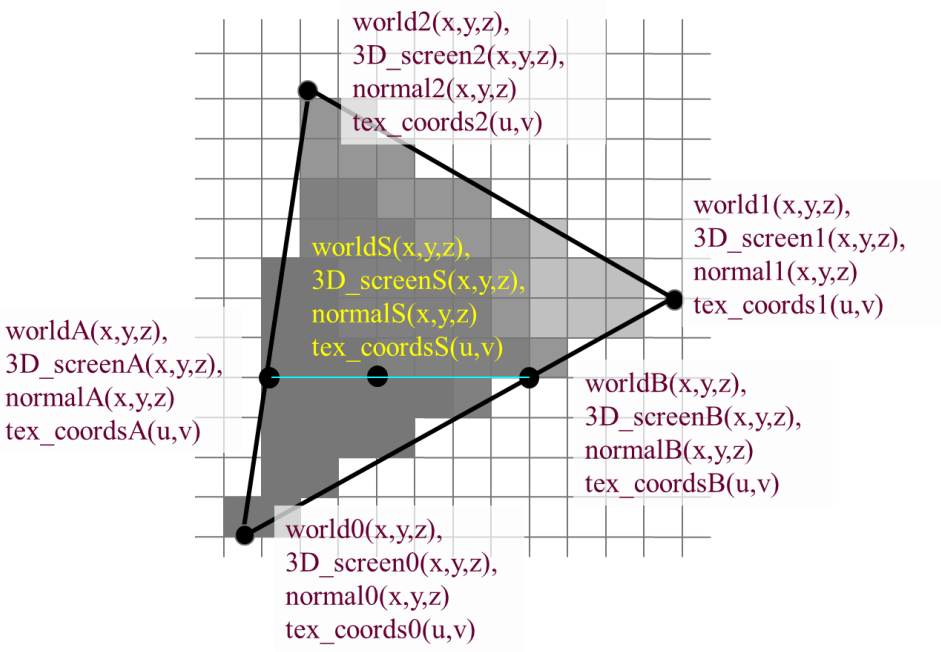
Review: Texture part 1

2D texture mapping:

- Paste a bitmap picture (texture) onto the surface of an object
- Texture stored in a (u,v) space
- Each vertex given (u,v) coordinates
- Interpolate (u,v) over triangle
- Look up texture value $T_{r,g,b}(u,v)$
- Modulate intensity at the pixel:
- If Gouraud interpolative shading, modulate interpolated intensity value
- If Phong interpolative shading, more options available since normal is interpolated and Phong equation used at pixel level:

$I_{r,g,b} = k_a I_a + I_L (k_d \mathbf{T_{r,g,b}(u,v)}(L.N) + k_s (R.V)^n)$





1. Introduction

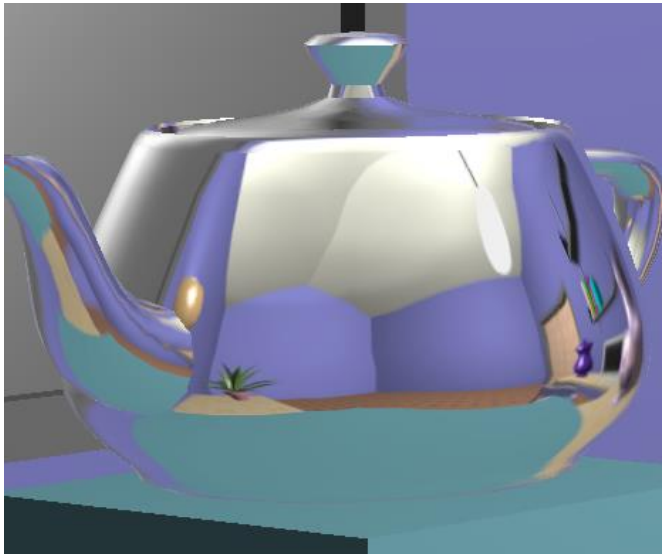
- There are a range of other texture approaches

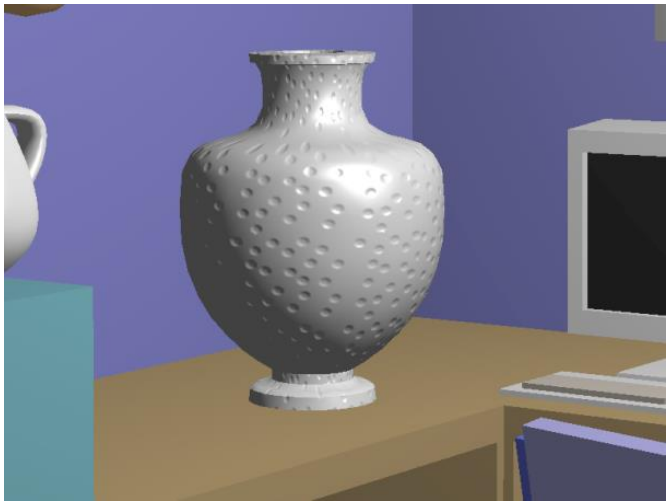
Today:

- Environment mapping →
- Bump mapping →
- Normal mapping
- Displacement mapping

Next week:

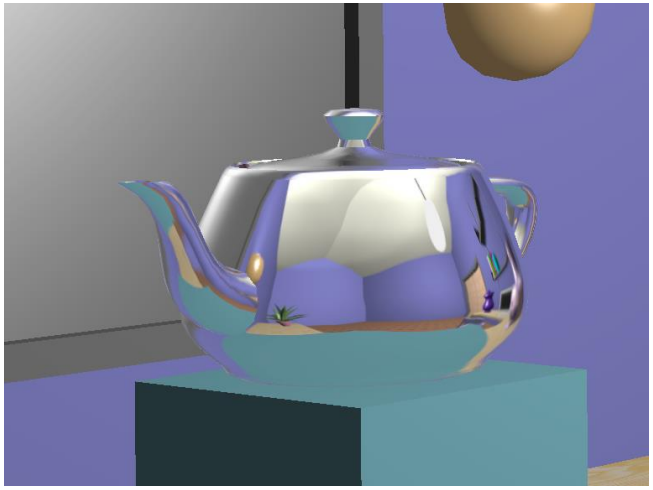
- 3D procedural texture mapping – “solid textures”

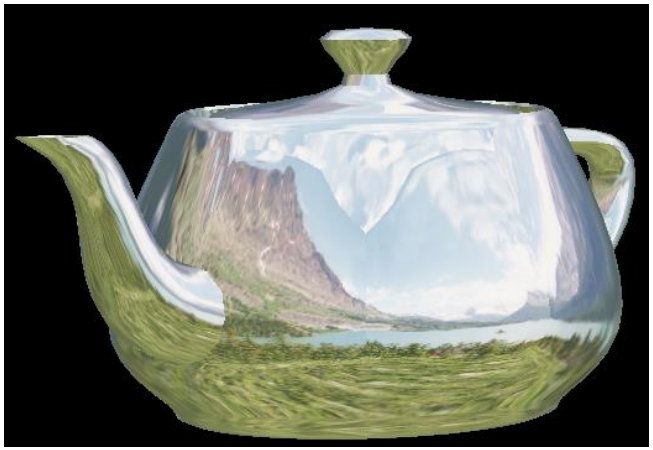




2. Environment mapping / Reflection mapping

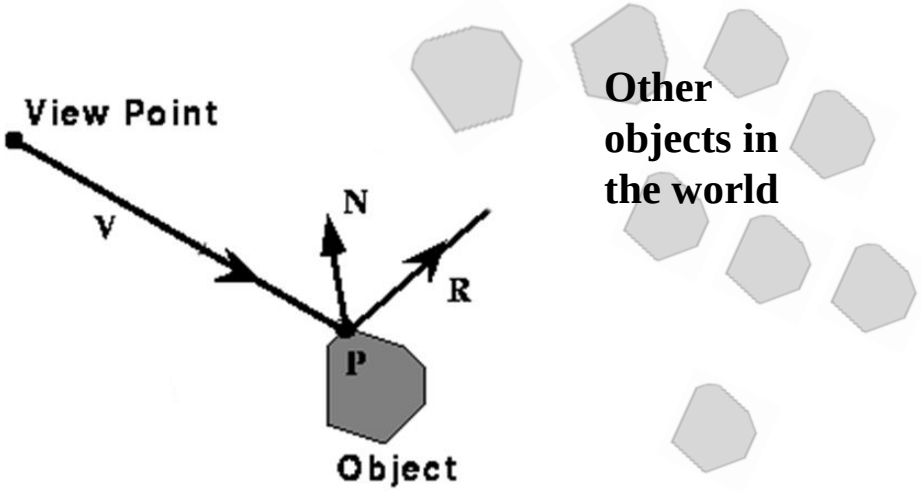
- Environment in which an object is placed is reflected in the surface of the object
- Examples:
  - Mirror sunglasses, shiny kitchen utensils, spaceman's helmet, etc
- Distinguish between two cases:
  - Immersion of synthetic object in a synthetic world
  - Immersion of synthetic object in the real world
- (History: http://www.pauldebevec.com/ReflectionMapping/)

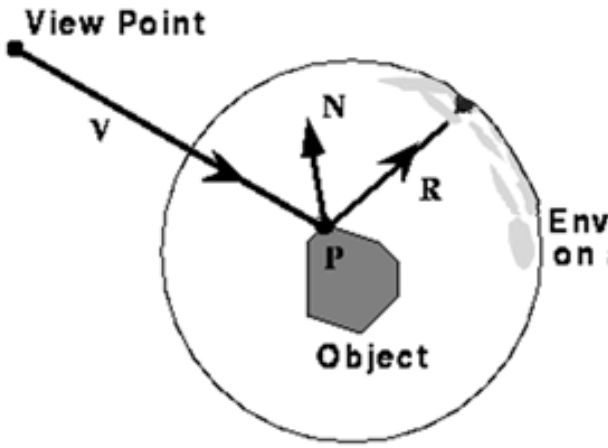




2.1 Environment mapping in a synthetic world

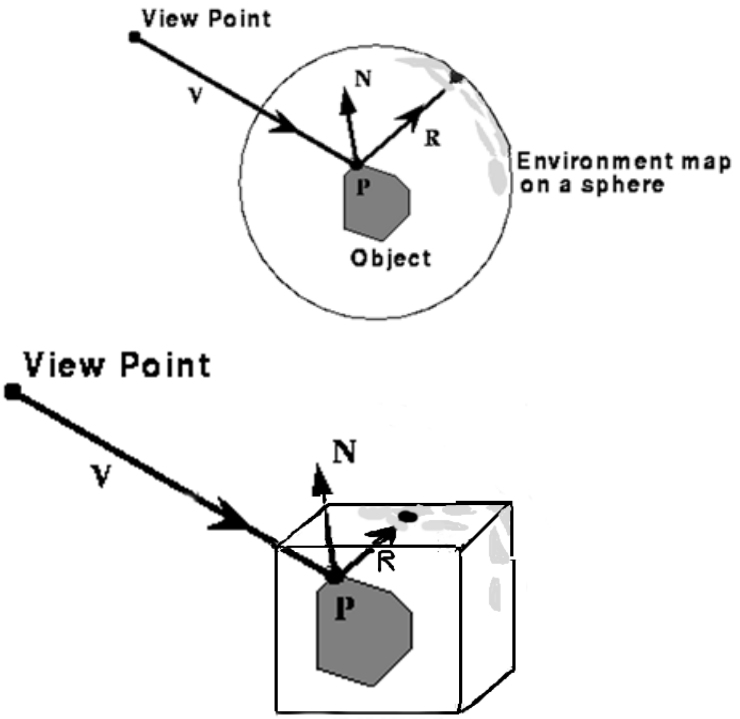
- General idea:
  - From viewpoint, find out what the reflected ray intersects in the world
  - But this is slow (see ray tracing lectures)
- Instead:
  - We store the surrounding world in a ‘surrounding texture’ that is associated with the object
  - From viewpoint, find out what the reflected ray intersects in the surrounding texture
  - This is viewpoint-specific





2.1 Environment mapping in a synthetic world

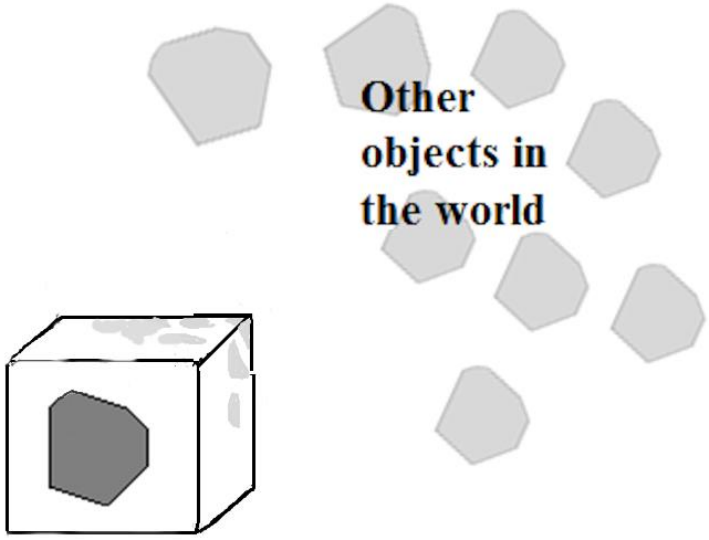
- We store the surrounding world in a ‘surrounding texture’ that is associated with the object
- Sphere mapping
  - More complicated
  - Artefacts near poles
- Cube mapping
  - Most common
  - Relatively easy to construct



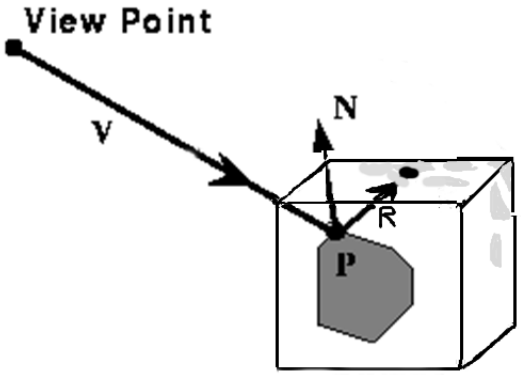
2.2 Cube mapping

Two stages:

- Stage 1 : create the cube map
  - Off line stage



- Stage 2: use this in rendering
  - Real-time usage



2.2.1 Cube mapping: off-line stage

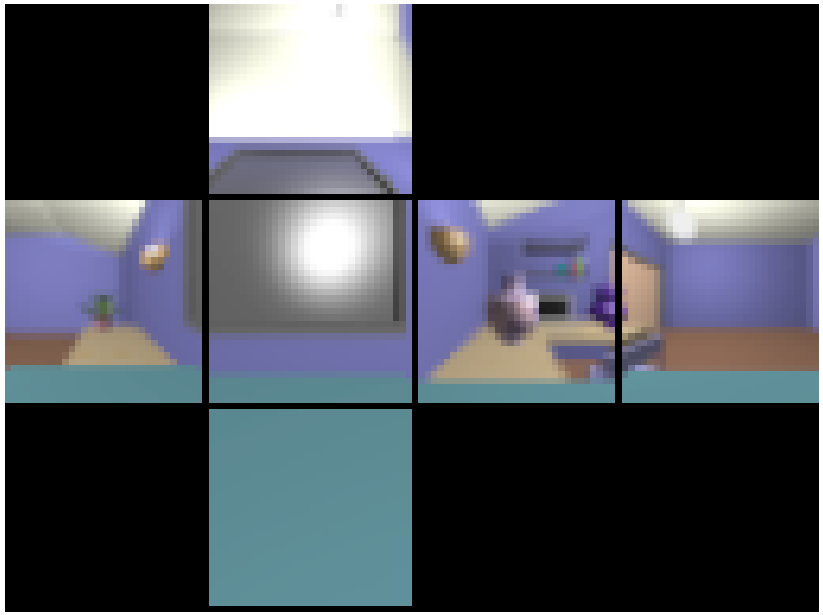
- Surround object to be mapped with a cube
- Use centre of a cube as a viewpoint and produce a rendered image of the environment as seen through each face

- *Note:* Although visible in the illustration, the red eye is meant to be in the centre of the cube and thus also in the approximate centre of the teapot.

Watt,00

2.2.1 Cube mapping: off-line stage

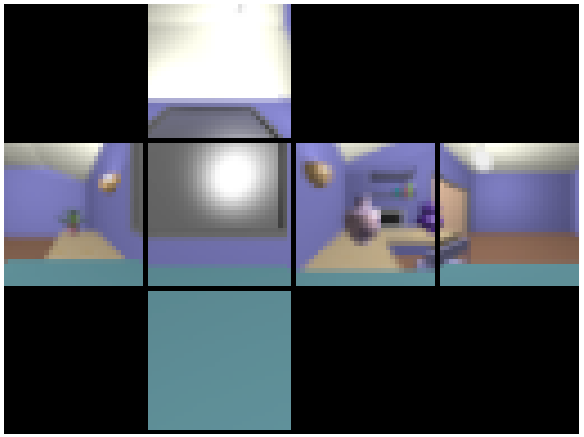
- Store the results as ‘texture’ maps on each face

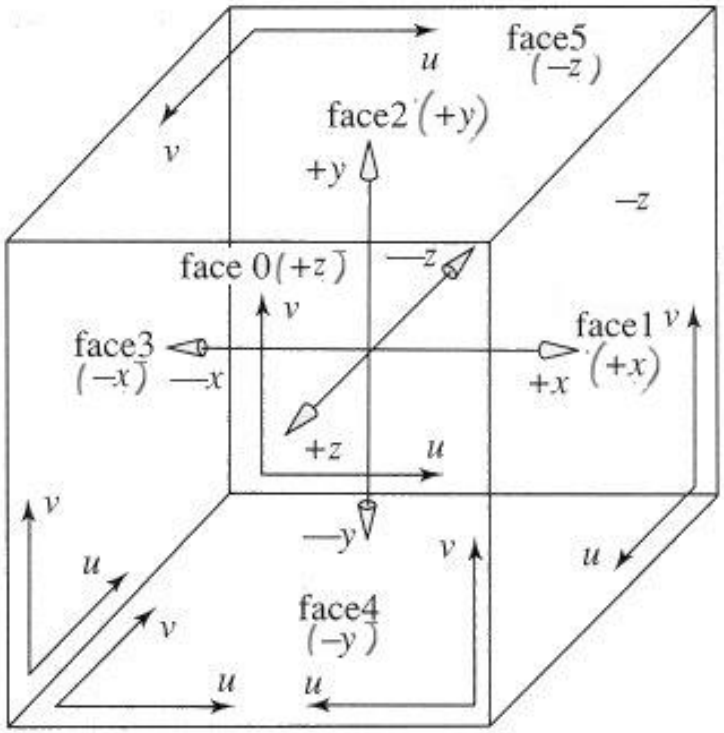


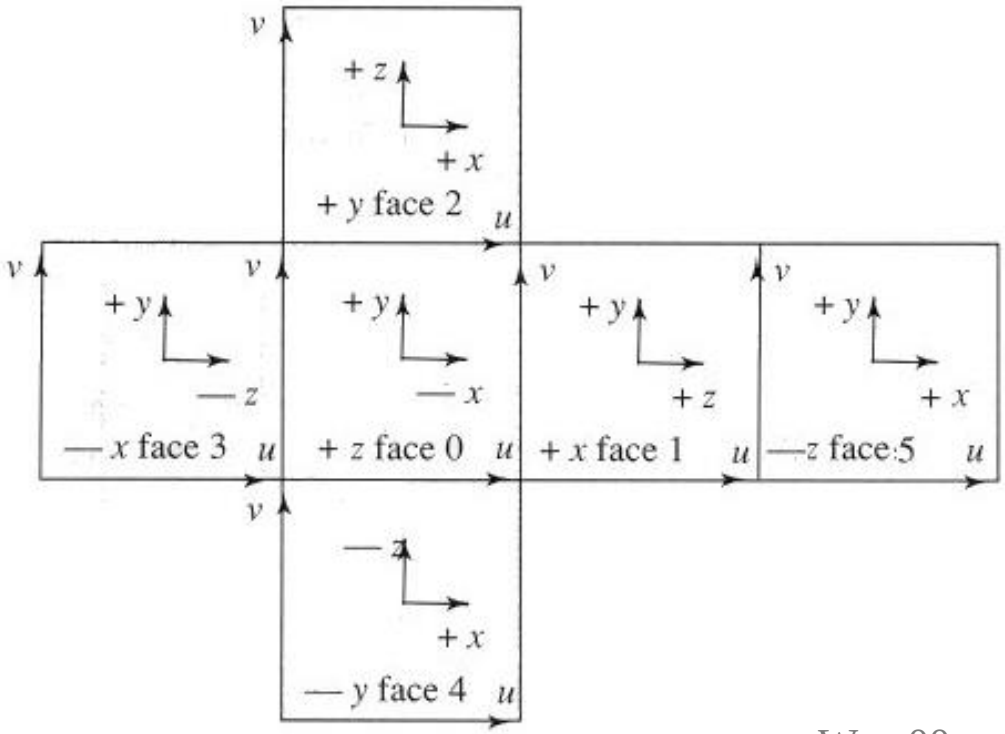
Low resolution: 32x32 pixels for each face

2.2.1 Cube mapping: off-line stage

- Each face is parameterised in u and v



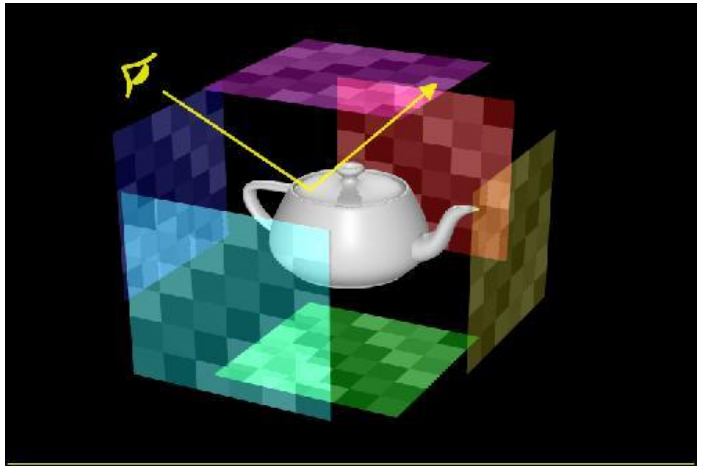




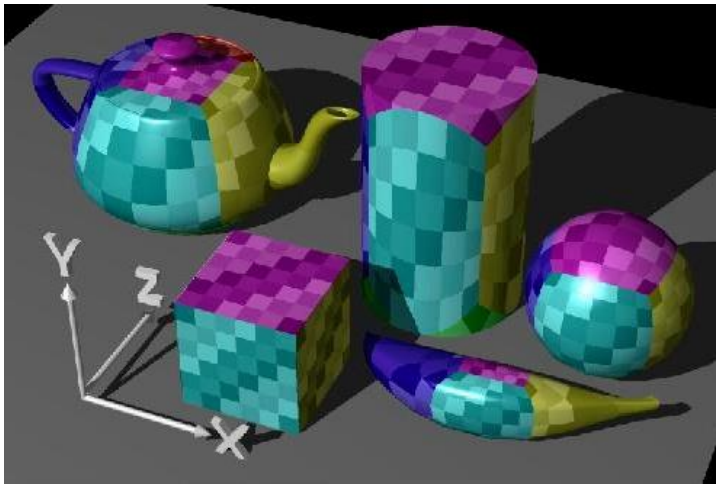
Watt,00

2.2.2 Cube mapping: off-line stage

- A reflected vector (calculated using viewpoint and vertex normal) is created for each polygon vertex
- Find the cube face that the reflected vector intersects
- Calculate u,v coordinates and look up value in texture map



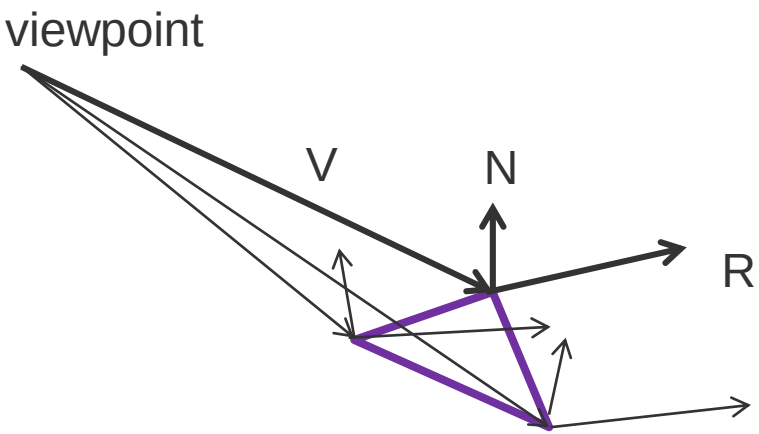
Exploded view of the surrounding cube on which the texture is stored

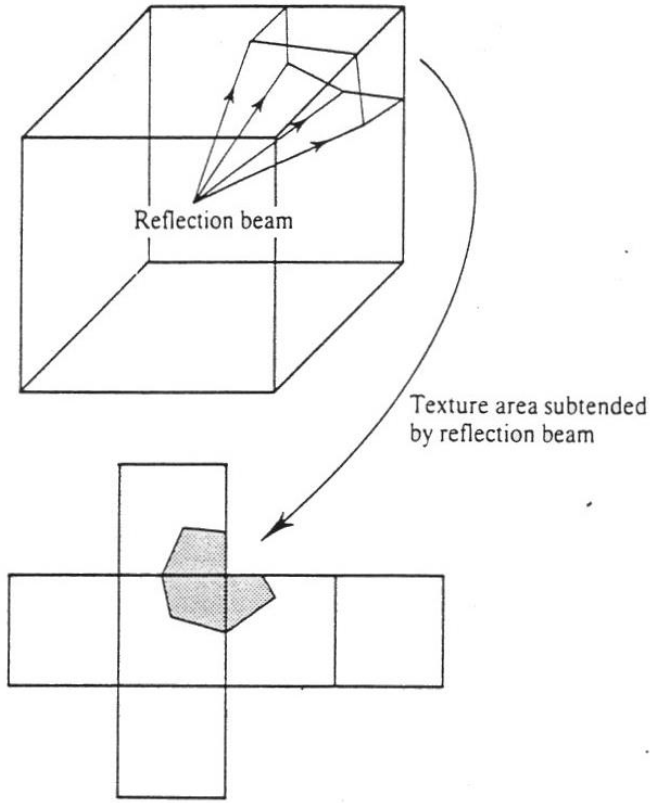


The SIGGRAPH 97 Education Slide set

2.3 An issue

- Reflection area is created for a polygon which may intersect more than one cube face

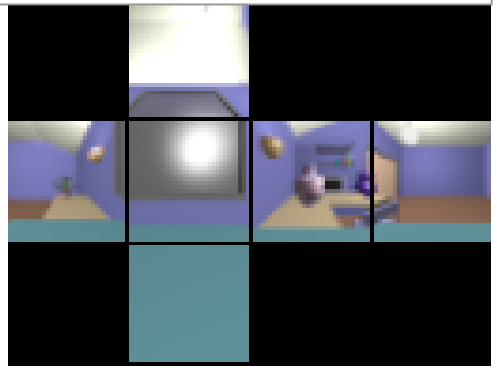




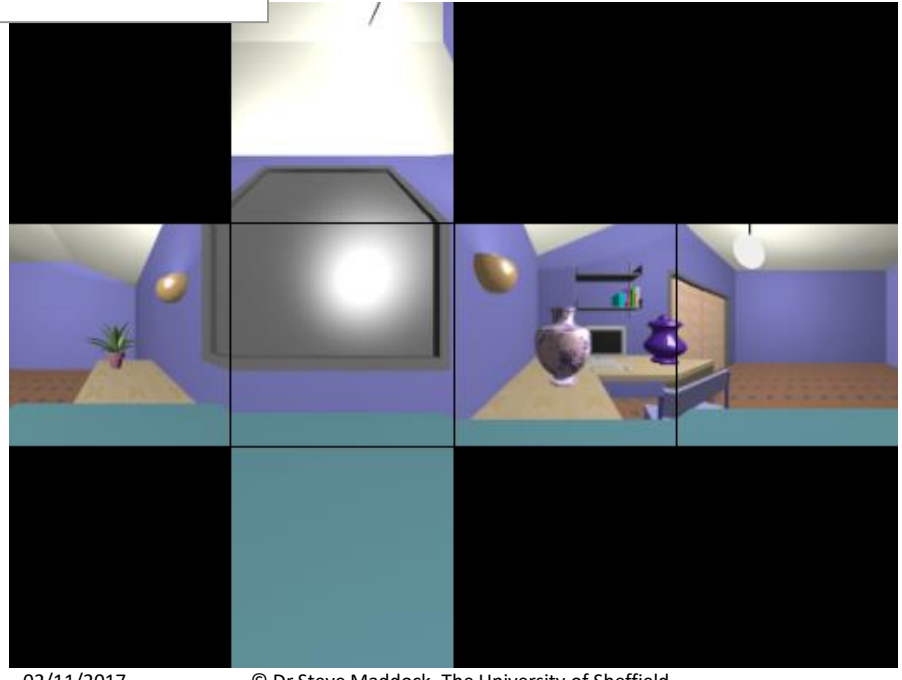
Watt,00

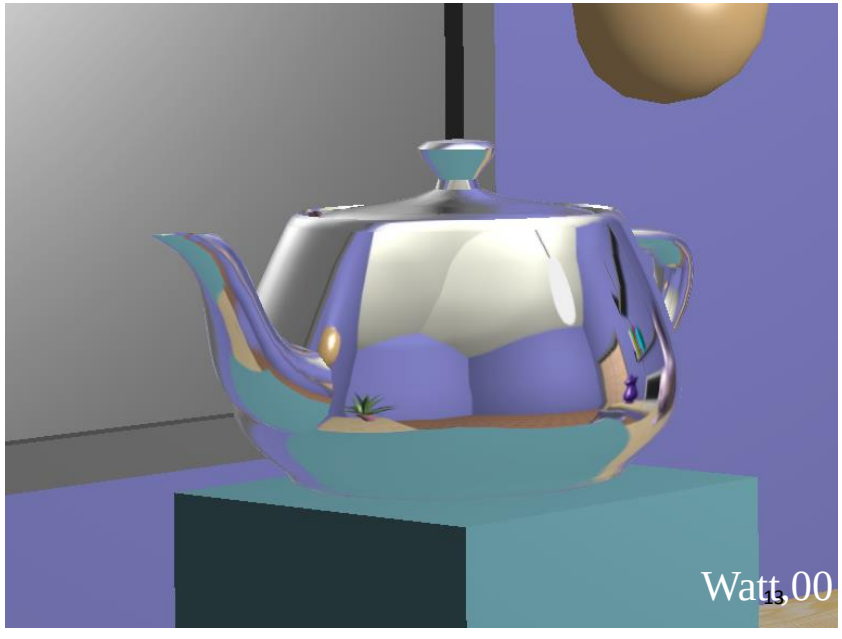
2.4 Resolution of environment map affects quality

32x32 pixels for each face

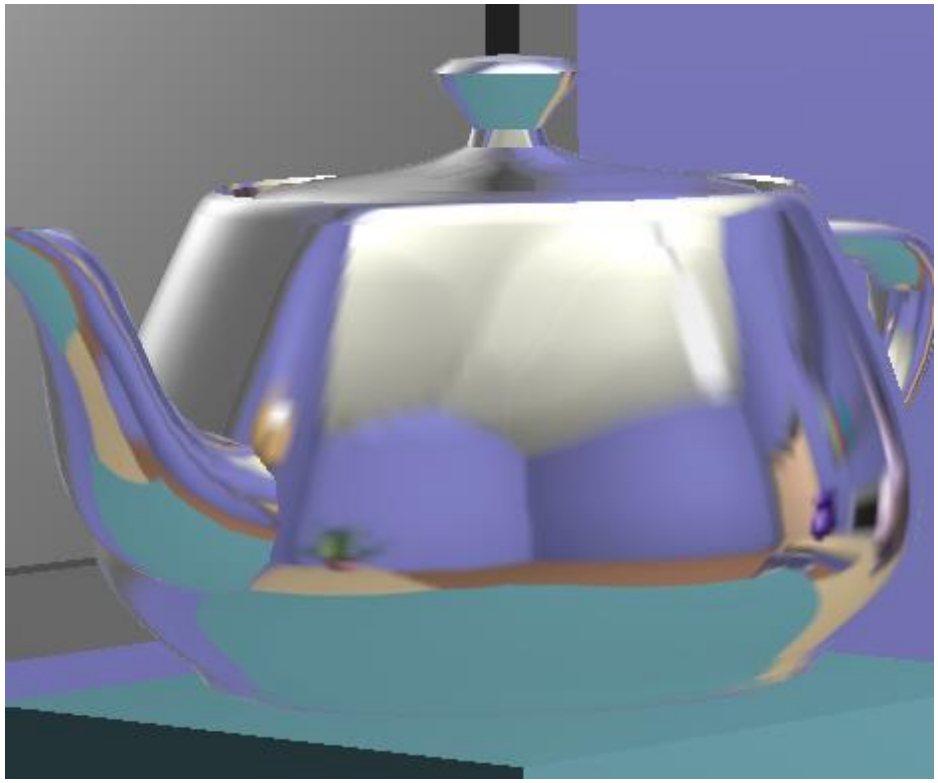


128x128 pixels for each face



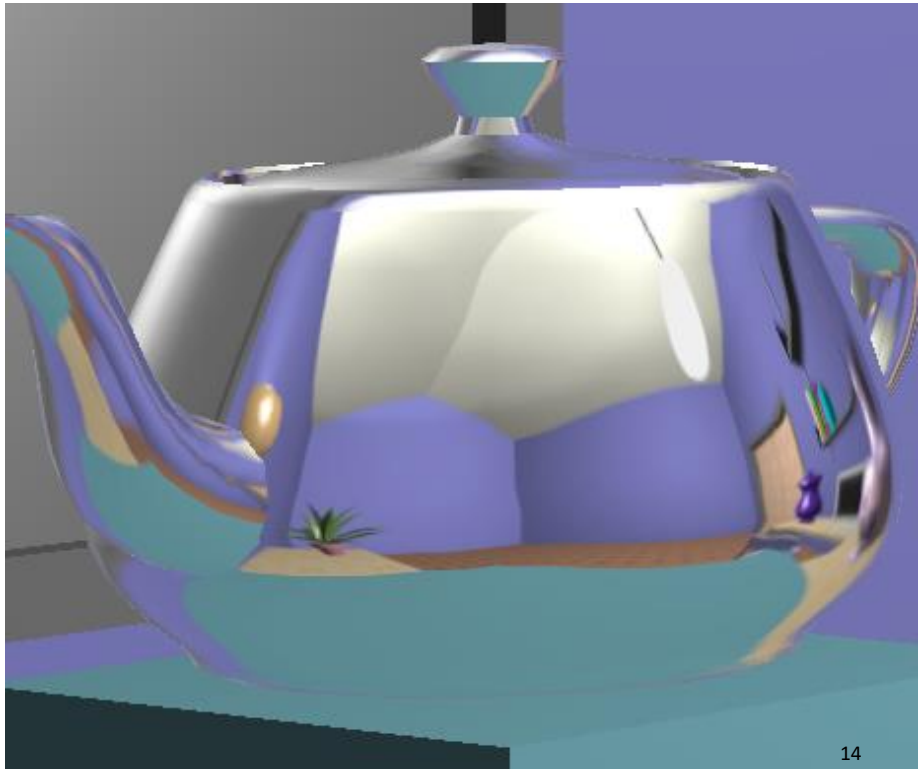


2.4 Resolution of environment map affects quality



32x32 pixels
for each face

128x128 pixels
for each face

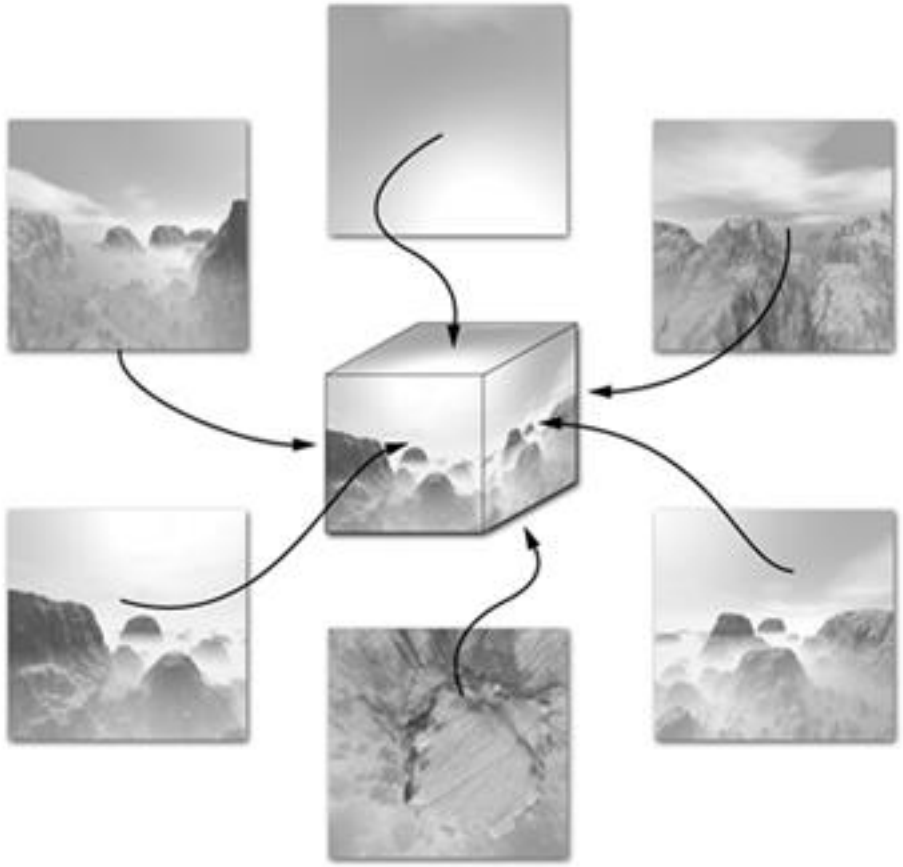


- Can combine with mip-mapping

Watt,00

2.5 Immersion of synthetic object in the real world

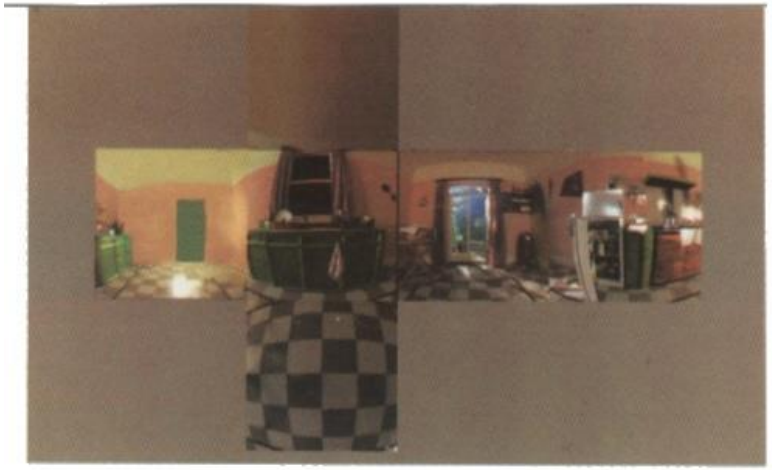
- Take photographs from a specific point in the real world looking in each of six directions corresponding to faces of a virtual cube at that point
- The six photographs become the textures using in cube mapping



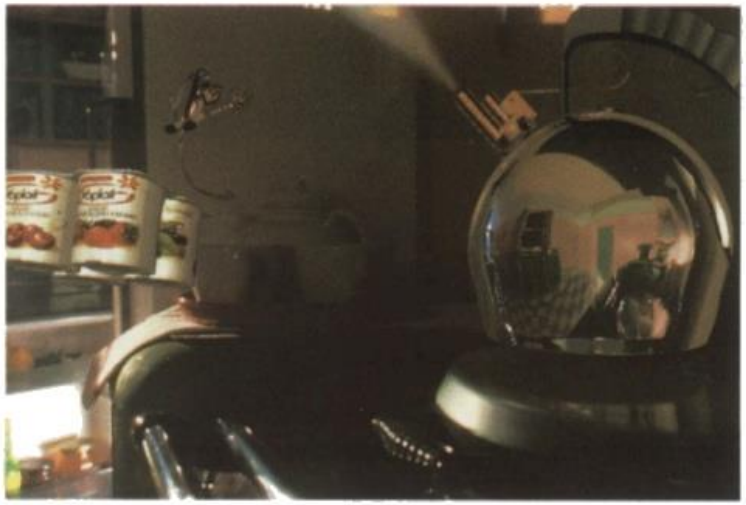
R. Fernando and M.J. Kilgard, "The Cg Tutorial: The Definitive Guide to Programmable Real-Time Graphics", Addison-Wesley, 2003, Chapter 7

2.5 Immersion of synthetic object in the real world

- The photographs of the real scene are taken from the position where the virtual object is to be inserted
- Disadvantage: Needs to be repeated if moving the object, but not if just deforming



15 Environment mapping: an environment map created by frame grabbing six photographs. Notice the discontinuities that occur across the seams in the map.



16 Environment mapping: a copper kettle rendered using the photographed environment map.

Watt & Watt, 92

2.5 Immersion of synthetic object in the real world

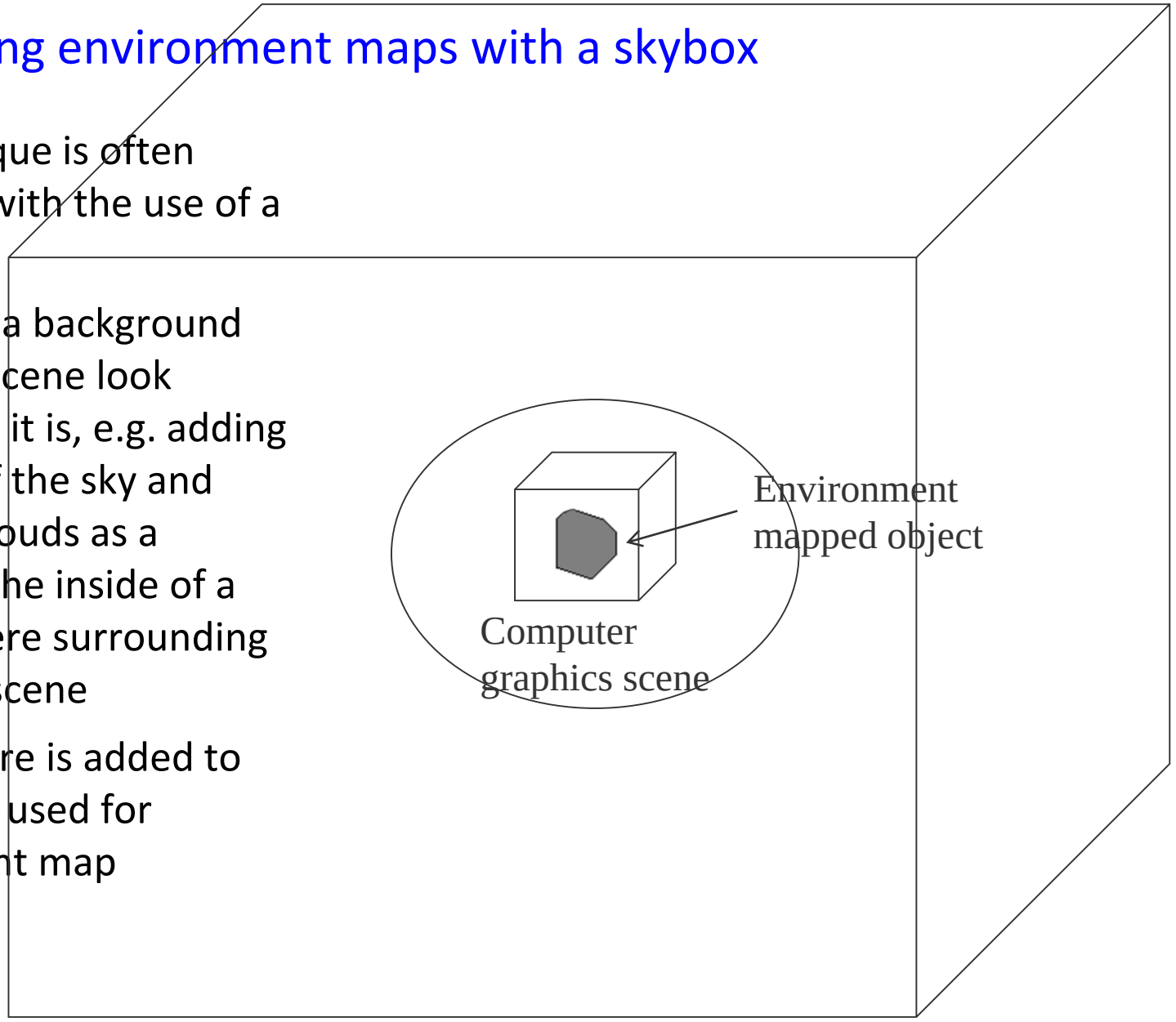
- The technique is used as a special effect in films:

"Terminator 2: Judgement Day", 1991. Director: James Cameron.
Studio: Carolco Pictures, Lightstorm Entertainment, Pacific Western, Canal+.
Distributed by TriStar Pictures

video1, video2

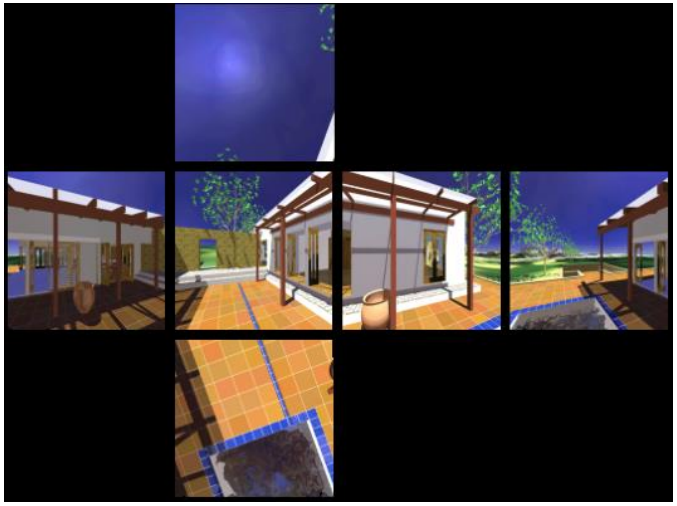
2.6 Combining environment maps with a skybox

- The technique is often combined with the use of a ‘skybox’
- A skybox is a background to make a scene look bigger than it is, e.g. adding a picture of the sky and (moving) clouds as a texture to the inside of a box or sphere surrounding the whole scene
- Same texture is added to skybox and used for environment map



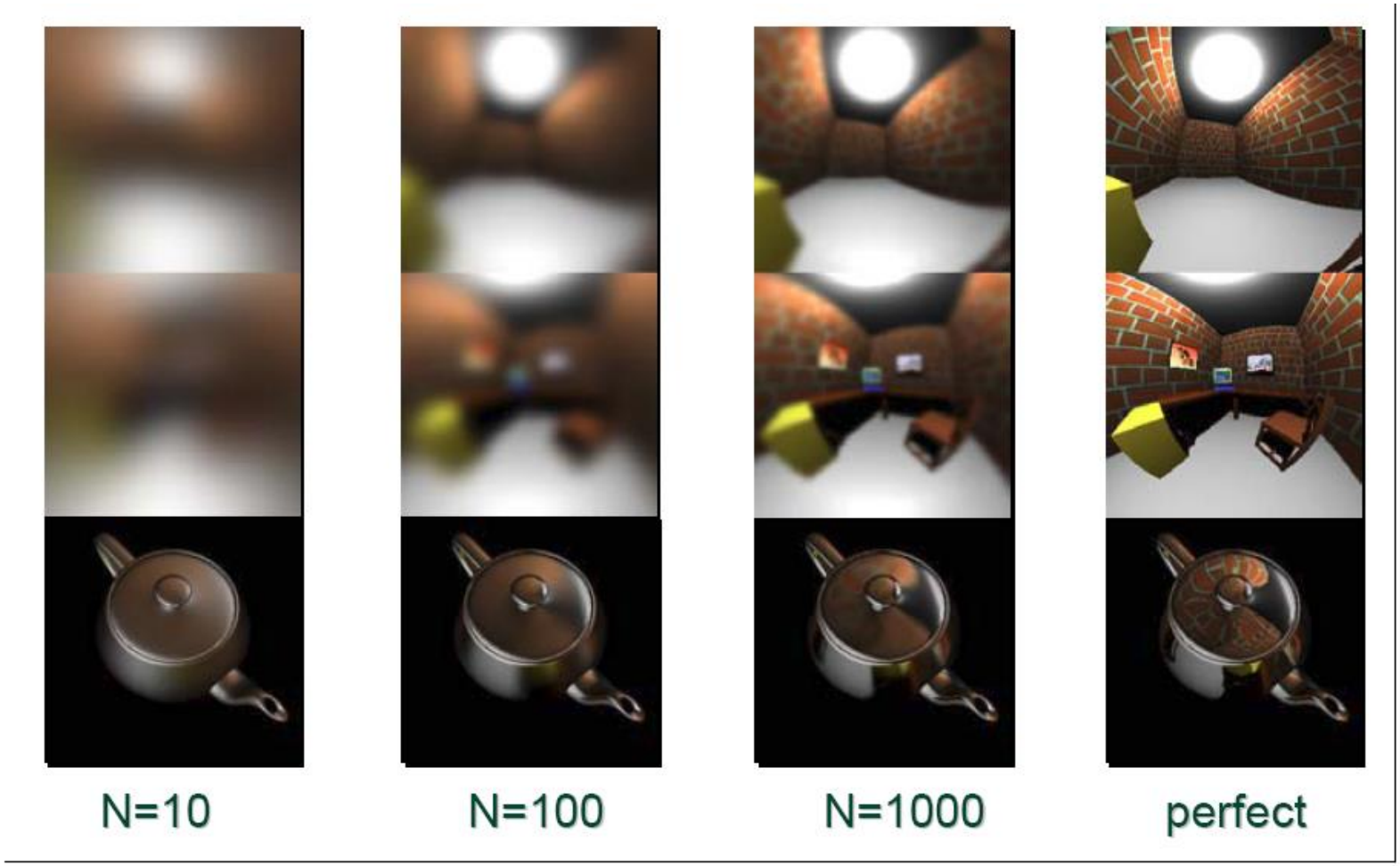
2.7 Environment mapping: Animation

- www.nVidia.com: DEMO (or movie)



- If object is deforming then can reuse same surrounding environment map
- If object is moving around the scene (i.e. translating), then environment map needs to be recalculated for each frame of animation (i.e. each new position)

2.8 Pre-filtered environment mapping

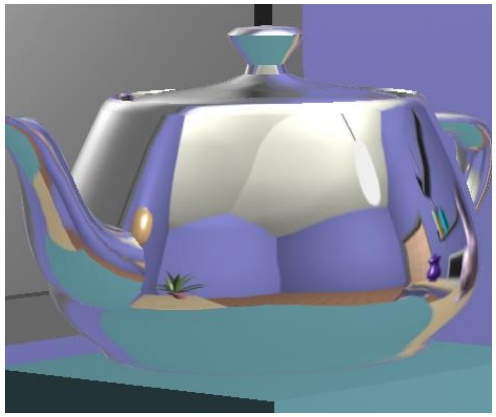


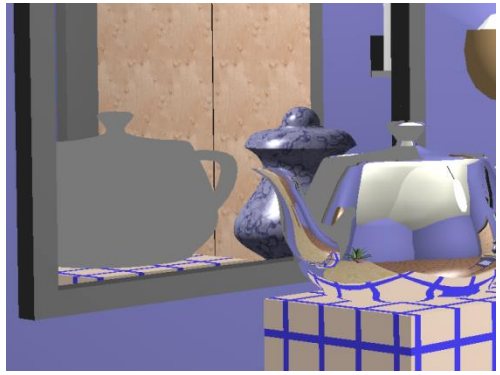
Here we have an example of Phong environment maps, for different exponents N=10,100,1000.

Slide Jan Kautz, UCL

2.9 Environment mapping : Disadvantages

- The reflected geometry is undoubtedly incorrect
  - But good enough to fool the viewer
- Quality depends on the resolution of the environment map
- Object cannot reflect in itself, e.g. teapot spout
- A separate map is required for each object in the scene, since the environment map must be constructed from the position of the object
- A new map is required for an object if it translates in the scene
- Neighbouring shiny objects will not interact
- We'll see that ray tracing sorts out all these problems

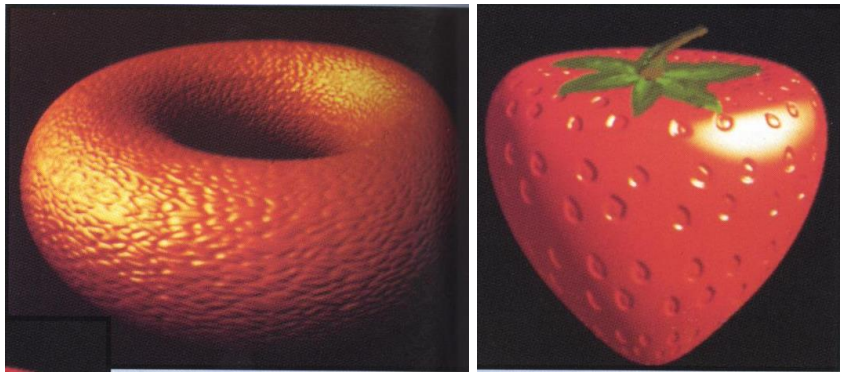




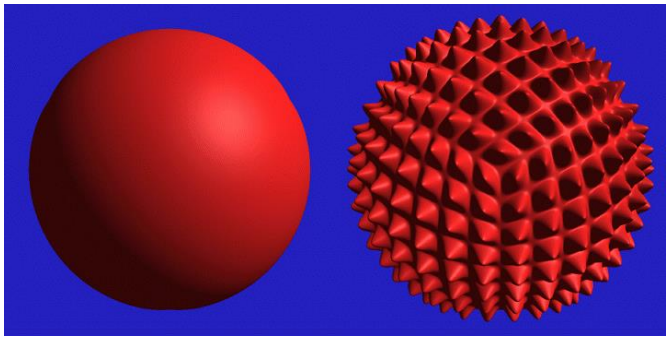
3. Creating bumps on a surface

Three alternatives:

- Bump mapping (Blinn, 88) →
  - Alter normal not geometry
  - Tricks the eye
- Normal mapping
  - Replace the normal
  - Normals are used to represent surface detail layered on a simplified model
- Displacement mapping →
  - Alter geometry



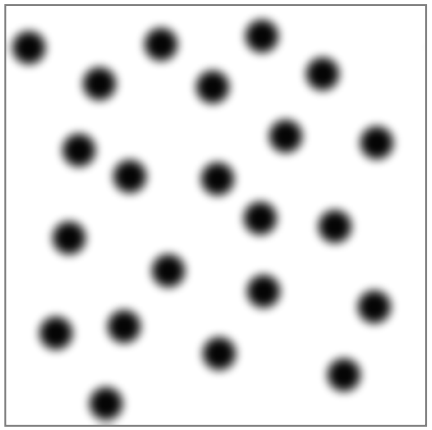
Blinn, 88

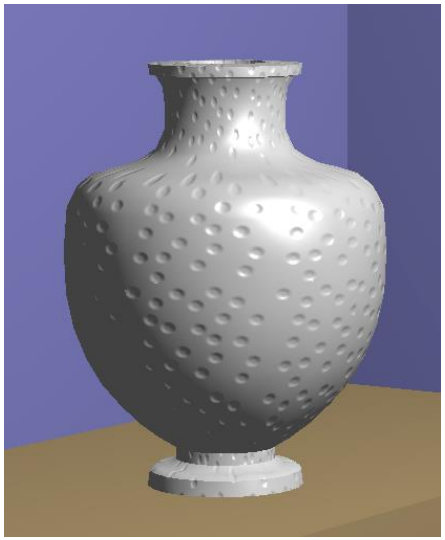


Durand, 06

3.1 Bump mapping

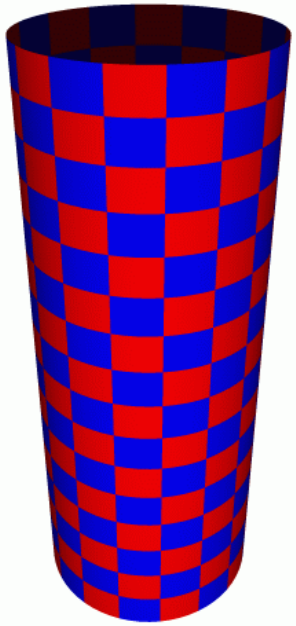
- Bump pattern is stored as a texture map
- Grey scale encodes the height of a virtual surface

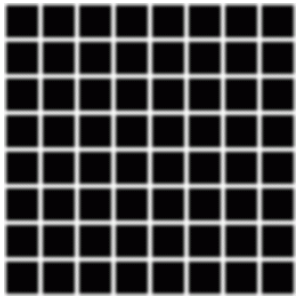




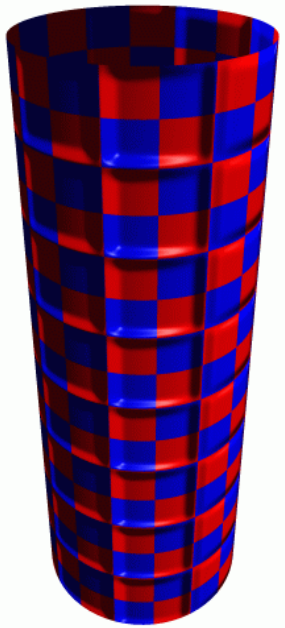
Watt,00

Cylinder w/Diffuse Texture Map





Bump Map

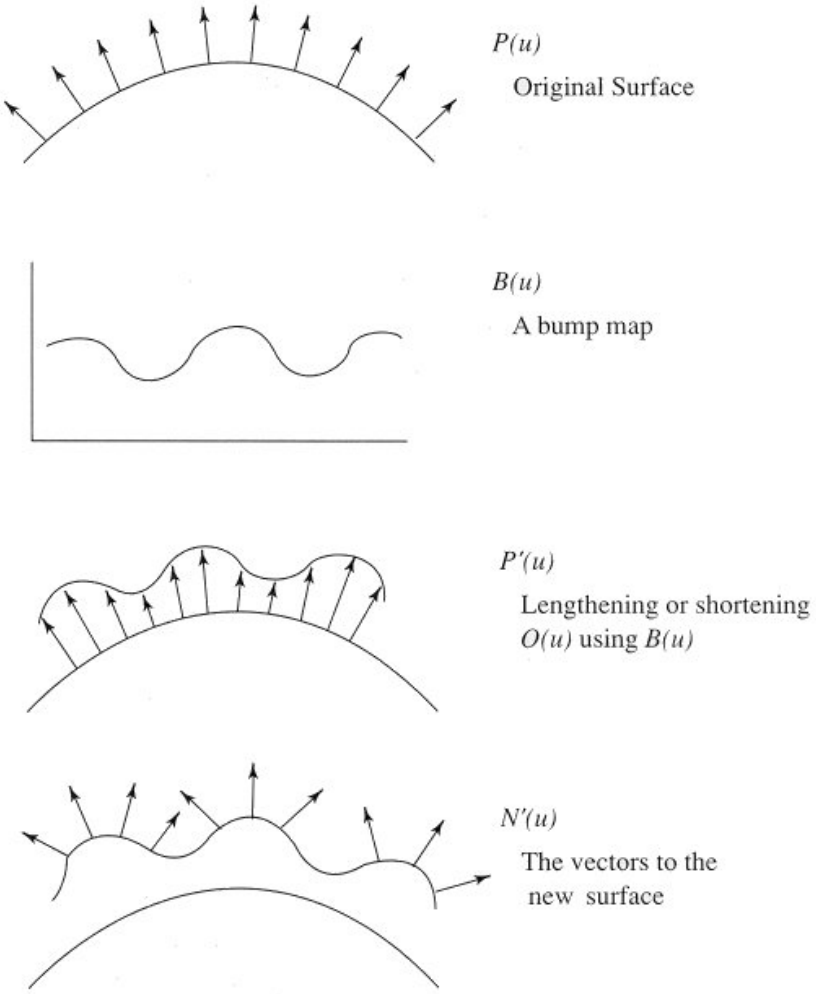


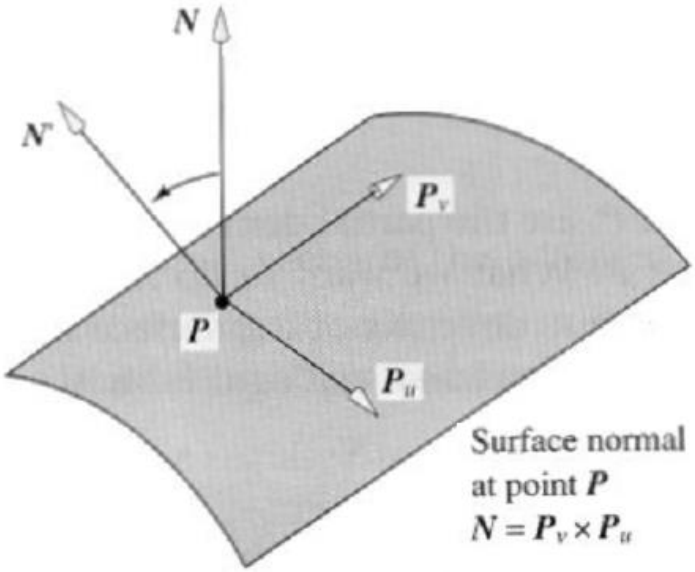
Cylinder w/Texture Map & Bump Map

Durand, 06

3.1 Bump mapping

- Use texture map to alter the surface normal when rendering
  - I = f(N)
  - If N is changed then the light intensity changes
  - Thus the eye believes there is a bump





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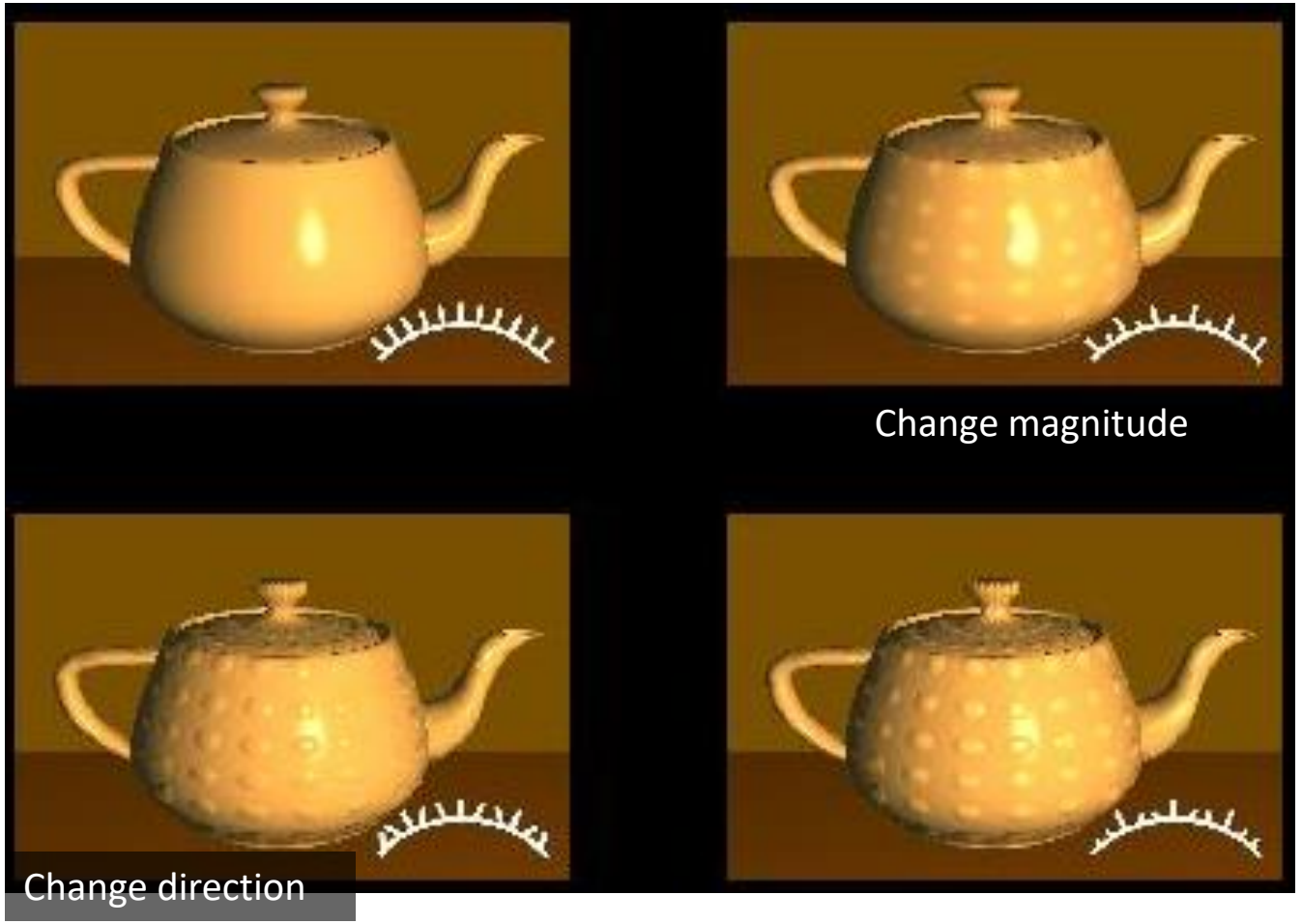
3.1 Bump mapping

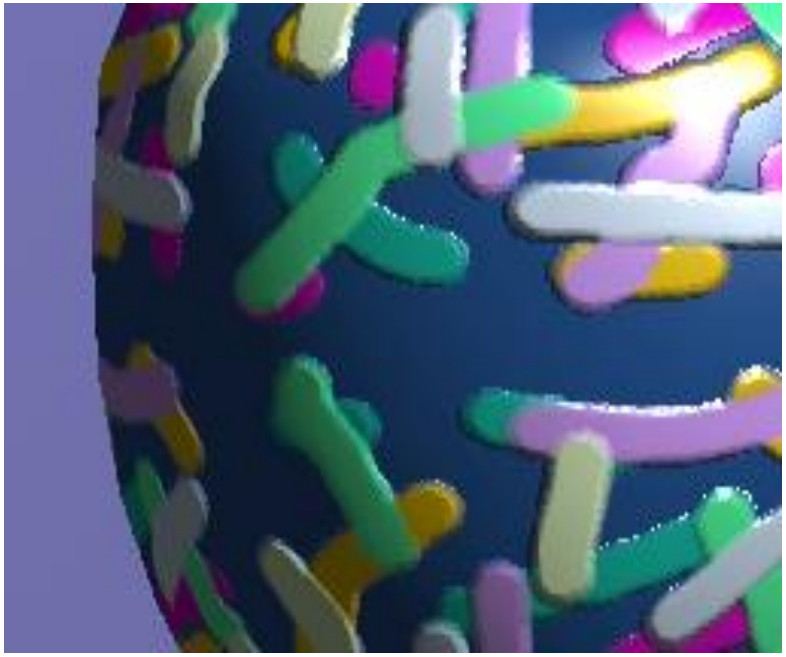
- Can be incorporated into interpolation of normals in a renderer
- Thus, needs Phong interpolative shading



3.1 Bump mapping

- Disadvantage: Silhouette edges remain unchanged

Blinn, 88

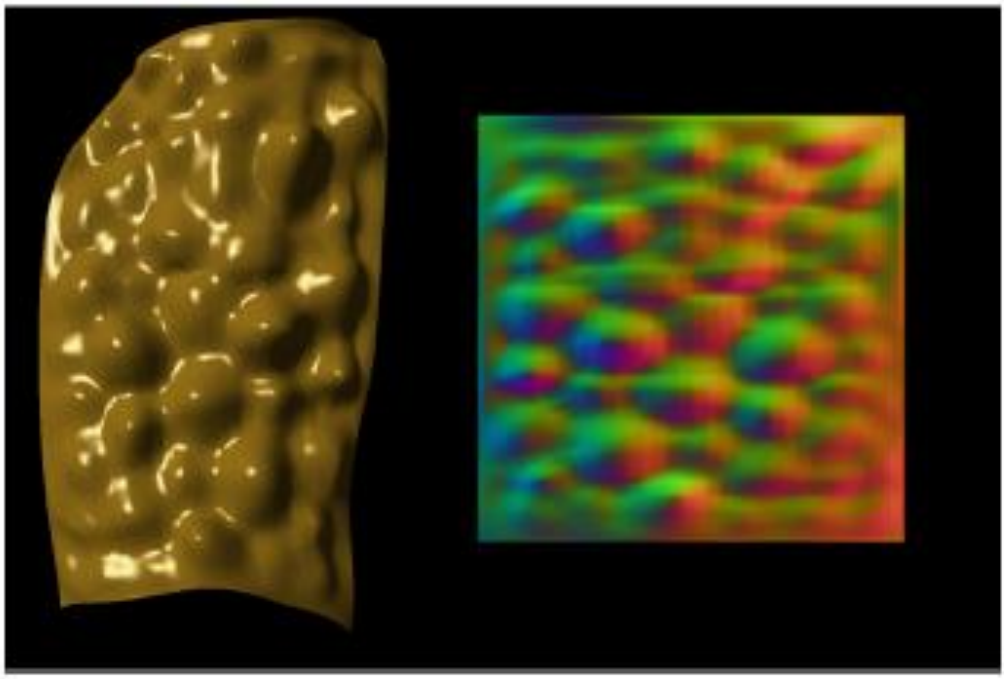


Watt,00

02/11/2017 © Dr Steve Maddock, The University of Sheffield

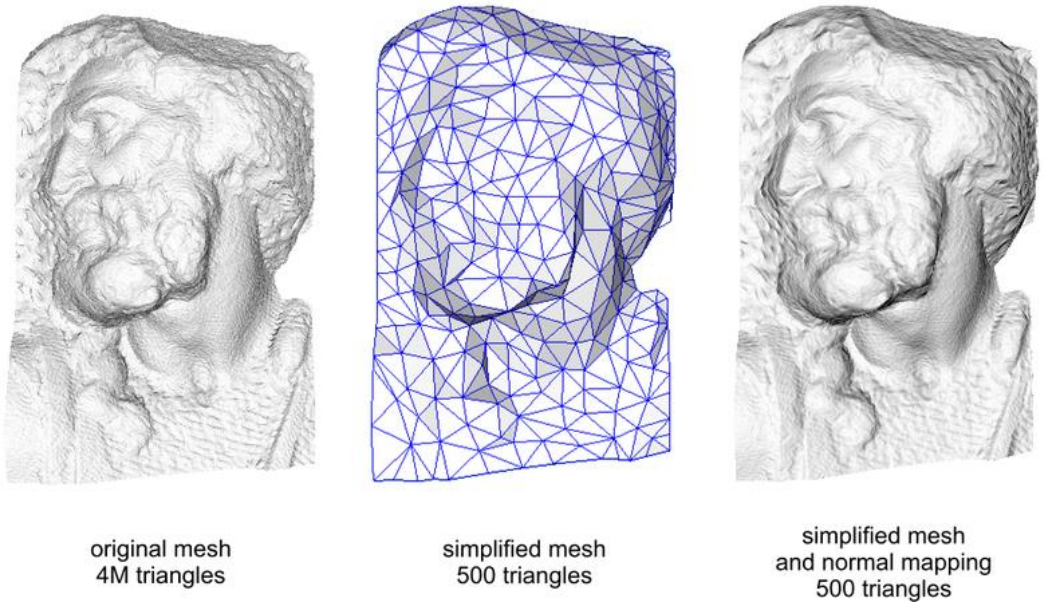
3.2 Normal mapping

- R,G,B in texture is used to store x,y,z components of normal
- For each normal component, [-1, 1] needs to be mapped to [0,1]
- The normal map is used to provide the normal when shading
  - Taking into account the orientation of the existing surface normal



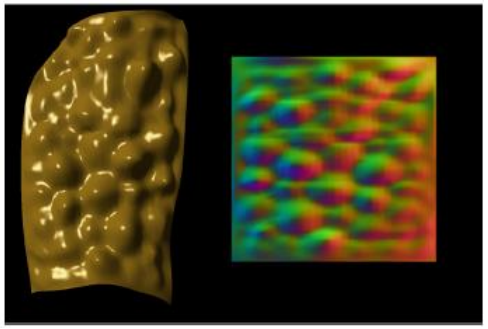
3.2 Normal mapping

- The normal map is used to encode the difference between a simplified mesh and an original mesh
- Then, only the simplified mesh triangles are rendered, with the normal map used to add the normal, thus tricking the eye into seeing the detail



(Example of normal mapping for recreating the details lost during a drastic simplification {{cc-by-sa}} # The author of this image is Paolo Cignoni)
http://en.wikipedia.org/wiki/File:Normal_map_example.png

3.2 Normal mapping

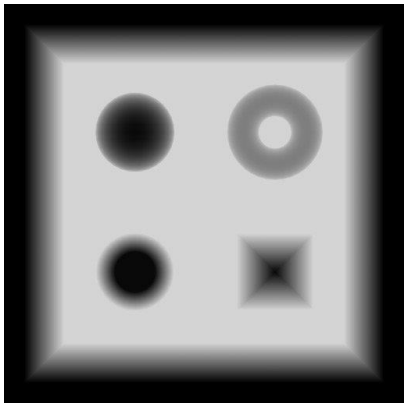


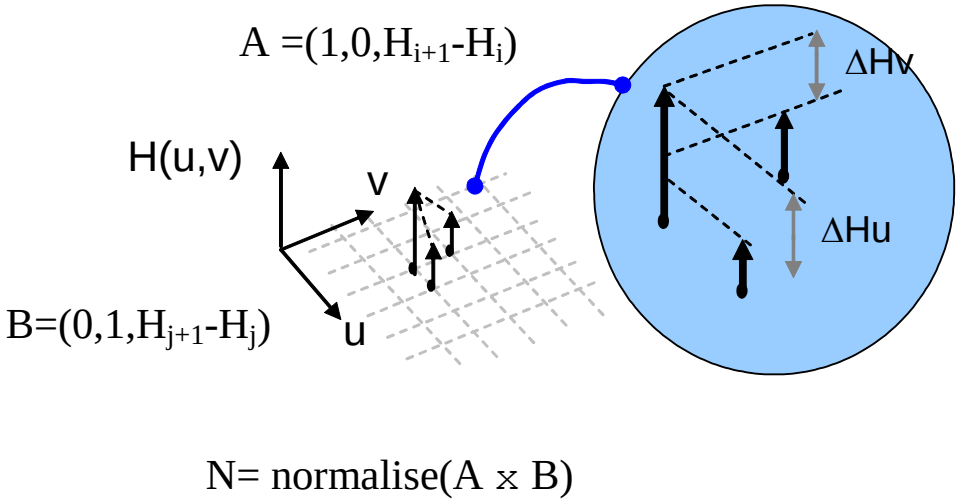
249,924 triangles 62,480 triangles 7,809 triangles 975 triangles

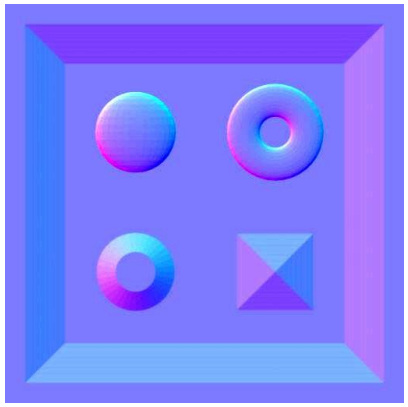
J.Cohen, M.Olano, D. Manocha, “Appearance-Preserving Simplification”, Proc Siggraph 1988, pp. 115-122

3.2 Normal mapping

- A bump map can be converted to a normal map
  - Calculate normals using partial differences between neighbouring heights



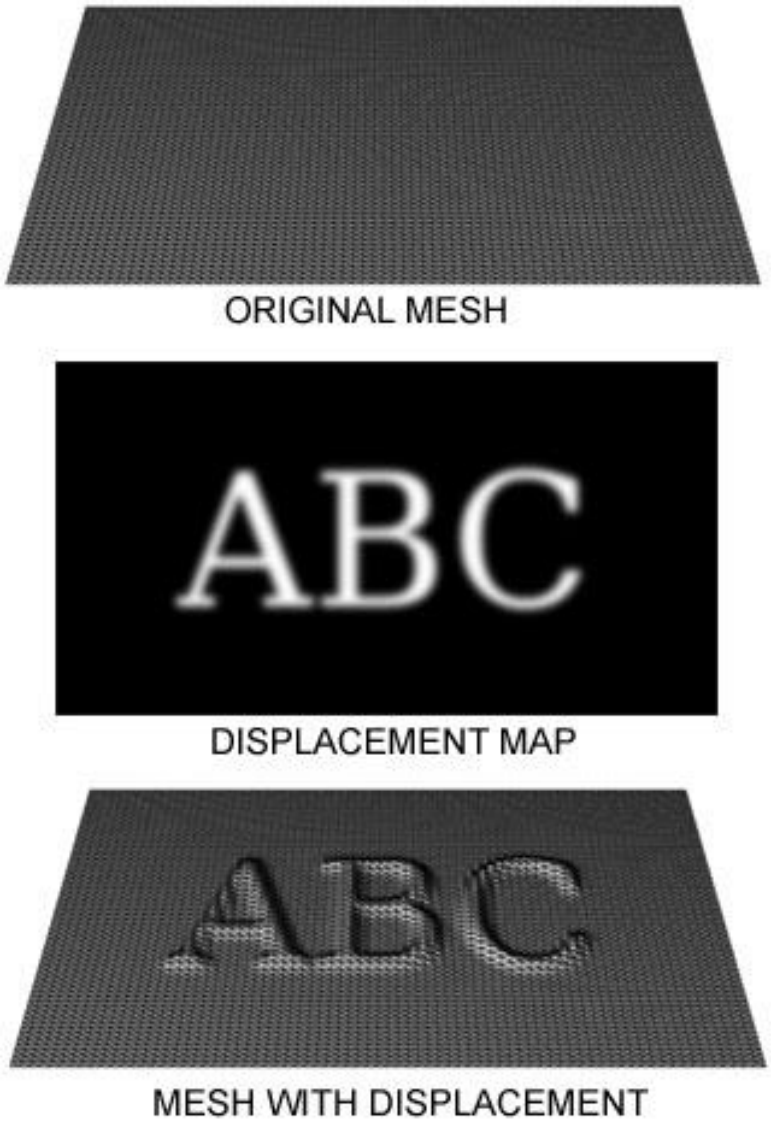




N= normalise(A x B)

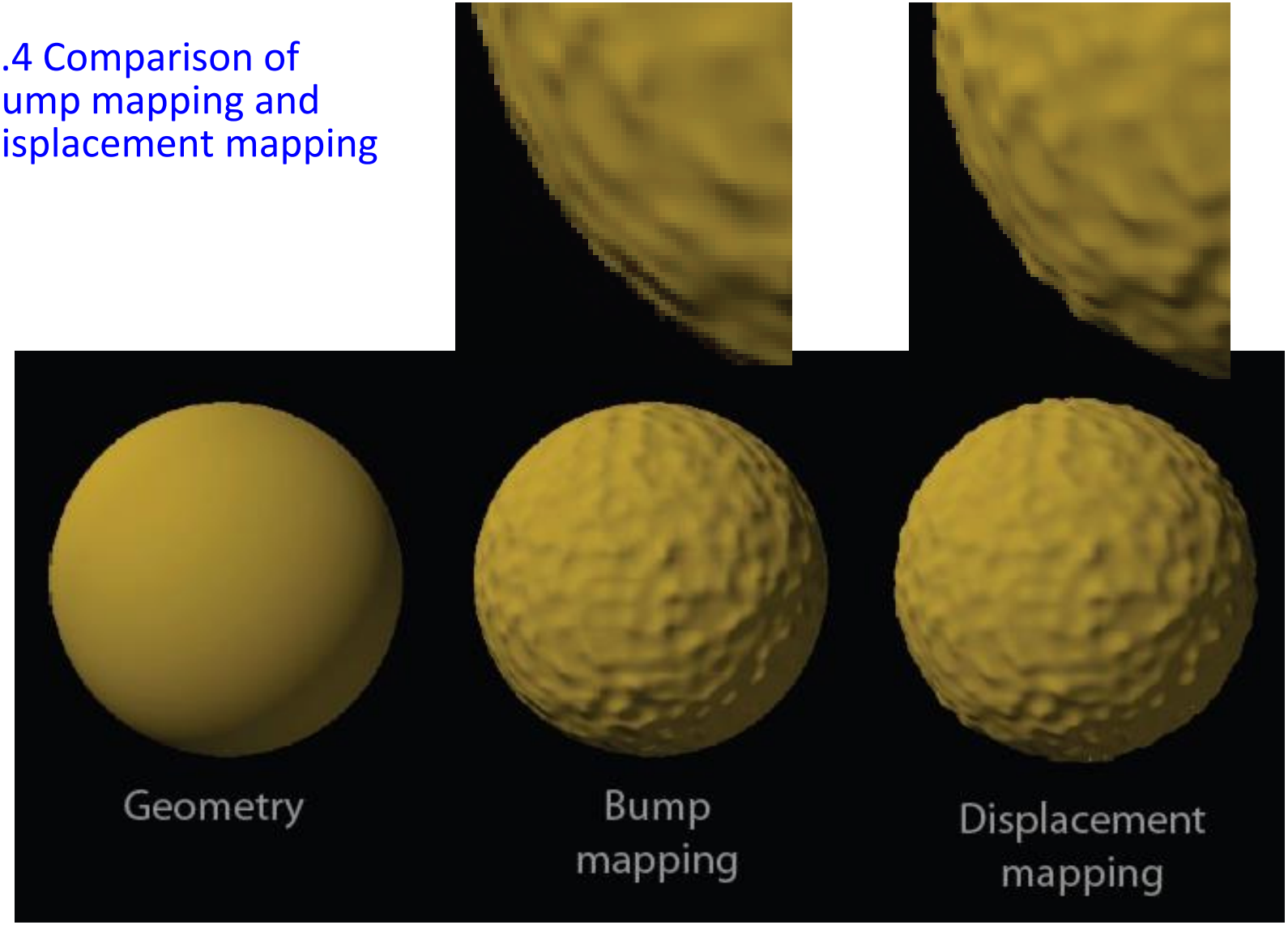
3.3 Displacement mapping

- Store height field in a texture map
- Alter the actual geometry of the object
- Relies on the geometry of the object being detailed enough
- Alternative: Convert texture to geometry and replace existing geometry of the object



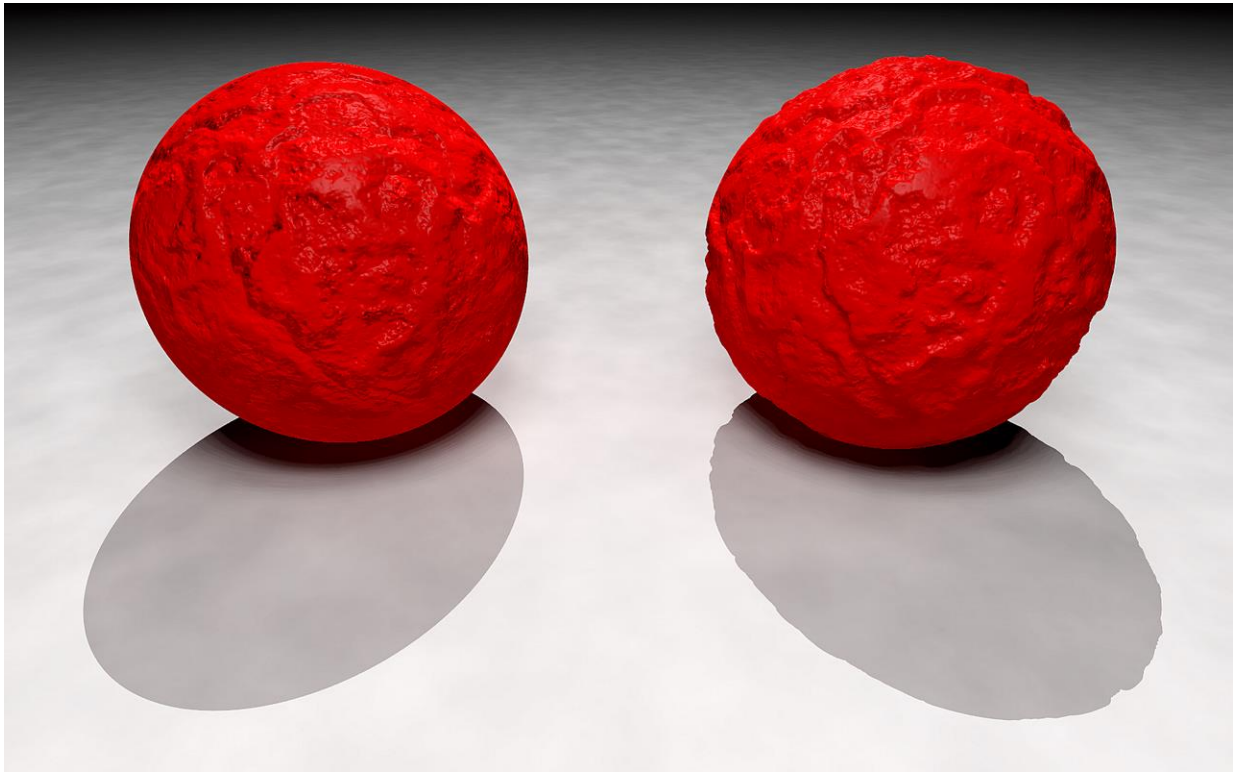
http://en.wikipedia.org/wiki/Image:Displacement.jpg

3.4 Comparison of bump mapping and displacement mapping



Steve Marschner, CS4620 Introduction to computer graphics, http://www.cs.cornell.edu/~srm/, 2008

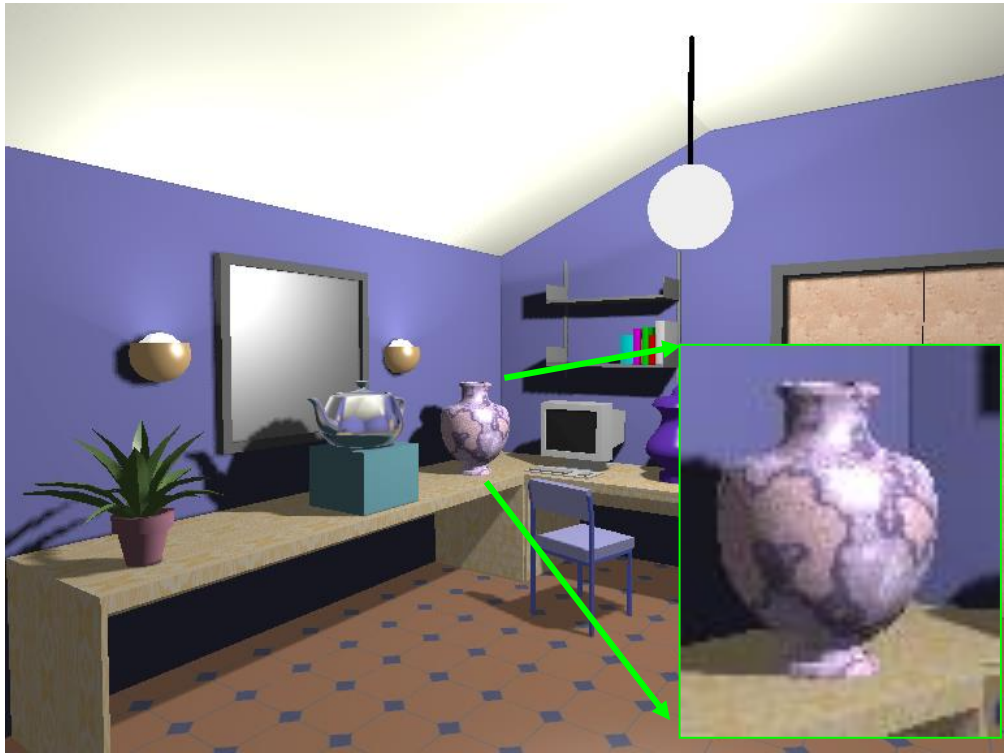
Example: function used to create a bump map or an isosurface



http://commons.wikimedia.org/wiki/File:Bump_map_vs_isosurface2.png
By GDallimore (Own work) [Public domain], via Wikimedia Commons

4. Summary

- Most common *texture mapping* approach is to apply 2D texture (colour) maps to polygon mesh objects
- Other approaches to add detail:
  - environment mapping
  - bump mapping
  - displacement mapping
- Next week:
  - 3D texture mapping →



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