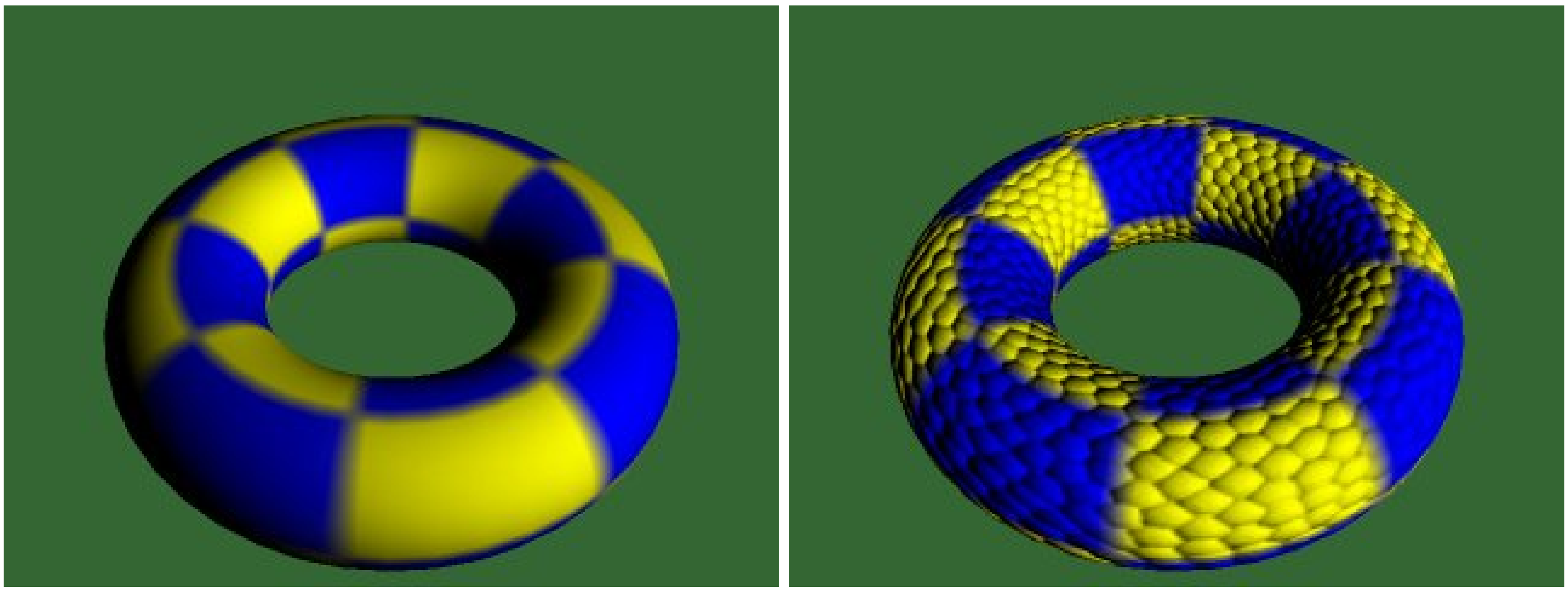
CS 112 - Bump Mapping and Environment Mapping

Bump Mapping

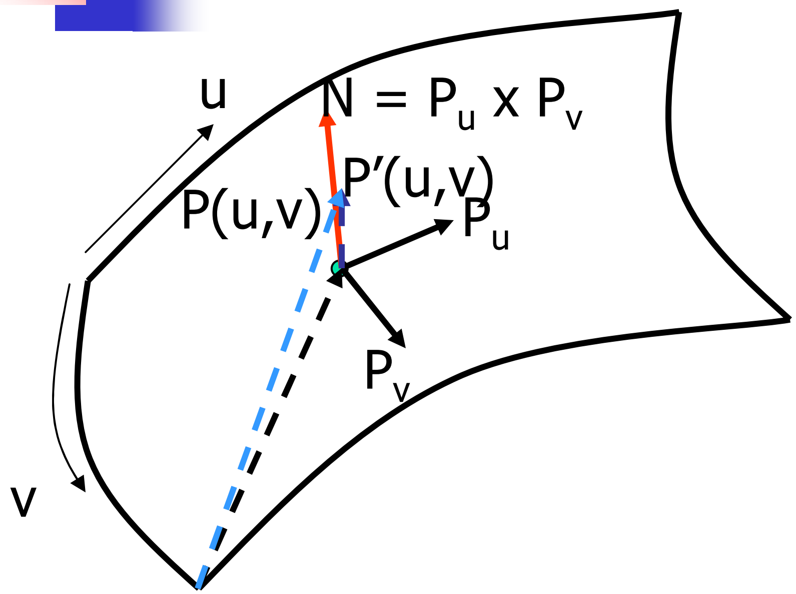
- Simulate the effects of details in geometry without adding geometry



Difference from Texture Mapping

- Texture mapping cannot simulate rough surface details
- Rough surfaces show illumination changes with the movement of the light or object
  - Textured objects cannot simulate that
  - Since independent of illumination parameters
- Basic Idea
  - Perturb the normal and use the perturbed normal for illumination computation

Normal Perturbation Theory



P – Point on the surface
P_u – Tangent at P in u direction
P_v – Tangent at P in v direction
N – Normal at P

Modify the surface position by adding a small perturbation (*called bump function)* in the direction of the normal:

$$P'(u,v) = P(u,v) + B(u,v)\,n$$

B(u,v) is a *scalar* function

This is a *vector* addition

Normal Perturbation Theory

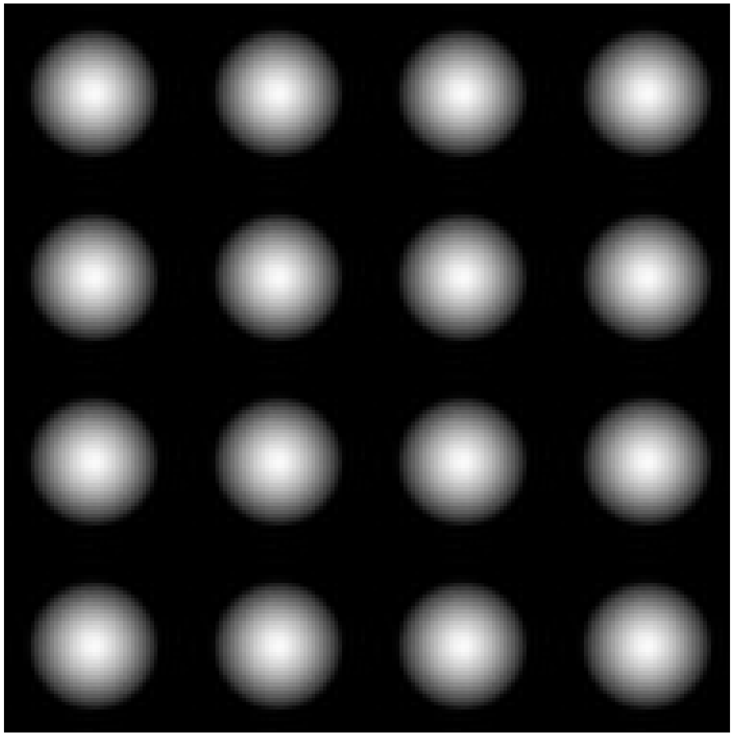
- $P'(u,v) = P(u,v) + B(u,v)\ N$
- $P'_u = P_u + B_u N + B N_u$
- $P'_u \approx P_u + B_u N$
- $P'_v \approx P_v + B_v N$
- $N' = P'_u \times P'_v$

$$= P_u \times P_v + B_v\ (P_u \times N) + B_u\ (P_v \times N) + B_u B_v\ (N \times N)$$

$$= N + B_v\ (P_u \times N) + B_u\ (P_v \times N)$$

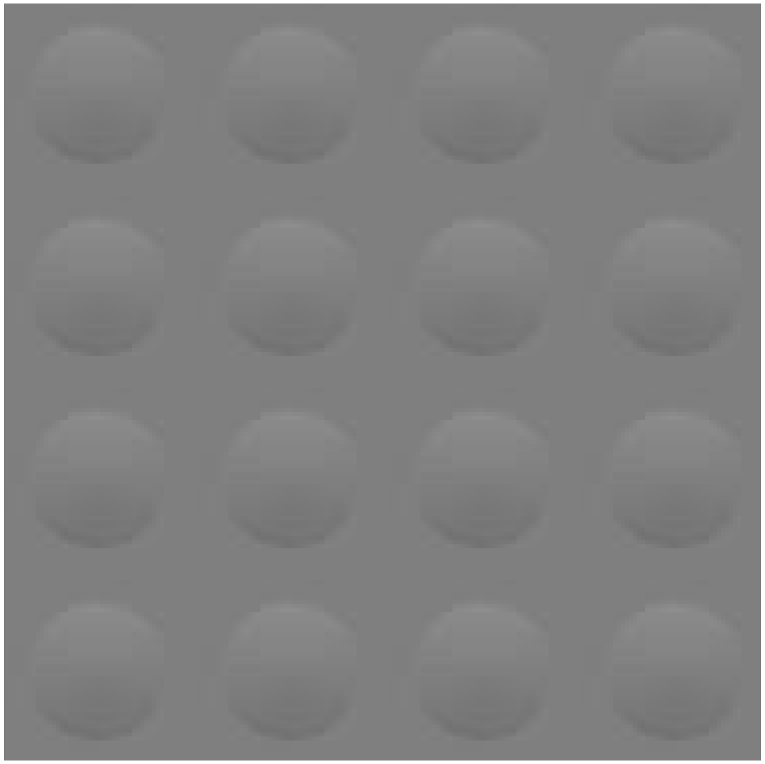
Implementation

- Start with a gray scale texture – B(u,v)



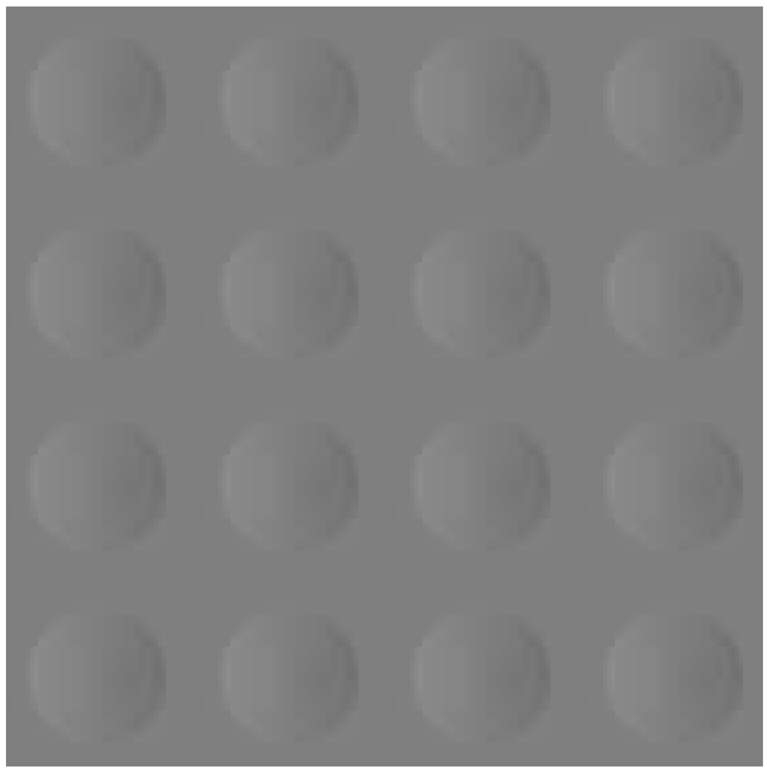
Implementation

- Find the image $B_u(u,v)$ by subtracting every pixel from its *right* neighbor



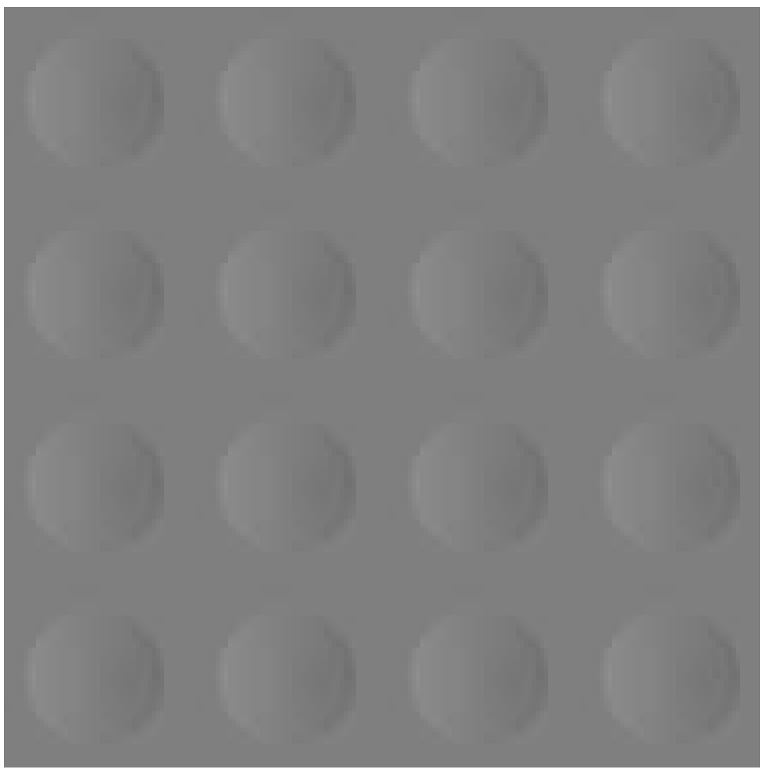
Implementation

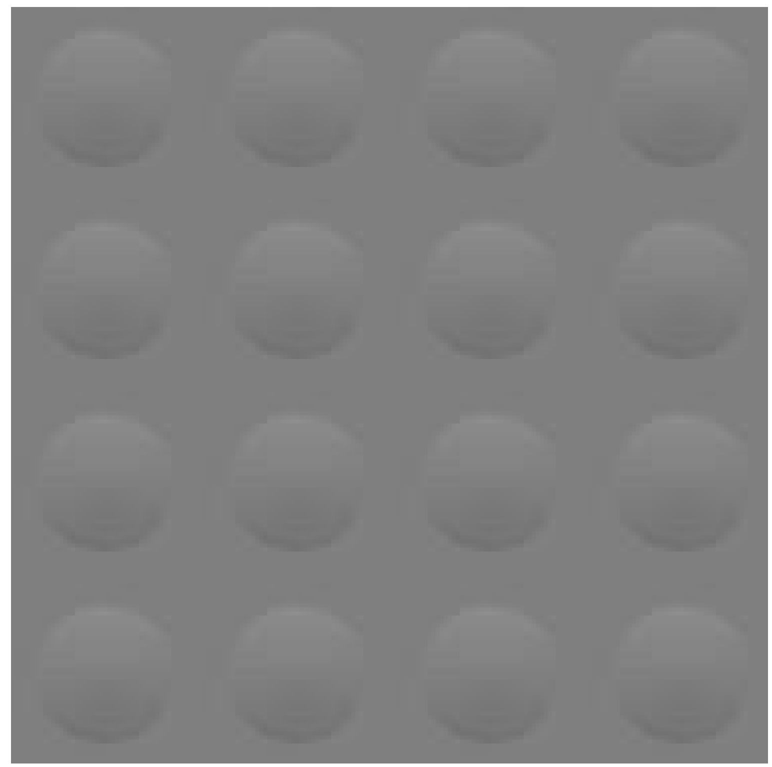
- Find the image $B_v(u,v)$ by subtracting every pixel from its *bottom* neighbor



Implementation

- $N' = N + \boxed{B_v}(P_u \times N) + \boxed{B_u}(P_v \times N)$





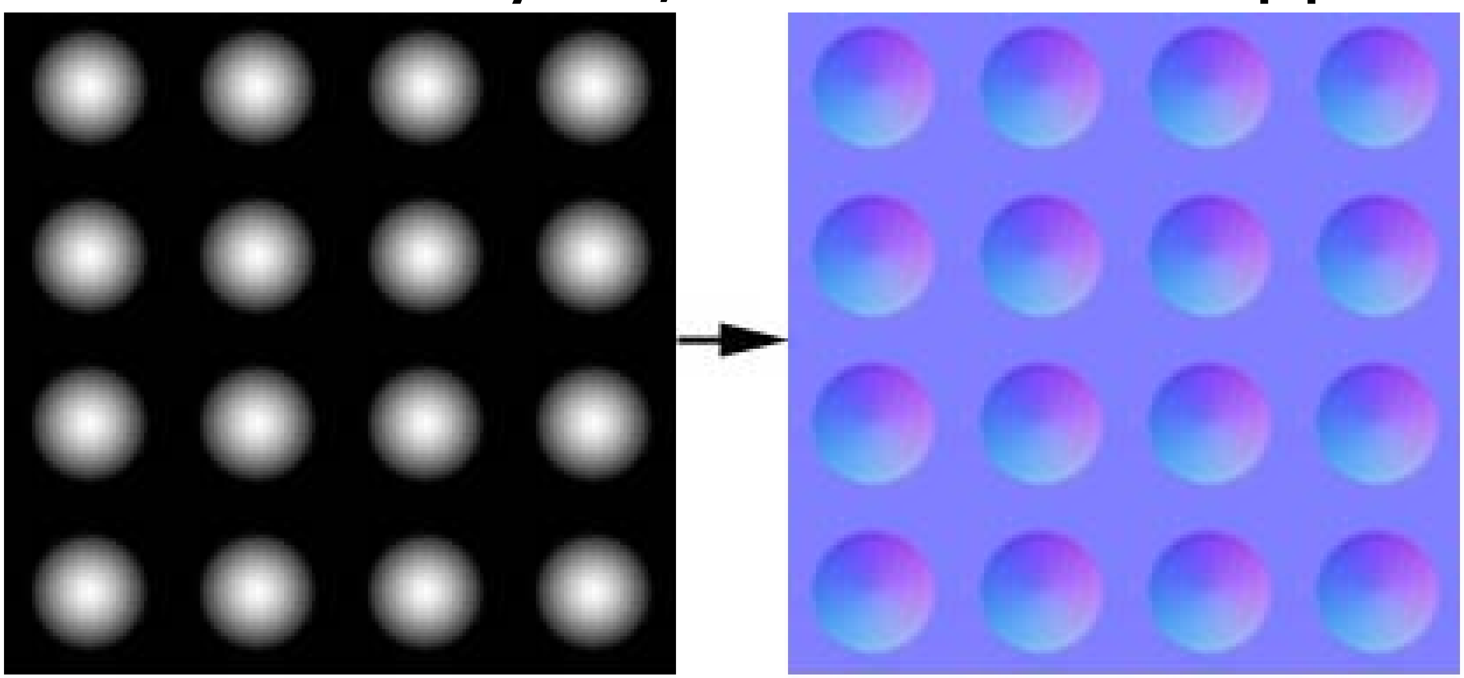
Implementation

- $N' = \boxed{N} + B_v \boxed{(P_u \times N)} + B_u \boxed{(P_v \times N)}$

  $(0, 0, 1) \quad (0, 1, 0) \quad (1, 0, 0)$
- These vectors are orthogonal to each other
- Define a *local* coordinate system at a vertex by normal and the tangent plane at this vertex
- $N' = (B_u, B_v, 1)$ – Perturbed normal in the local coordinate system of each triangle

Normal Map

- $N' = (B_u, B_v, 1)$ - Stored as RGB value
- Since B is always 1, it is bluish in appearance

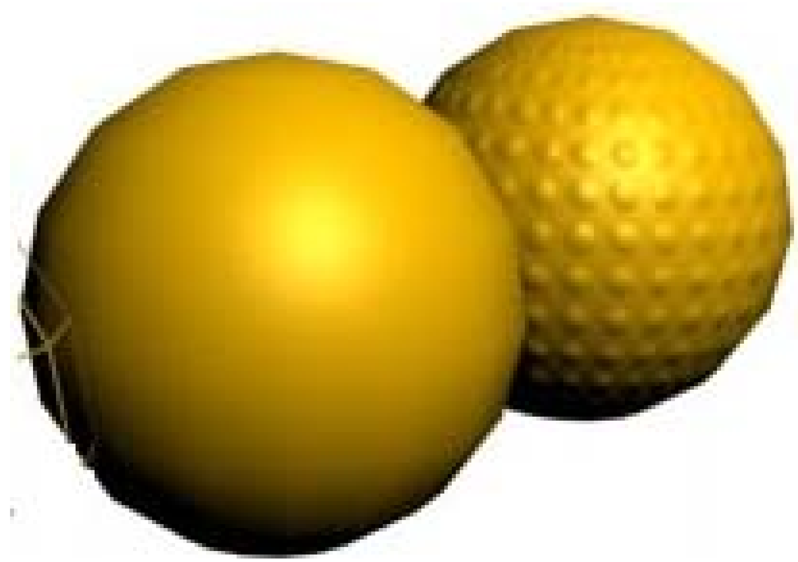


Light and View Vector

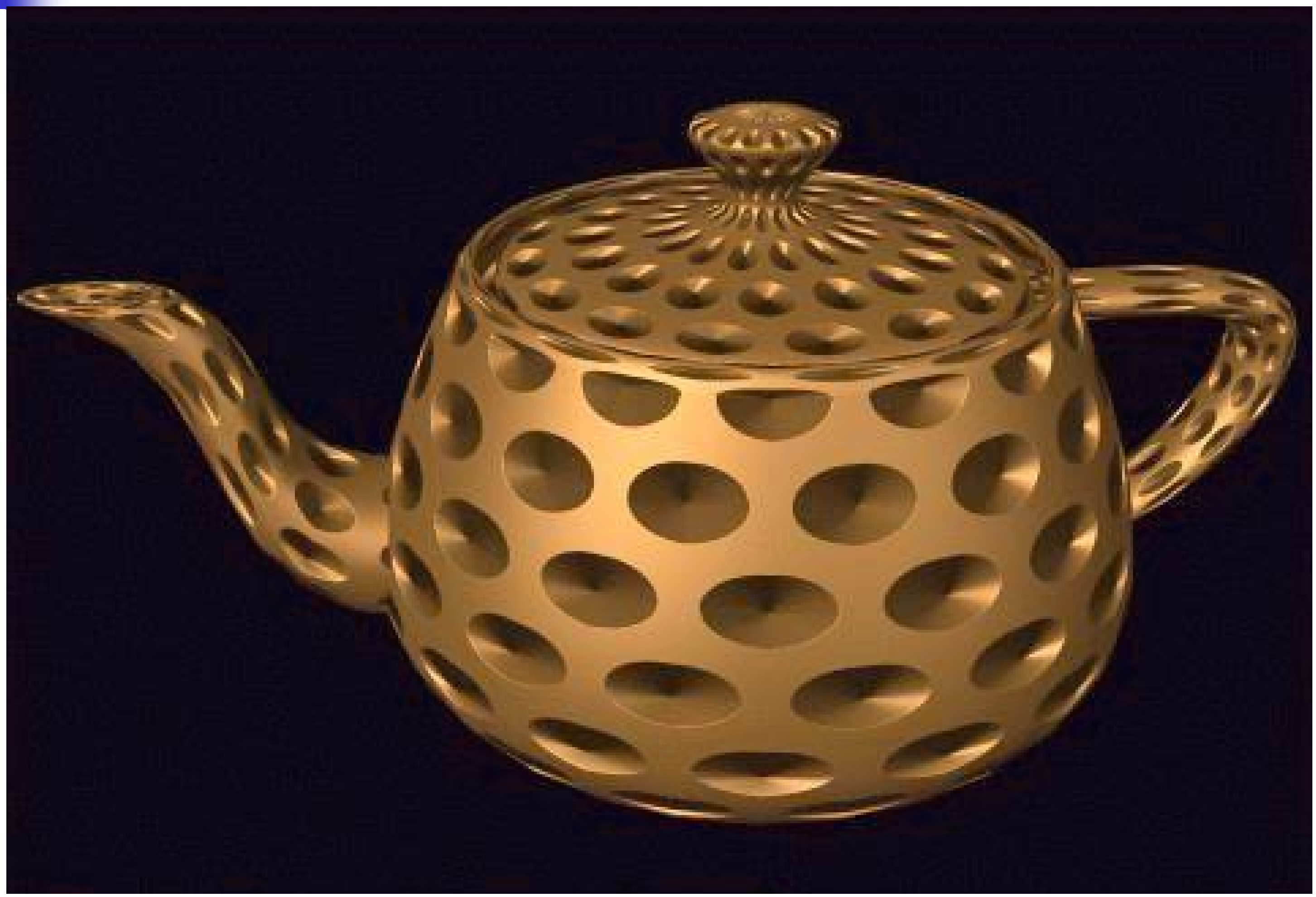
- Light and View vectors
  - Defined in the *global coordinate system*
- Convert these to the local coordinate system
  - Standard coordinate transformation

Rasterization

- Using pixel shaders
  - Interpolate light vector
  - Interpolate normal
  - Find the perturbed normal from the normal map
  - Do lighting computation in the local coordinate system



Examples



Interpolating Vectors?

- Yes, using pixel shaders you can do it
- So, you can do Phong shading using pixel shaders
- Standard openGL lighting does NOT do phong shading

Environment Map

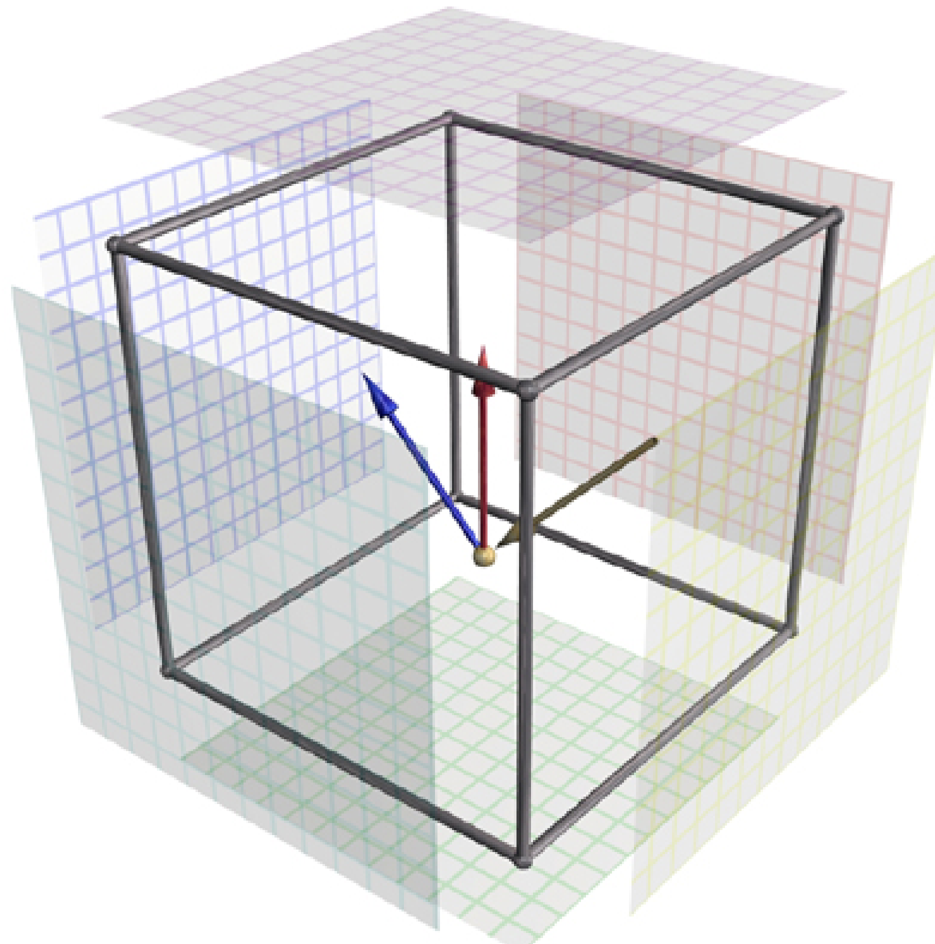
- Simulating the effect of reflection of environment on a shiny object

Environment Map

- Generate the map of the environment
  - On a sphere, cube or paraboloid
- Use a view-dependent mapping on the geometry

Generating the Map (Cube)

- Render the scene from one point, six times with six different view frustums
- On six planes of a cube



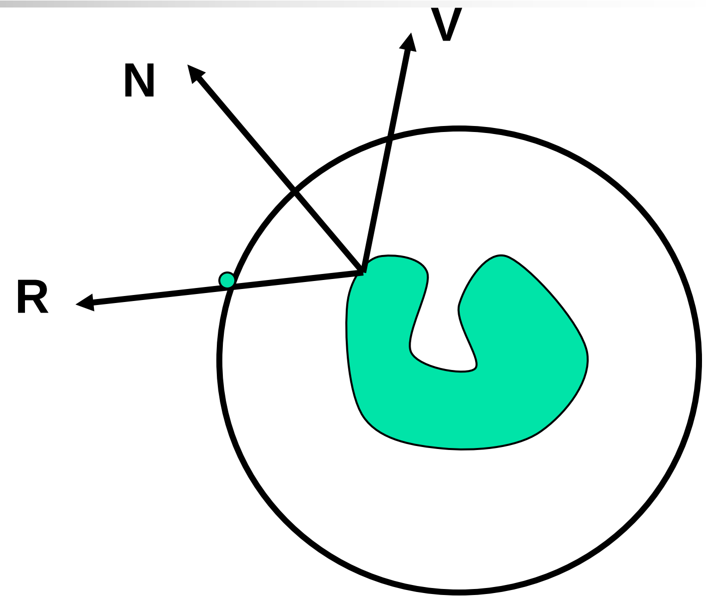
Cubic Environment Map

Generating the Map (Sphere)

- Use a angle parameterization
- Use ray tracing to sample the angles at uniform intervals
- OpenGL provides a spherical mapping for this

Mapping the Environment

- Enclose the arbitrary geometry in the sphere or the cube
- Reflect the view vector about the normal
- The environment in the direction of R is getting reflected about N and reaching the viewer at V



What does this remind you of?

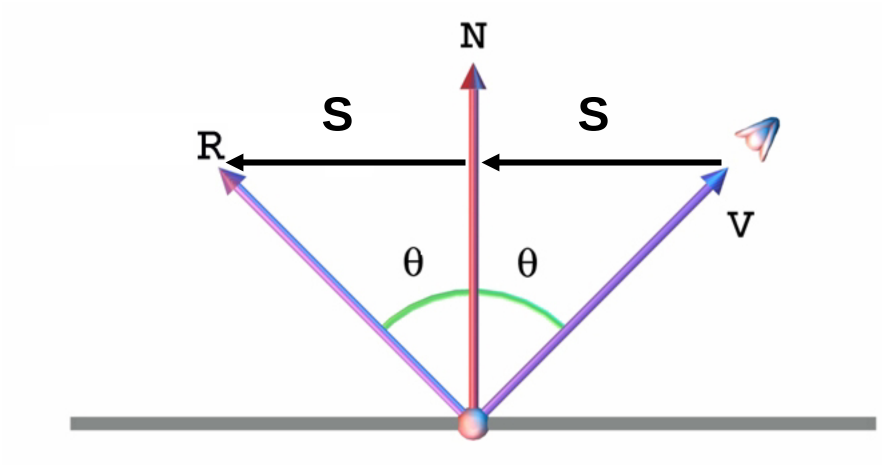
Difference: For texture mapping, the mapping dependent on geometry (vertex and normals), here it depends on the view

How to find R?

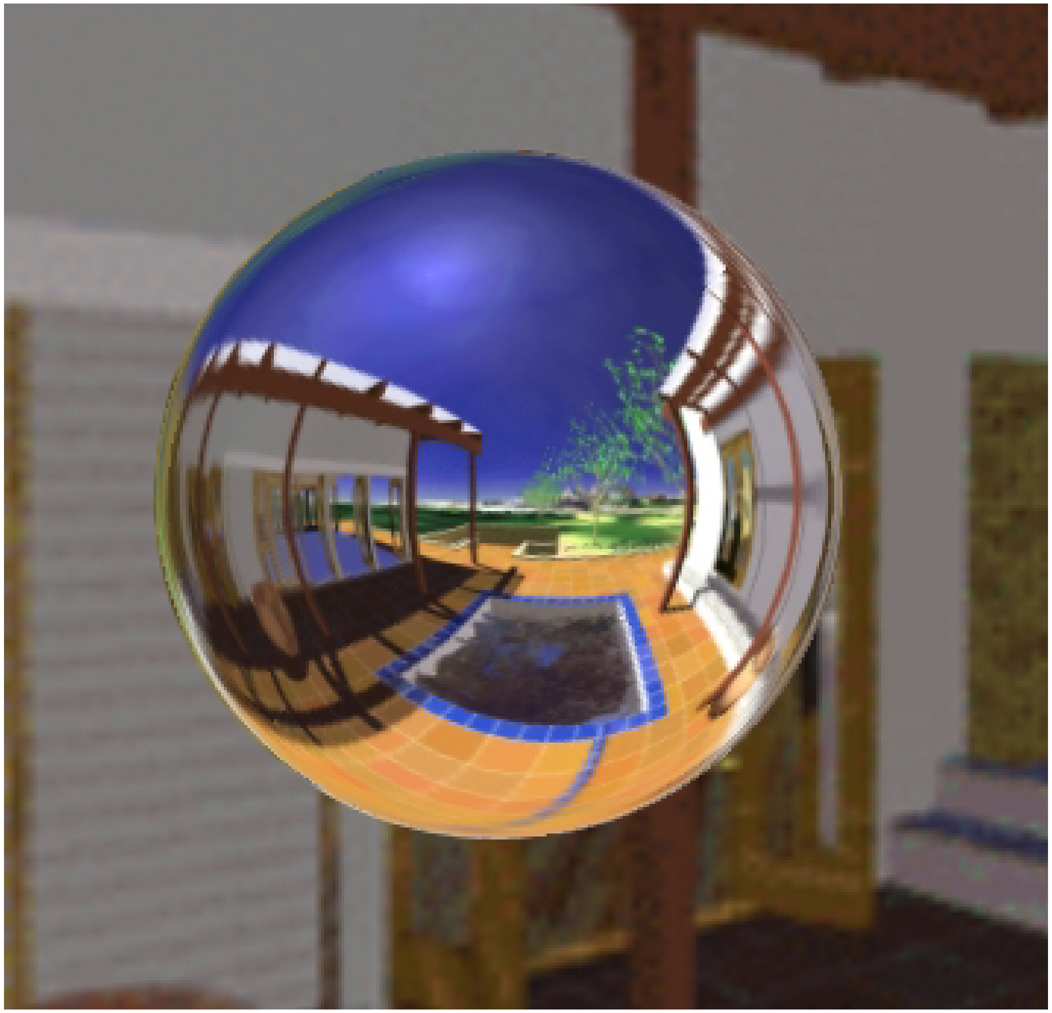
- $S = V \cos\theta - V$
- $-V + R = 2S$
- $R = 2S + V$

  $= 2V \cos\theta - V$

  $= 2V (N.V) - V$



Results



It is an approximation

- Ideally, we should get self reflections
- In this case, we would not get
- This is just an approximation
- To get accurate environment map, we have to use ray tracing