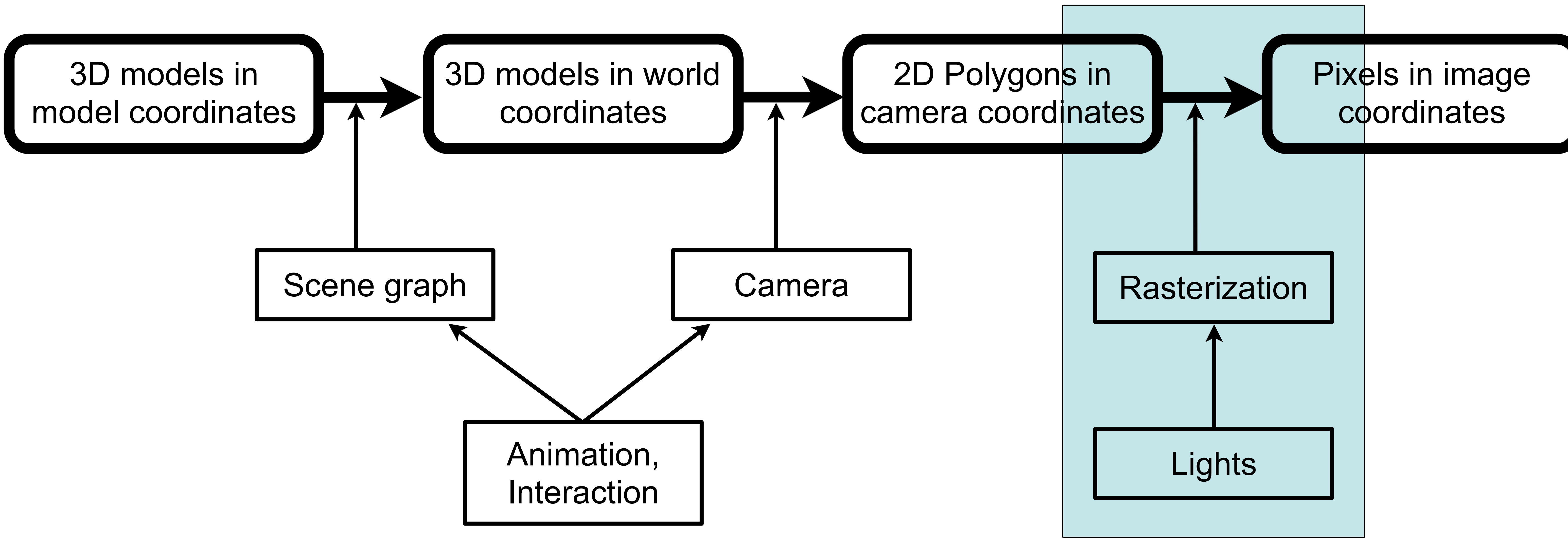
Computer Graphics 1

Chapter 6 (May 27th, 2010, 2-4pm):

Material descriptions - appearance

The 3D rendering pipeline (our version for this class)



Surfaces in nature

- What does a surface do to light? (mini-Brainstorming)

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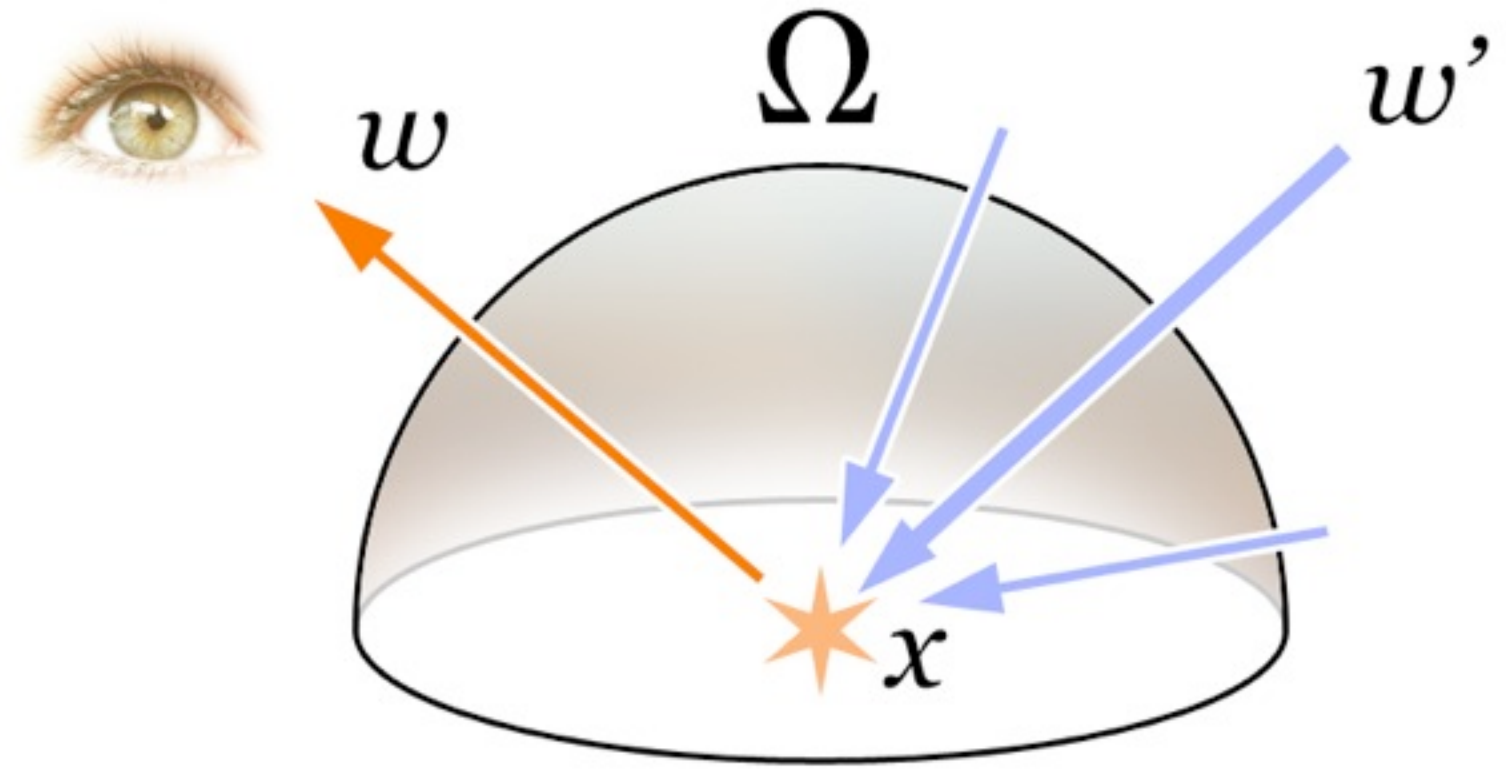
The rendering equation [Kajiya '86]

$$\underline{I_o(x,\vec{\omega})} = \underline{I_e(x,\vec{\omega})} + \int_\Omega \underline{f_r(x,\vec{\omega}',\vec{\omega})}\,\underline{I_i(x,\vec{\omega}')}\,\underline{(\vec{\omega}'\cdot\vec{n})}\,d\vec{\omega}'$$

- I_o = outgoing light
- I_e = emitted light
- Reflectance Function
- I_i = incoming light
- angle of incoming light

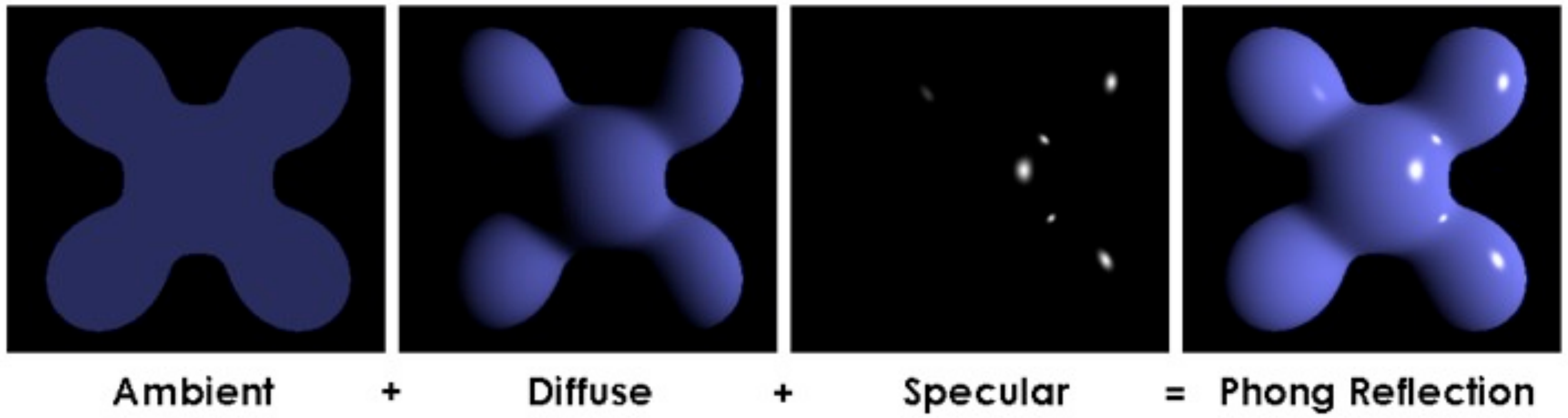


- Describes all flow of light in a scene in an abstract way
- doesn‘t describe some effects:
  –
  –

http://en.wikipedia.org/wiki/File:Rendering_eq.png http://de.wikipedia.org/w/index.php?title=Datei:Phong_components_version_4.png

Phong's illumination model [Bùi Tường Phong, 1973, PhD thesis]

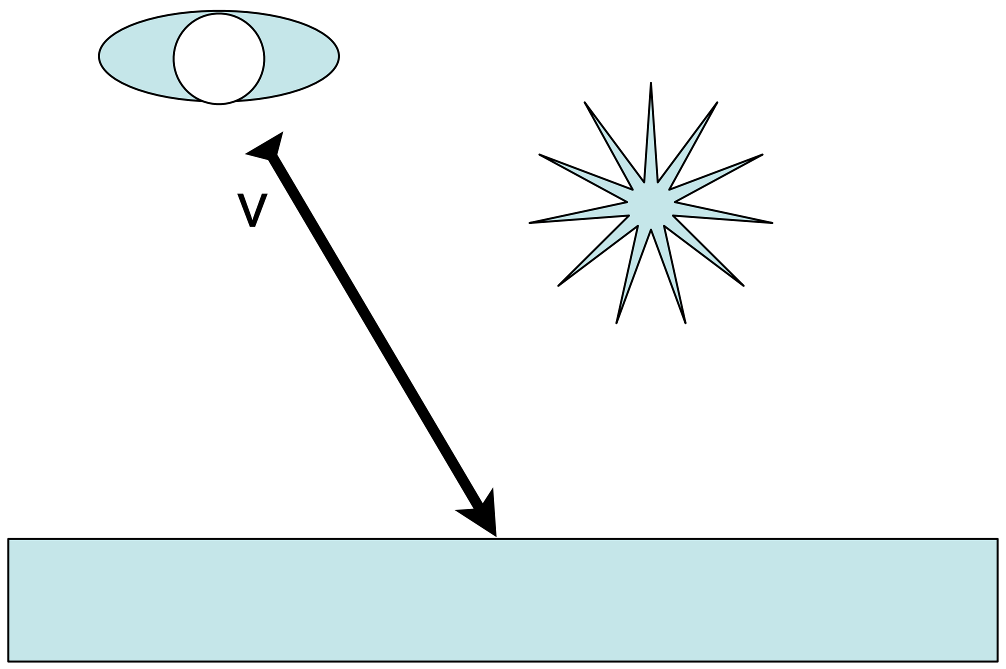
$$I_o = I_{amb} + I_{diff} + I_{spec}$$



- strong simplification and specialization of the situation
  - just 1 light source from a clear direction l
  - viewing direction is given as v
- only 3 components:
  - ambient component: reflection of ambient light source from and in all directions
  - diffuse component: diffuse reflection of the given light source in all directions
  - specular component: „glossy" reflection creating specular highlights

Ambient component

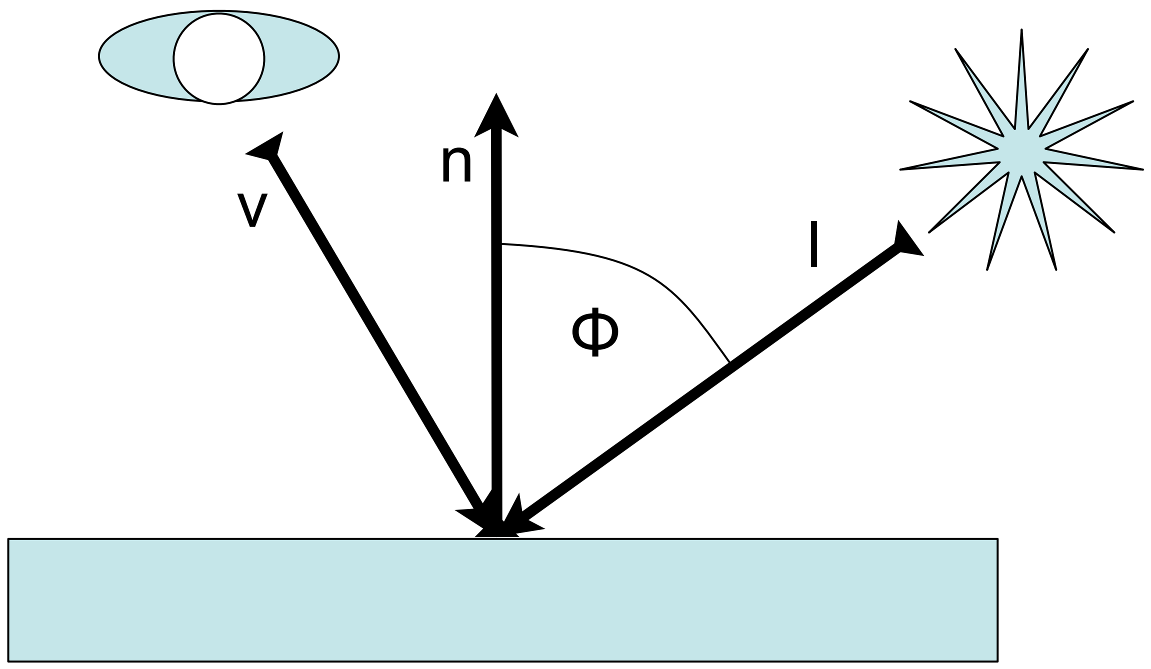
- I_a = Intensity of the ambient light source
- independent of any directions
- can simulate a „glowing in the dark“
- can be seen as the equivalent to emitted light I_e in the rendering equation



$$I_{amb} = I_a k_a$$

Diffuse component

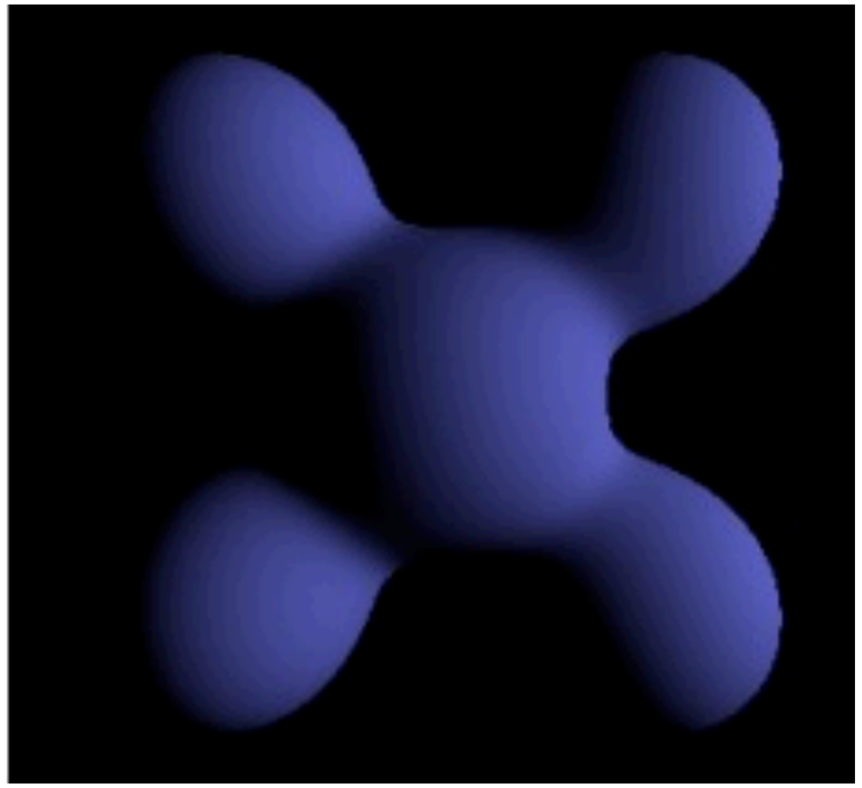
- diffuse reflection is equal in all directions
- depends on the angle of incident light
  - light along the surface normal : maximum
  - light perpendicular to the normal: 0



- cosine function describes the energy by which a given area is lit, dep. on angle
  - hence, cosine is used here

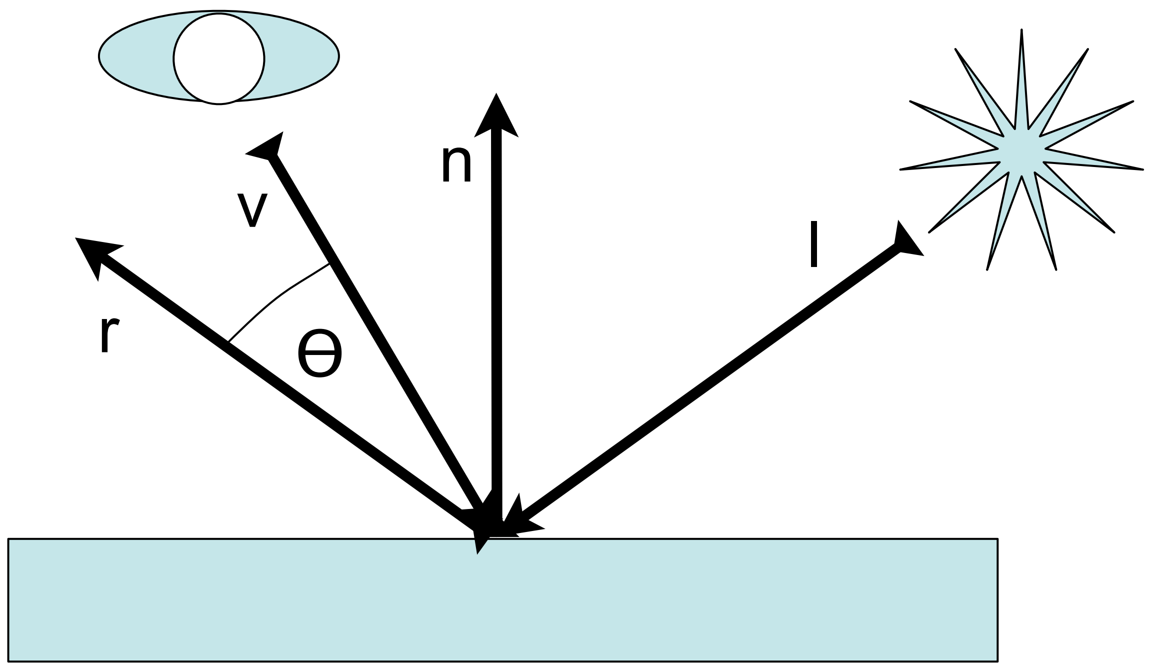
$$I_{diff} = I_i k_d cos\phi = I_i k_d(\vec{l} \cdot \vec{n})$$

- visual equivalent in nature: paper

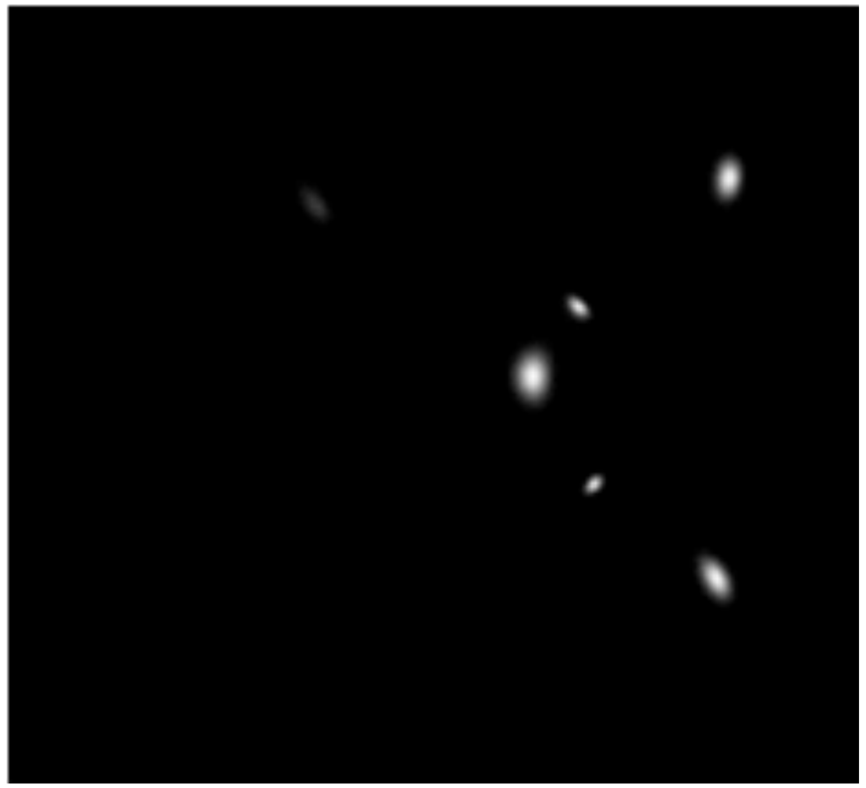


Specular reflection

- let r be the reflection of l on the surface
- specular reflection depends on the angle between v and r
- v = -r: maximum
- v and r perpendicular: minimum
- function $\cos^n$ behaves correctly
  - exponent n determines how wide the resulting specular highlight is
  - other functions could be used as well

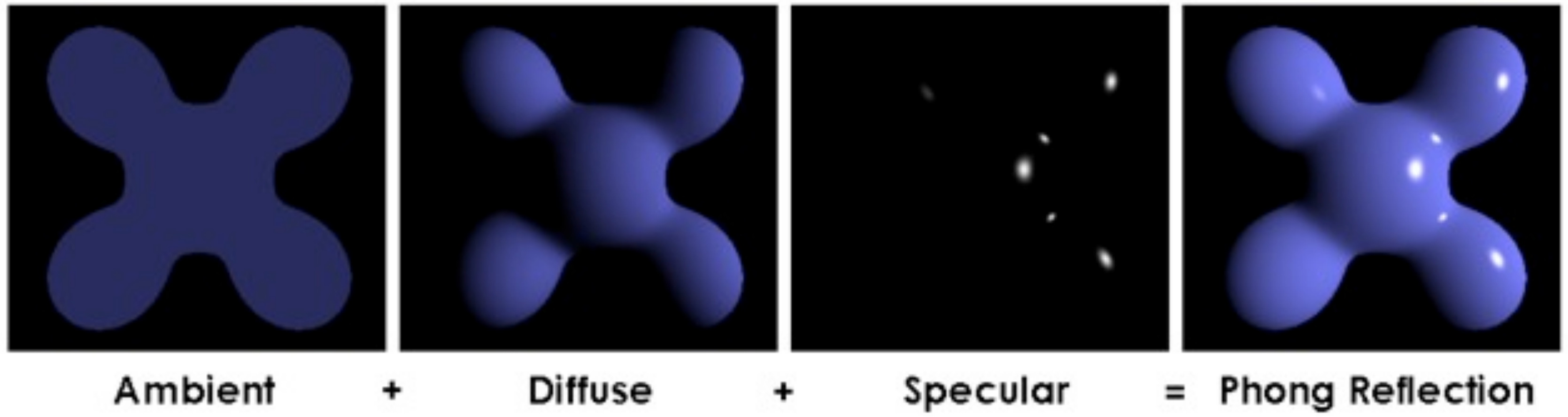


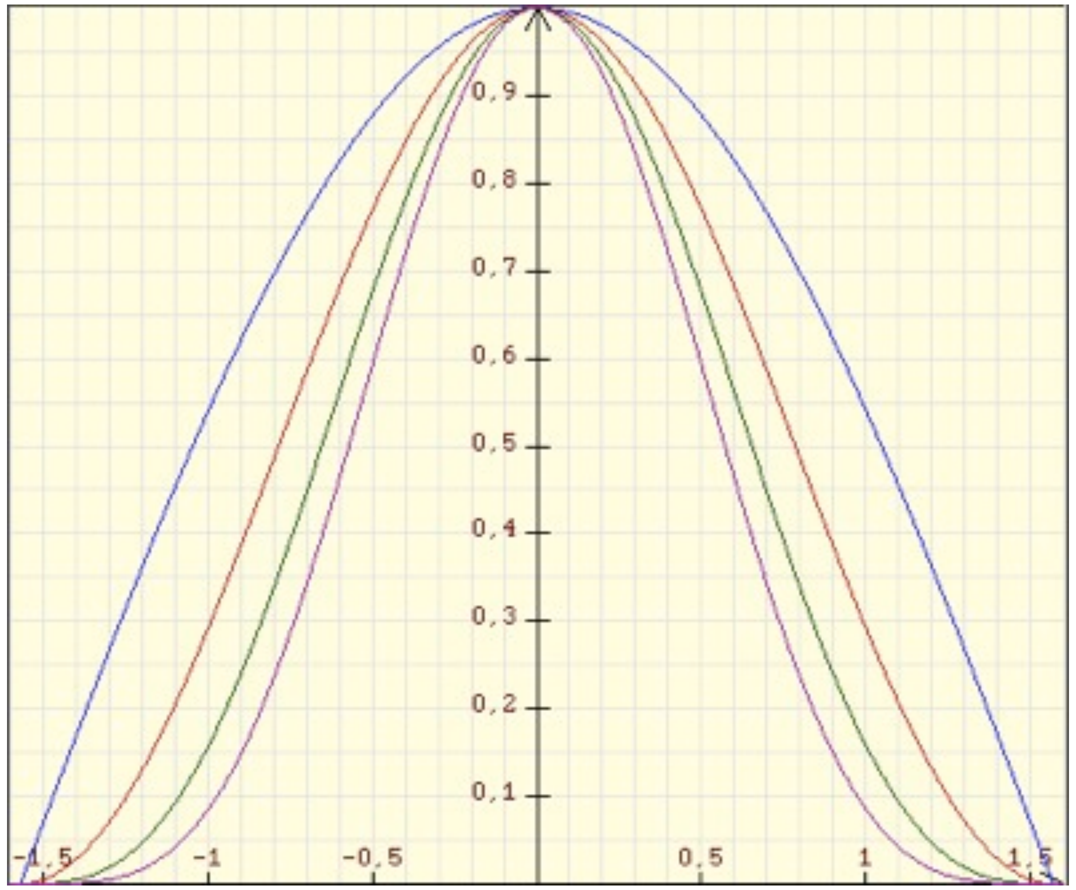
$$I_{spec} = I_i k_s cos^n\theta = I_i k_s (\vec{r} \cdot \vec{v})^n$$



Tweaking the parameters

$$I_o = I_{amb} + I_{diff} + I_{spec} = I_a k_a + I_i k_d(\vec{l} \cdot \vec{n}) + I_i k_s(\vec{r} \cdot \vec{v})^n$$





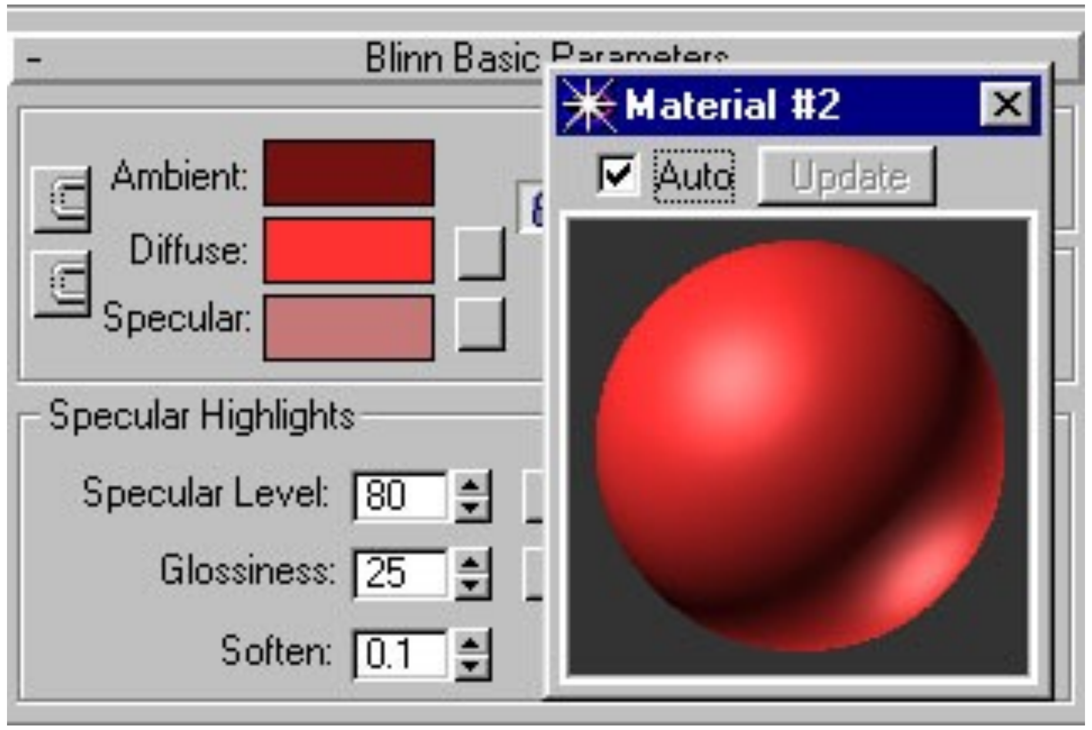
- choose $k_s = 0$ for perfectly matte material
- choose $k_a > 0$ to avoid harsh shadows
- keep k_a small to avoid „glowing“ objects
- add in some $k_s > 0$ to add gloss
- adjust the size of specular highlights with n

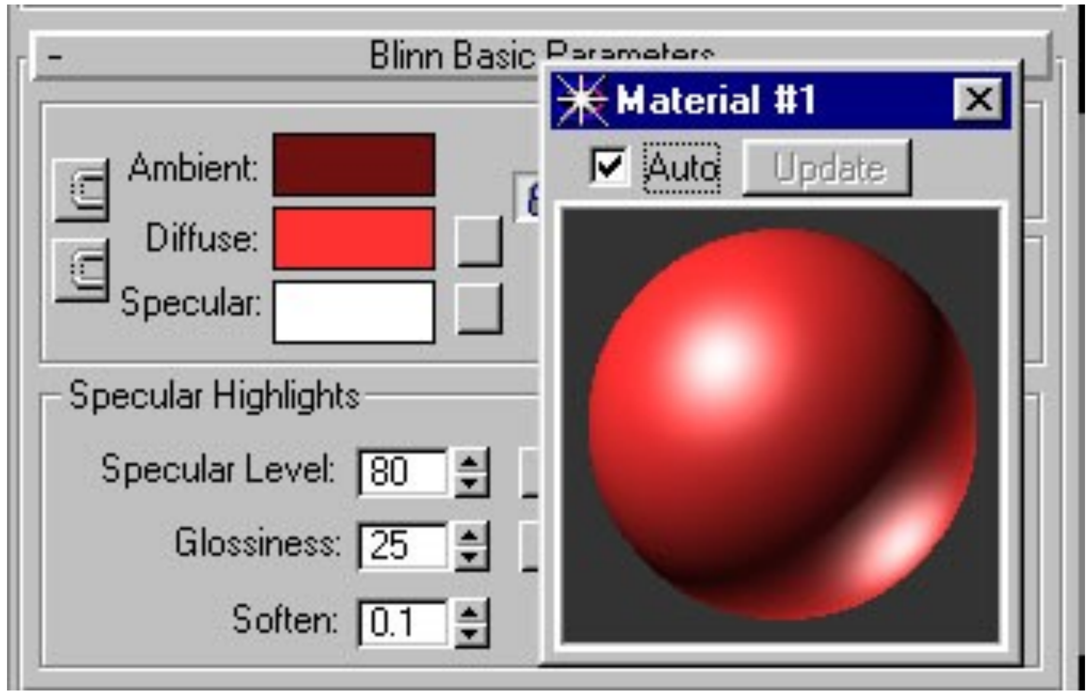
- all of these calculations generalize to (RGB) color, of course!

The VRML material node

```
Material {
  exposedField SFFloat  ambientIntensity  0.2          # [0,1]
  exposedField SFColor  diffuseColor      0.8 0.8 0.8  # [0,1]
  exposedField SFColor  emissiveColor     0 0 0        # [0,1]
  exposedField SFFloat  shininess         0.2          # [0,1]
  exposedField SFColor  specularColor     0 0 0        # [0,1]
  exposedField SFFloat  transparency      0            # [0,1]
}
```

shininess in VRML is multiplied by 128 to produce n in the lighting model.

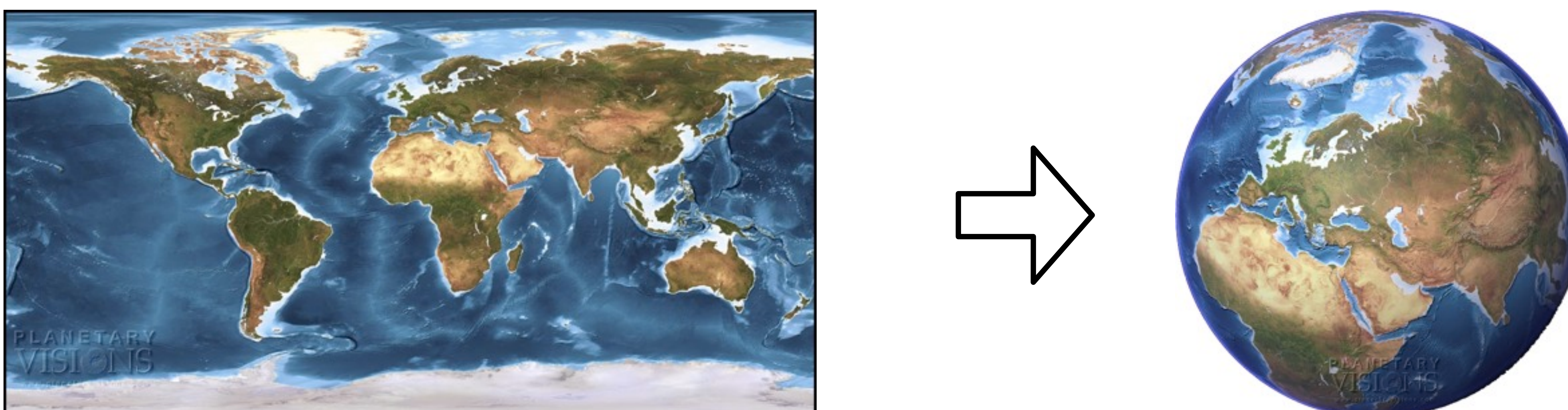




http://dxyner2000.com/tutorials/tut3.1.htm http://www.planetaryvisions.com/Texture_map.php?pid=4128

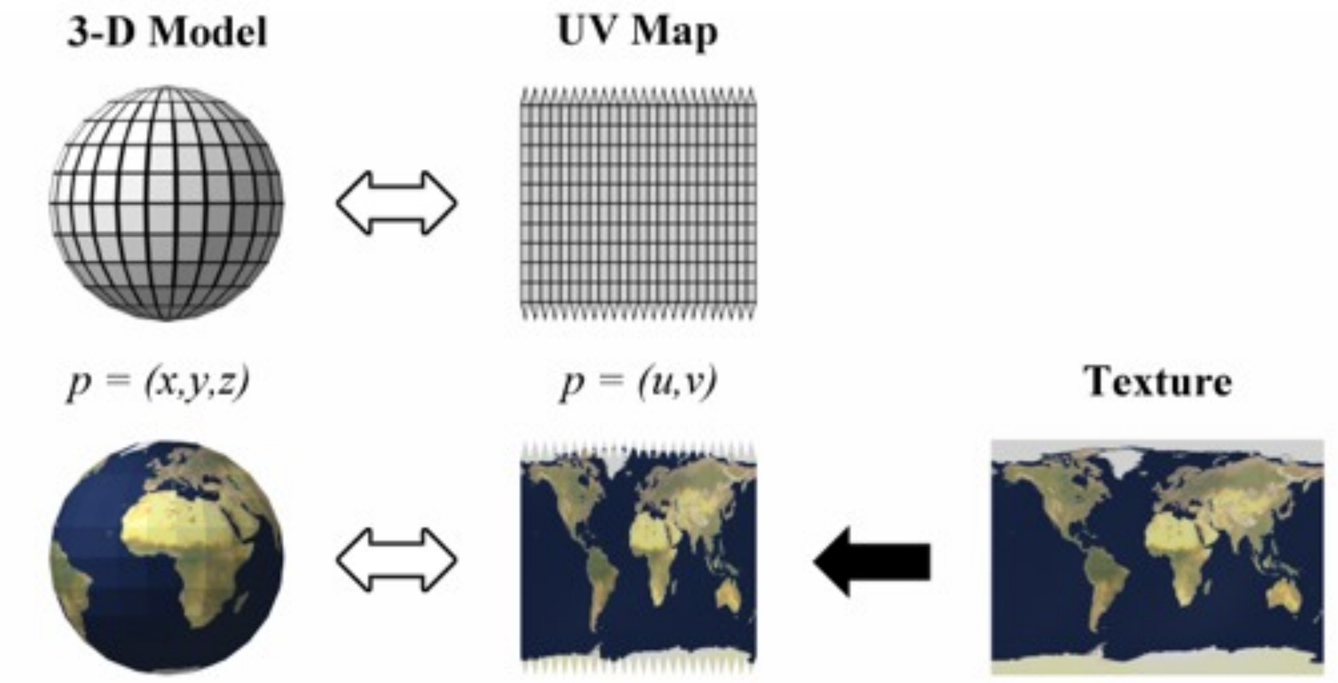
Textures and maps

- one of the simplest and oldest ways to achieve good looking objects with simple geometry
- texture design is a very complex task, needs a lot of imagination!
- idea: use a bitmap image, shrink wrap around the object
- use bitmap contents for object surface color: image map
  - can be used for other parameters, e.g., normal, elevation, transparency, reflection
- problem: what does shrink wrap mean exactly?

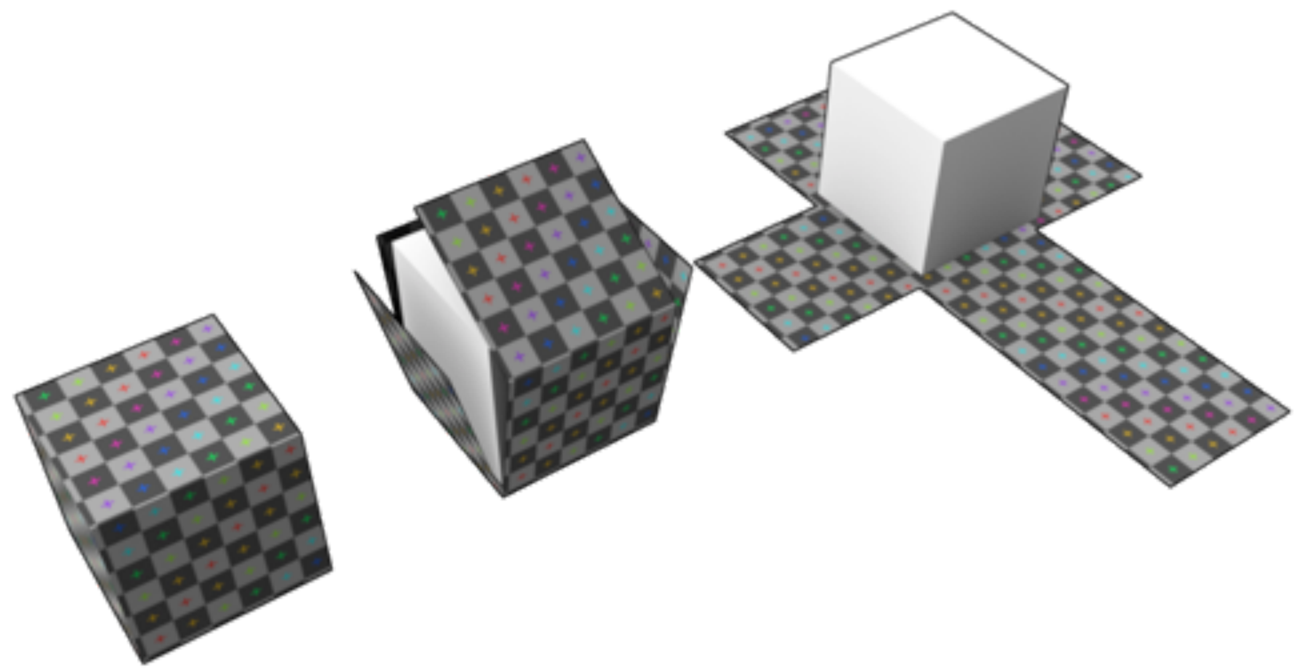


Texture coordinates and UV mapping

- each texture is mapped to a 1x1 square
- each object defines u,v coordinates
  - such that u,v are both between 0 and 1
- straightforward for geometric primitives
  - different possibilities
  - conventions exist
- not so easy for polygon models
  - can be defined per vertex
  - ...but who wants to do this?
  - simplifications: shrink a sphere onto the object
    - works fine with convex objects
    - always tricky for complicated objects



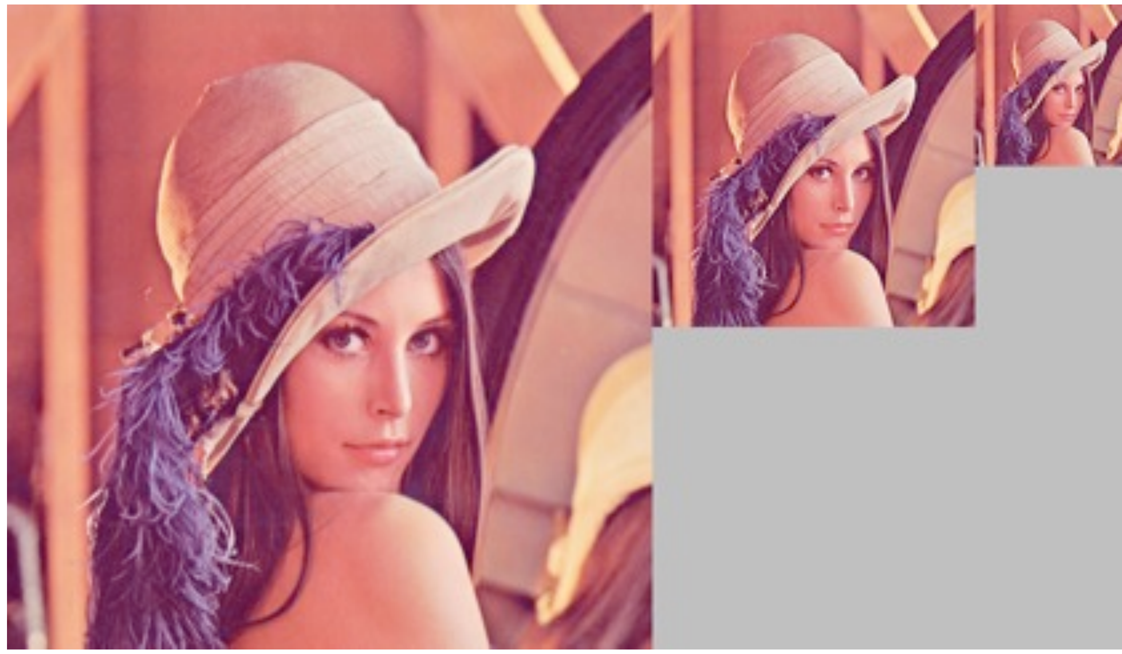
http://upload.wikimedia.org/wikipedia/commons/0/04/UVMapping.png



http://en.wikipedia.org/wiki/File:Cube_Representative_UV_Unwrapping.png

Texture filtering

- During rasterization, for each rendered pixel of the textured object we need to look up a color value from the texture
  - will almost always fall between texture pixels (texels)
  - texture may have too much resolution: sampling or integration
  - texture may have too little resolution: interpolation
- naive approach: pick the nearest neighbor pixel
  - leads to blocky textures
- better approach: bilinear filtering
  - pick the 4 neighboring pixels and linearly interpolate
  - eliminates excessive integration over pixels



http://wiki.aqsis.org/dev/texture_filtering

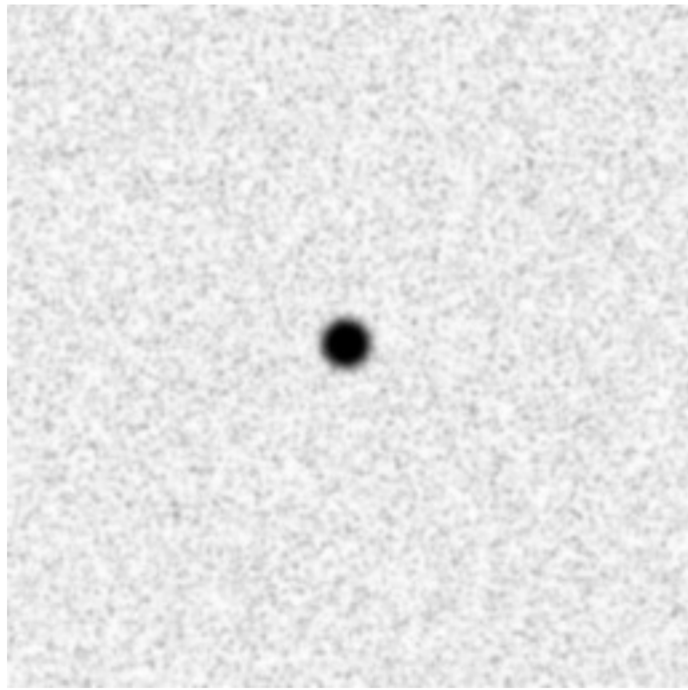
- Mip map: image pyramide with image scaled to 1/4 area in each step
- trilinear filtering: find the 2 best levels of the mip map and interpolate between them

Bump Mapping

- texture file is only greyscale
- grey value determines the elevation of the surface
  - e.g., black = dent, white = bulge

- can simulate complex 3D surface structure on very simple geometry
- often used together with image maps to enhance realism
- only modifies surface color, not silhouette!

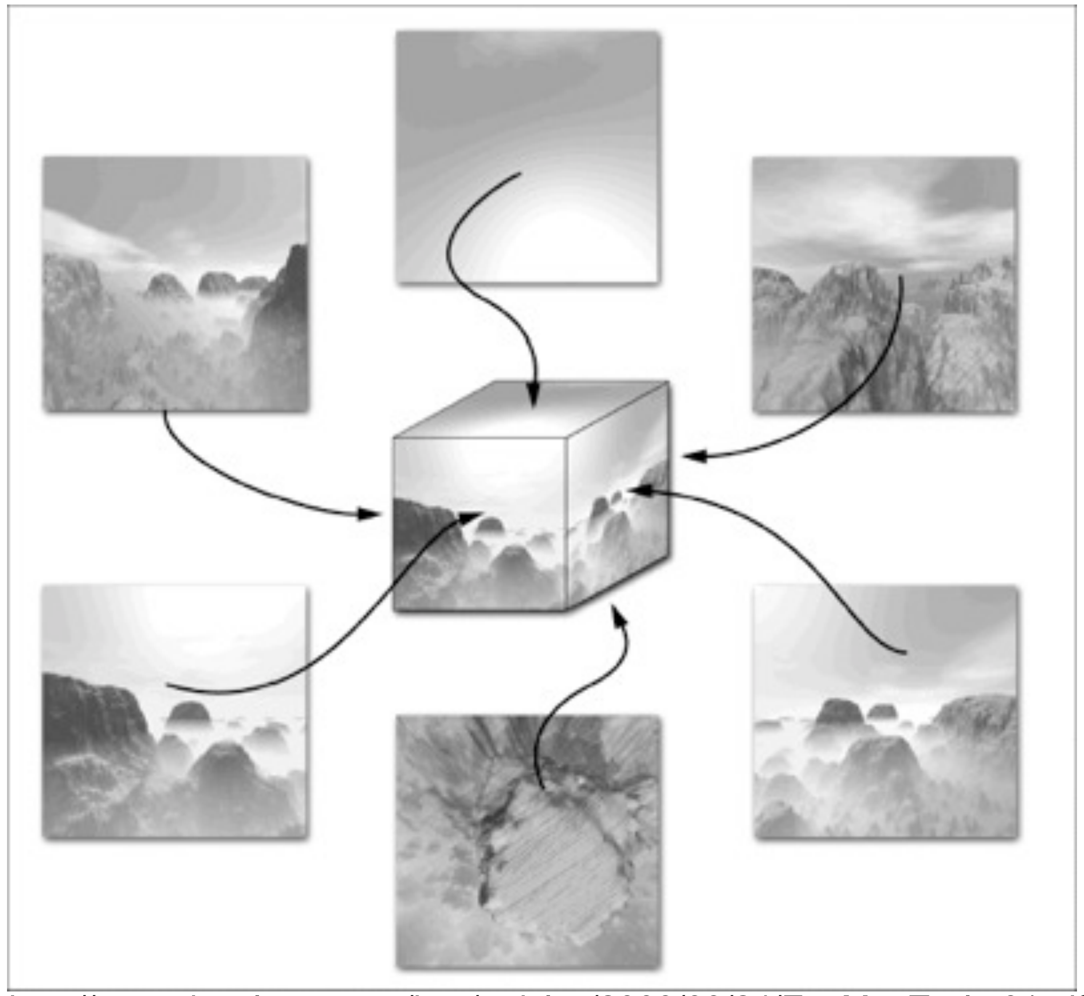
- introduced by Jim Blinn in 1978
  - related and improved techniques with similar look in use today: normal mapping, displacement mapping



http://en.wikipedia.org/wiki/Bump_mapping

Environment maps

- maps show the environment of the object
  - inside out view, 360 degrees in all directions
  - can be represented as 6 sides of a cube
  - can be photographed in a real environment
- can be used to calculate appropriate reflections
  - problem: ________________________________
- can also be used for lighting
  - record map in real environment
  - light a 3D model with it
  - this model will seem as if lit in the real environment
  - useful for combining real and virtual objects

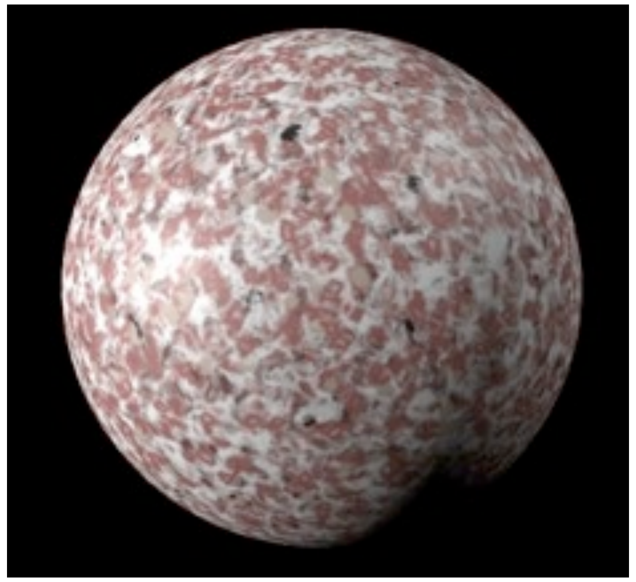


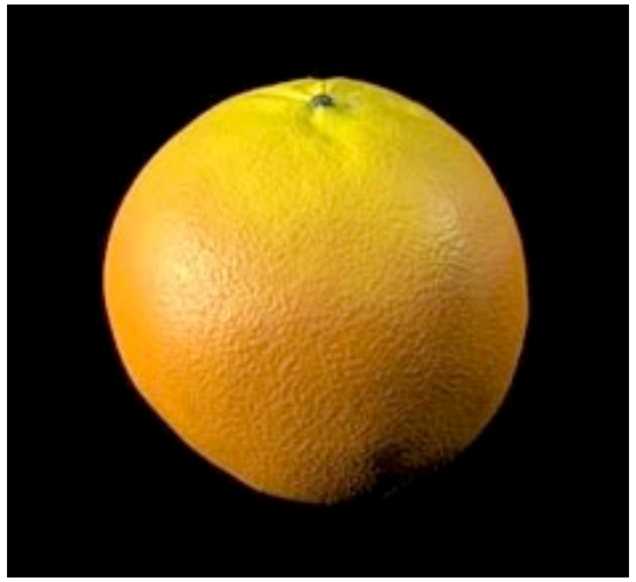
http://www.developer.com/img/articles/2003/03/24/EnvMapTecIm01.gif

http://tfc.duke.free.fr/

Procedural surface descriptions

- programming languages for surface descriptions
- can influence various stages of the rendering pipeline
  - in particular: can implement textures and the phong model
  - but also much more...
- can describe real 3D structures
  - not just surface color
- state of the art in high end 3D graphics
  - e.g., RenderMan, used in PIXAR movies
  - also in OpenGL, DirectX
- detailed implementation varies depending on the platform
- in OpenGL: vertex shaders and fragment shaders
  - fragments = parts of an object that cover 1 screen pixel





https://renderman.pixar.com/products/tools/rms-slim.html

OpenGL: Vertex and Fragment shaders

- A vertex shader can do the following:
  - transform the vertex position using the modelview and projection matrices
  - transform normals, and if required normalize them
  - generate and transform texture coordinates
  - lighting per vertex or compute values for lighting per pixel
  - color computation
- A fragment shader can do the following:
  - compute colors, and texture coordinates per pixel
  - apply a texture
  - fog computation
  - compute normals if you want lighting per pixel

- This, and more details at: http://www.lighthouse3d.com/opengl/glsl/

Links, various

- You‘ve been doing 3DCG too long if ...when people ask you, "What's up?", you reply "Y": http://www.deakin.edu.au/~agoodman/scc308/toolong.html

- Detailed class material from one of the world‘s leading groups: http://graphics.stanford.edu/courses/
- Compact overviews from the wisdom of the masses ;-): http://en.wikipedia.org/wiki/Rendering_(computer_graphics)

- Kajiya, James T. (1986), "The rendering equation", Siggraph 1986: 143, doi:10.1145/15922.15902

- Some nice tutorials related to this class: http://www.lighthouse3d.com/