Computer Graphics

Review

Taku Komura

Overview

- Review
- Some additional things

Review

- Graphics pipeline
- Modeling, object representations
  - Procedural modeling, L-System
- Projection and Rasterization
- Illumination
- Hidden surface removal
- Texture mapping, bump mapping, environment mapping
- Anti-alising
- Shadows
- Global Illumination
- Curves and surfaces

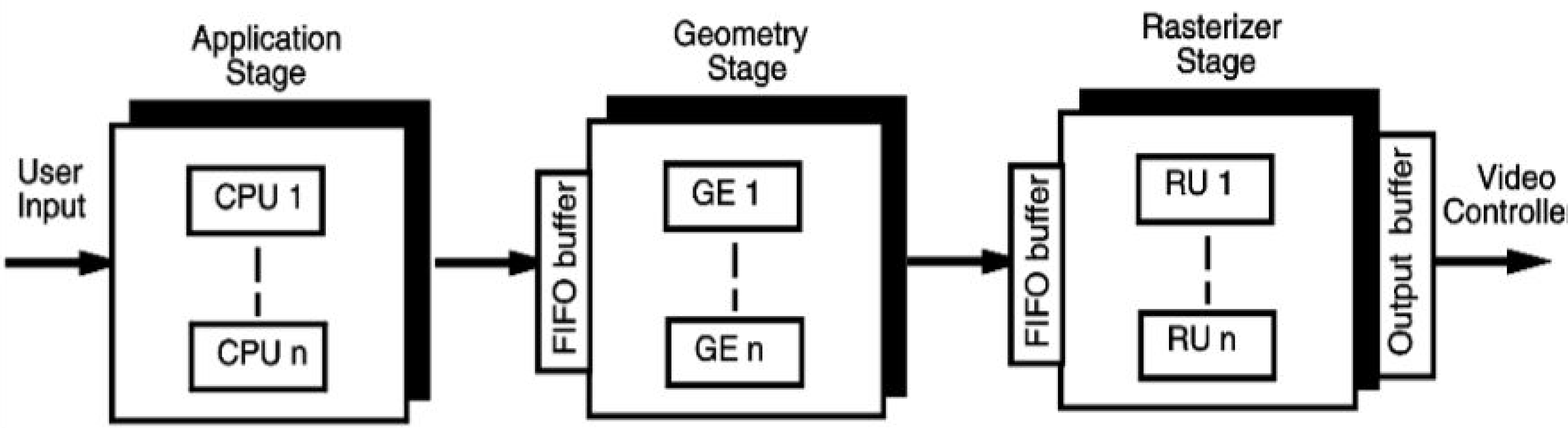
Graphics Pipeline

Three stages

- Application stage
  - Entirely done in the CPU
  - Loading data, getting user input
- Geometric stage
  - Applying transformation to vertices
  - Computing the attributes for the vertices
- Rasterization stage
  - Per pixel computation
  - Converting the continuous representation to the discrete representations

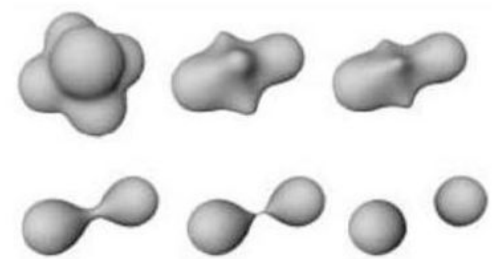
In which stage the following events happen?

- Illumination in Phong shading
- Illumination in Gouraud shading
- Bump mapping
- Antialiasing
- Computing the pose of a robot character
- Hidden surface removal

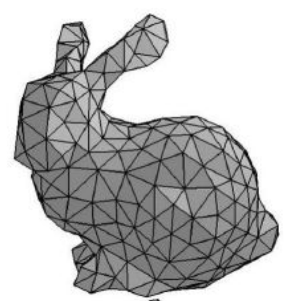


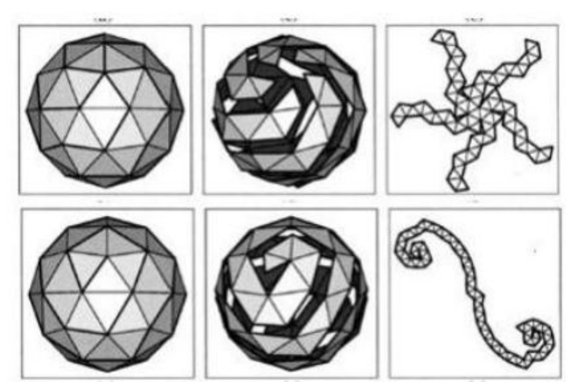
Modeling objects

- Triangle Strips
- Metaballs
- Procedural methods
- Parametric surfaces (NURBS etc)
- Subdivision surfaces
- 3D scanning
- Procedural methods

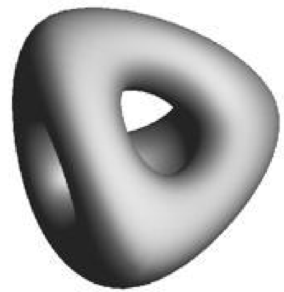


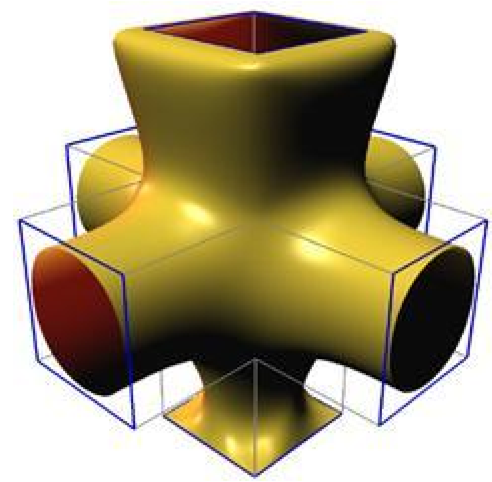
Some determinstic 3D branching plants.

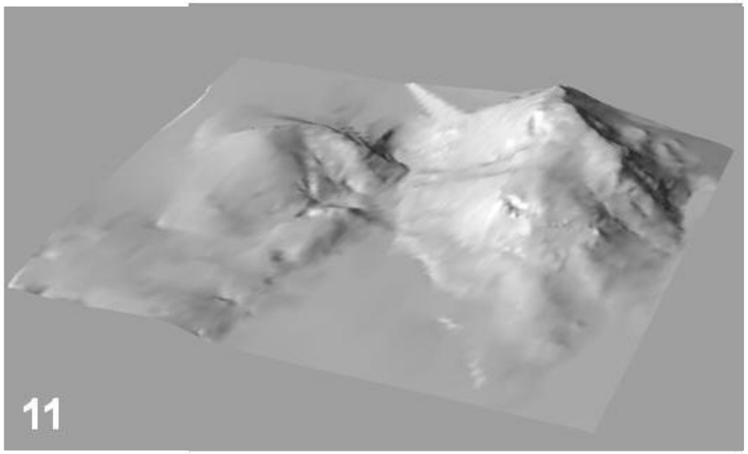




What are the good ways to model the following objects?

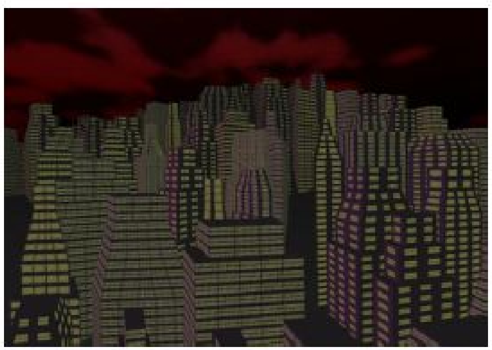


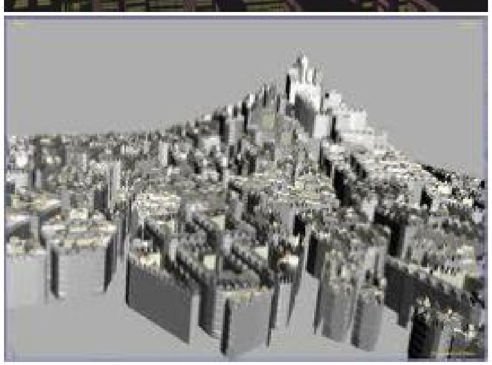


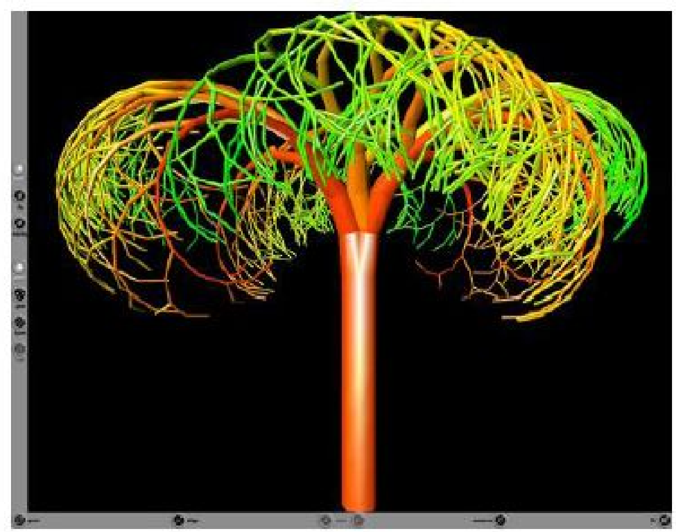


Procedural Modeling

- Modeling objects by rules
  - Modeling cities and trees
  - Example: L-system (trees, flowers)

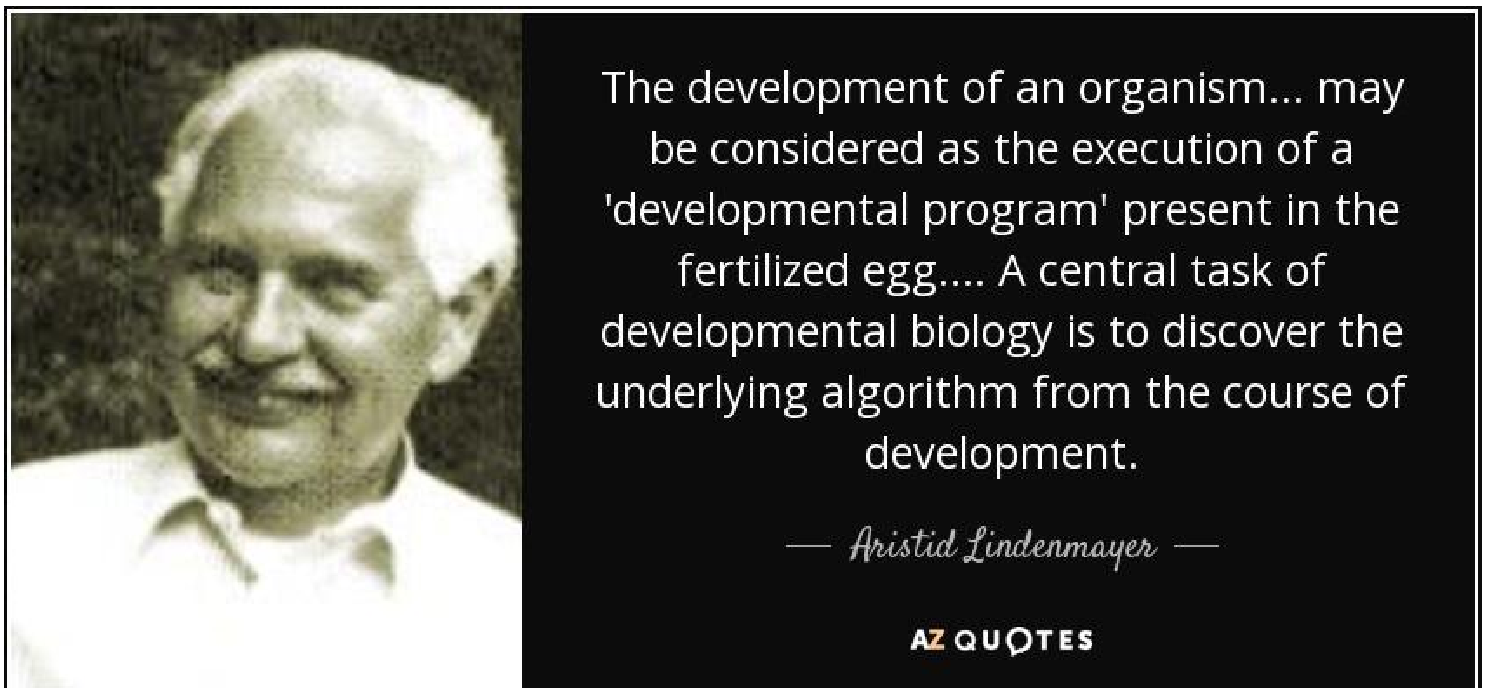






What is an L-System ?

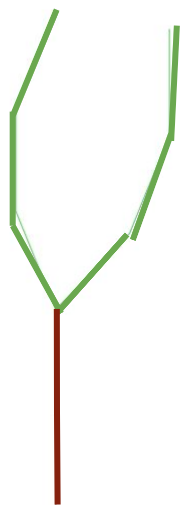
- Lindenmayer system, or L-System, was introduced in 1968 by the biologist Aristid Lindemmayer
- A mathematical theory on plant development.



L-Systems

- Representing plants by strings

F=C0FF-[C1-F+F+F]+[C2+F-F-F] →



- Starting from an *axiom*
- Expand based on deterministic rules

Example

- Variables a, b
- Axiom : a
- RULES: a->aba, b->bbb

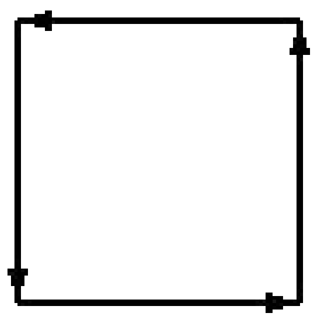
- How does it go on then?
  - Step #0 : a (axiom)
  - Step #1 : aba
  - Step #2 : aba bbb aba
  - Step #3 : aba bbb aba bbb bbb bbb aba bbb aba
  - Step #4 : ...

Turtle interpretation of L-strings

- ***F*** Move forward a step of length *d* and connect the new position with the last position by a line segment.
- \+ Turn left by angle (counter clockwise)
- \- Turn right by angle (clockwise).

δ

δ

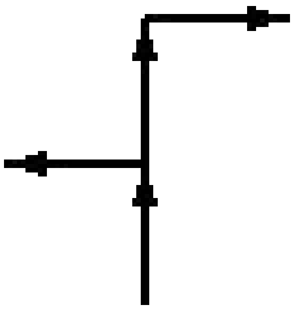


Turtle interpretation, $\delta = 90$ degrees,

$F+F+F+F$

Bracketed L-systems

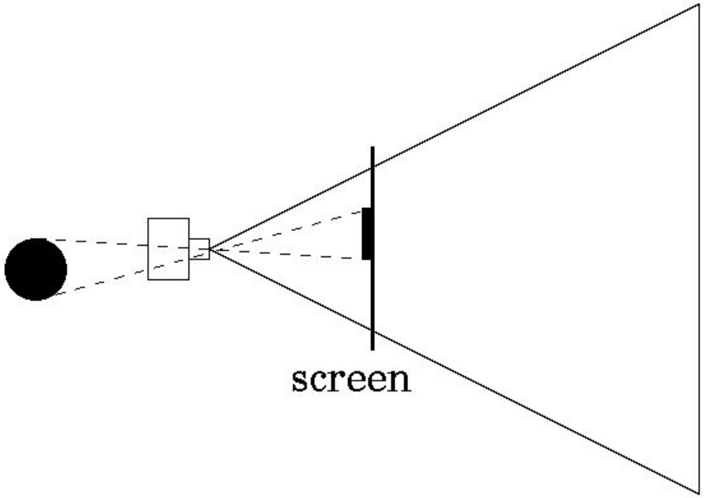
- In order to specify the data structure for presenting axial trees, the concept of ``strings with brackets" was introduced
- The L-system's alphabet is extended by two new commands
  - [Push the current state of the turtle onto a stack.
  -] Pop a state from the stack and make it the current state of the turtle.

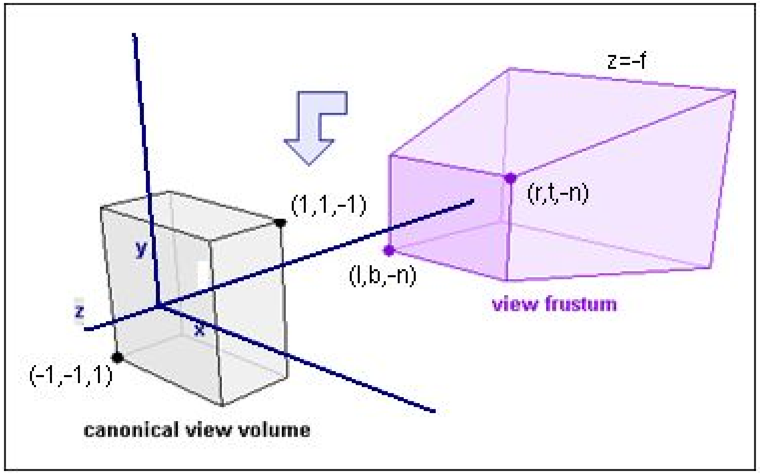


Bracketed L-string, $\delta = 90$ degrees, $F[+F]F[-F]$

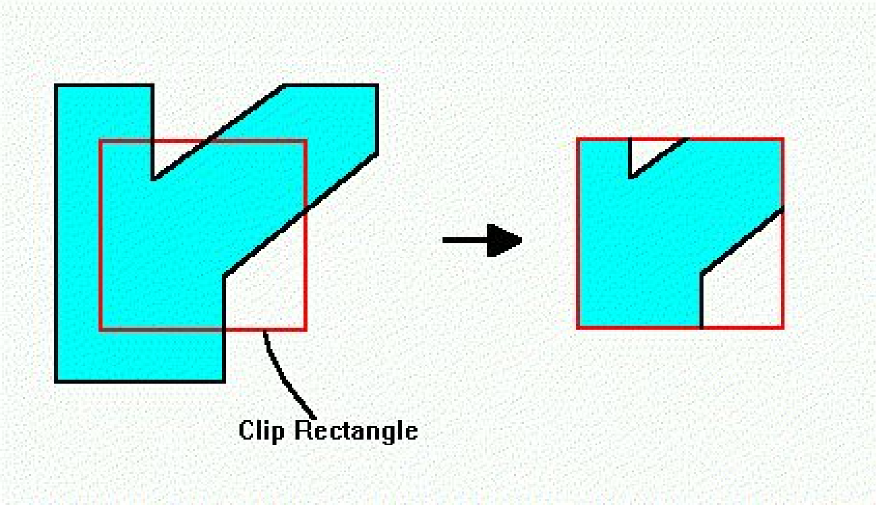
http://www.kevs3d.co.uk/dev/lsystems/#

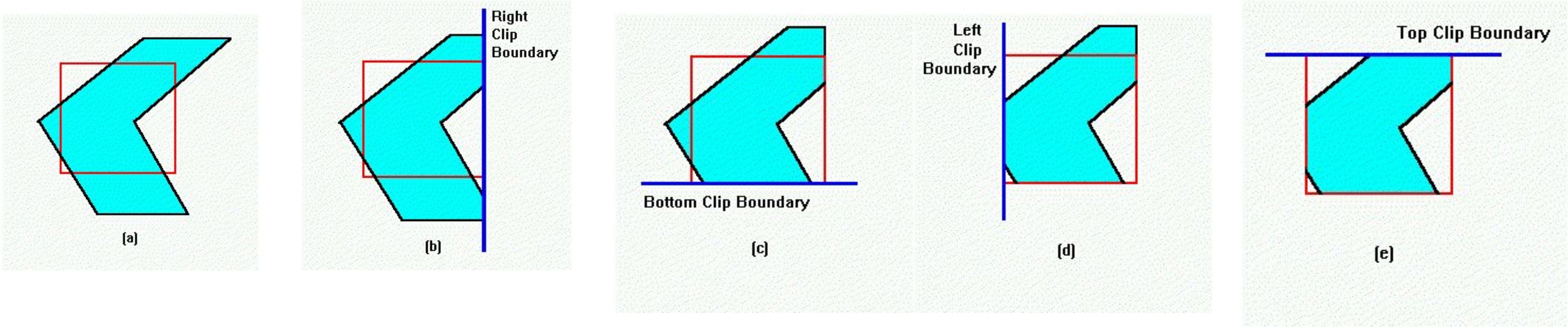
Projection


screen


z=-f
(1,1,-1)
(r,t,-n)
y
(l,b,-n)
z
x
view frustum
(-1,-1,1)
canonical view volume

Clipping

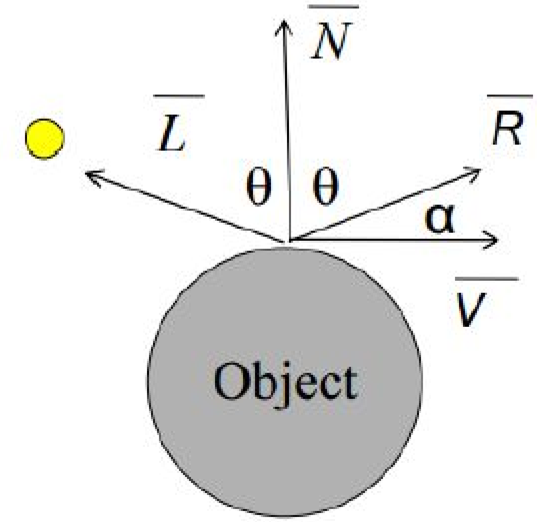

Clip Rectangle


(a)
Right
Clip
Boundary
(b)
Bottom Clip Boundary
(c)
Left
Clip
Boundary
(d)
Top Clip Boundary
(e)

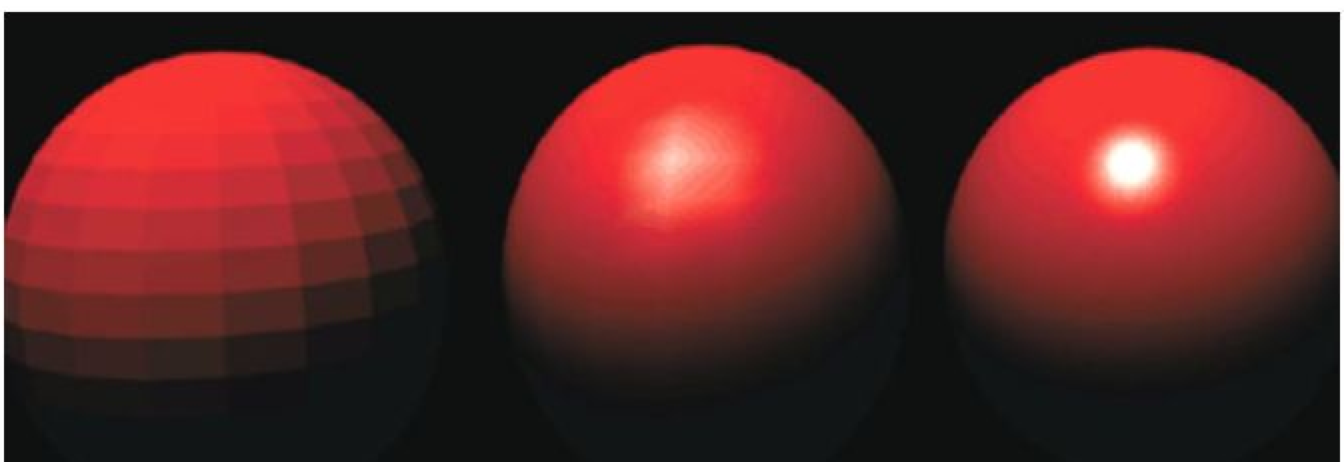
Illumination and Shading

Phong Illumination Model

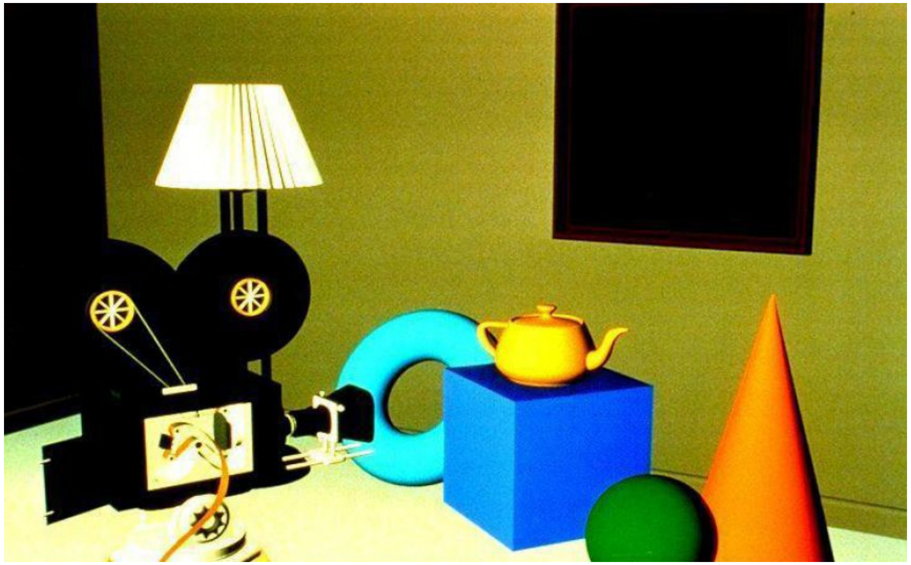
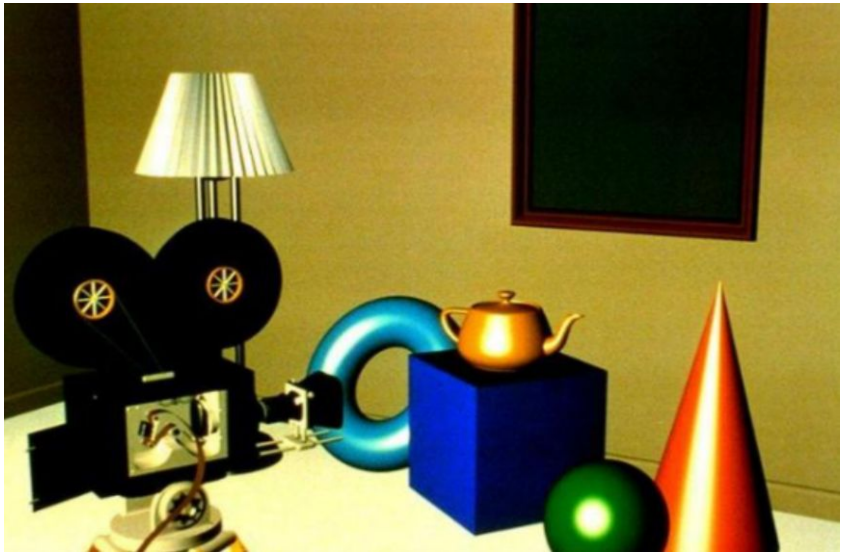
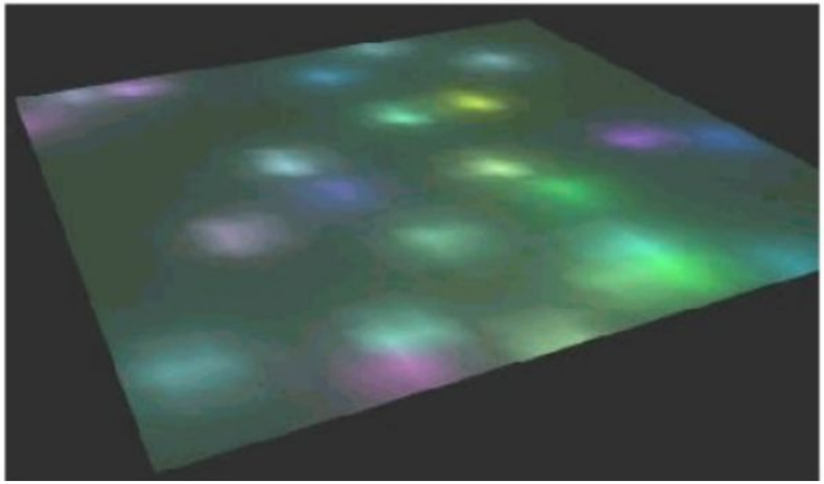
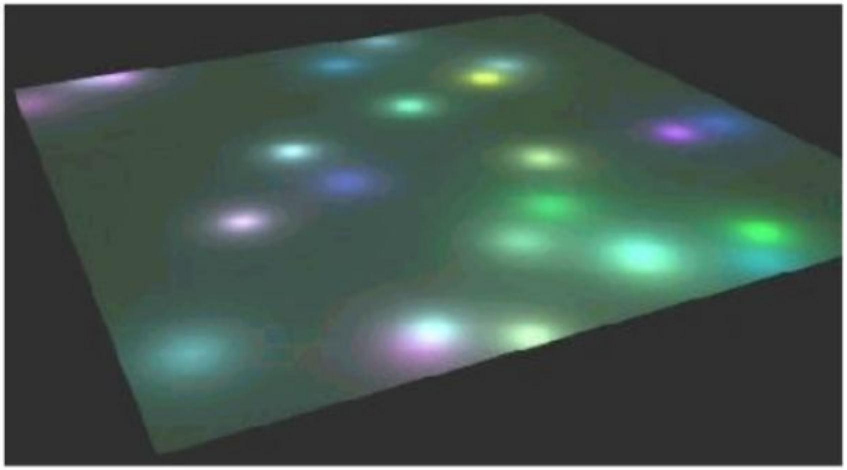
$$I_\lambda = I_a k_a + \sum_{p=1}^{lights} I_p [k_d(\overset{\cos\theta}{\overline{N} \bullet \overline{L}}) + k_s(\overset{\cos\alpha}{\overline{V} \bullet \overline{R}})^n]$$



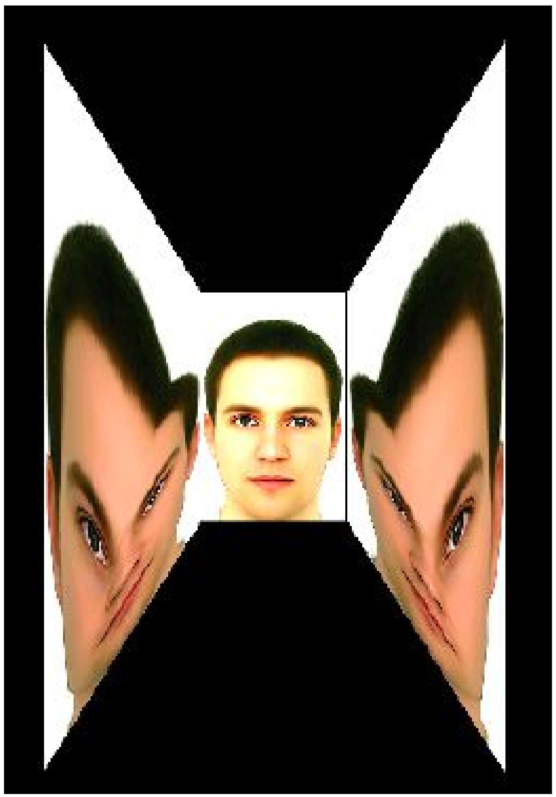
Flat shading, Gouraud shading, Phong shading



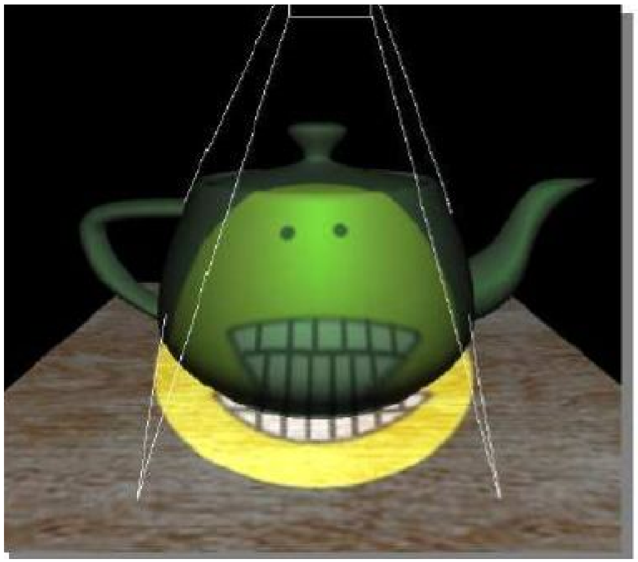
Illumination and Shading

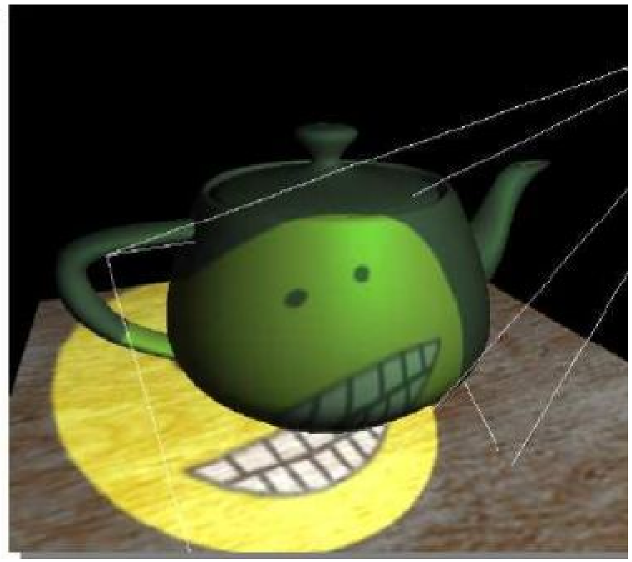





Texture Mapping



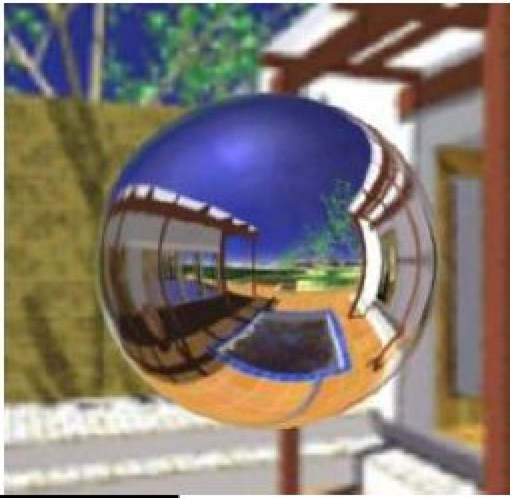
Texture Mapping

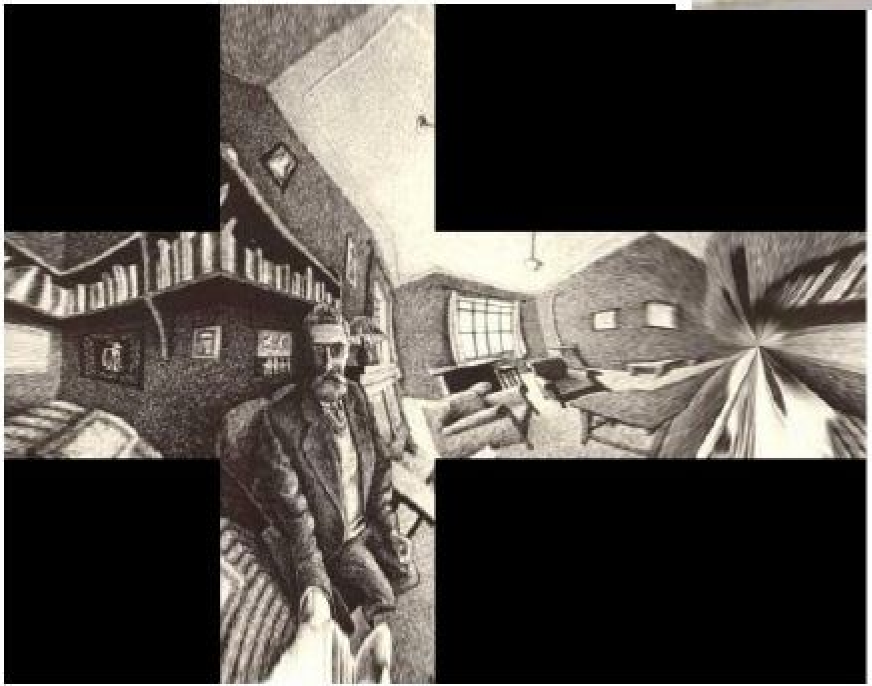




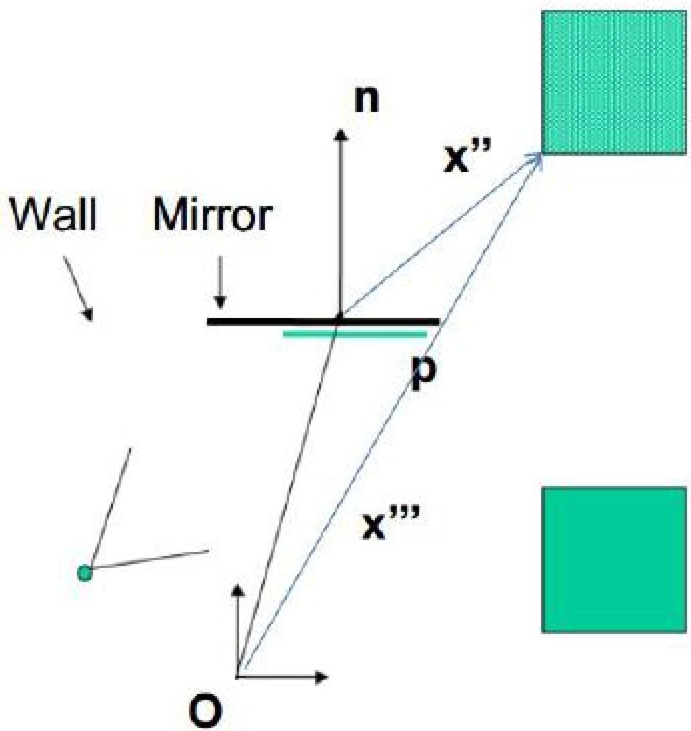
What is the mapping function?

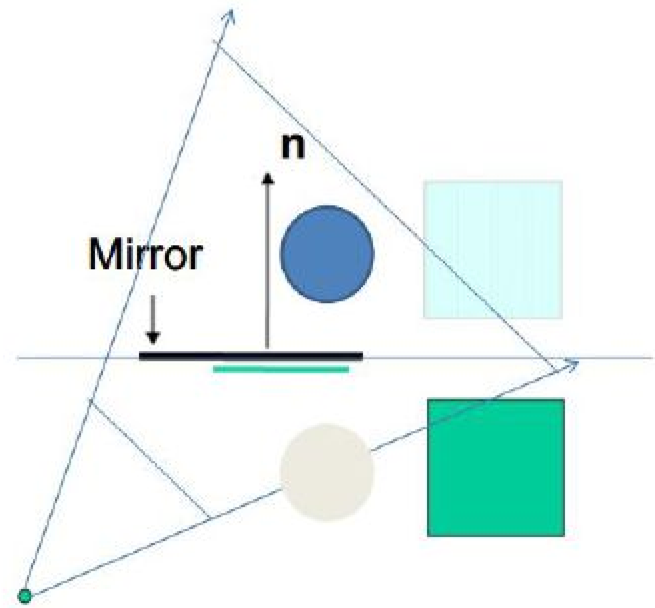
Environment Mapping

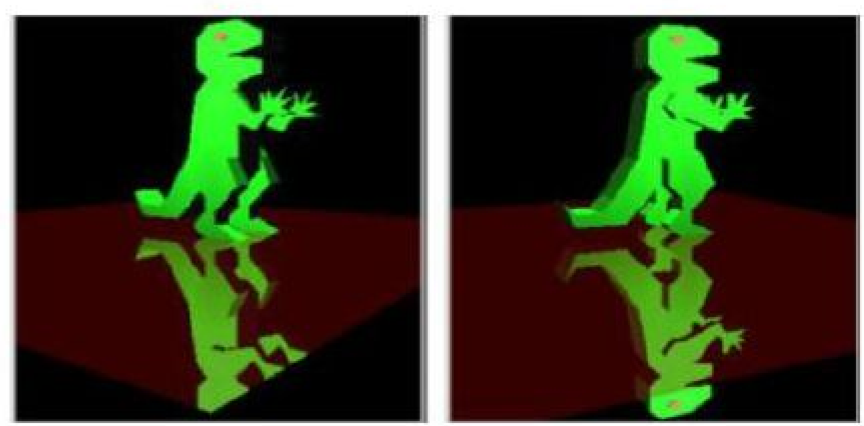




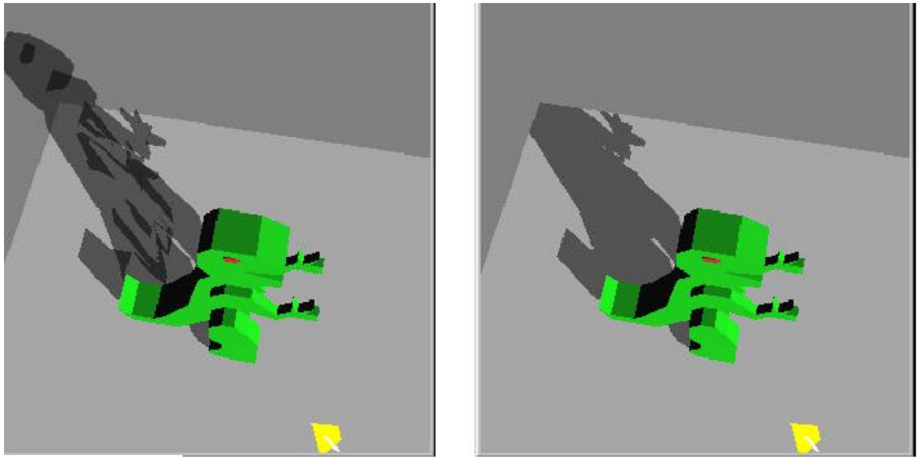
Mirrored world

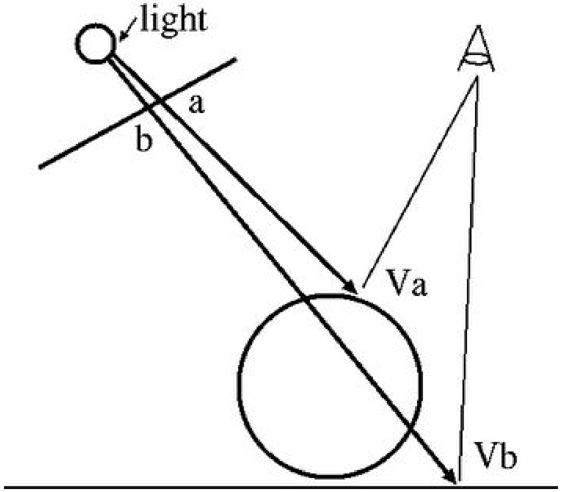


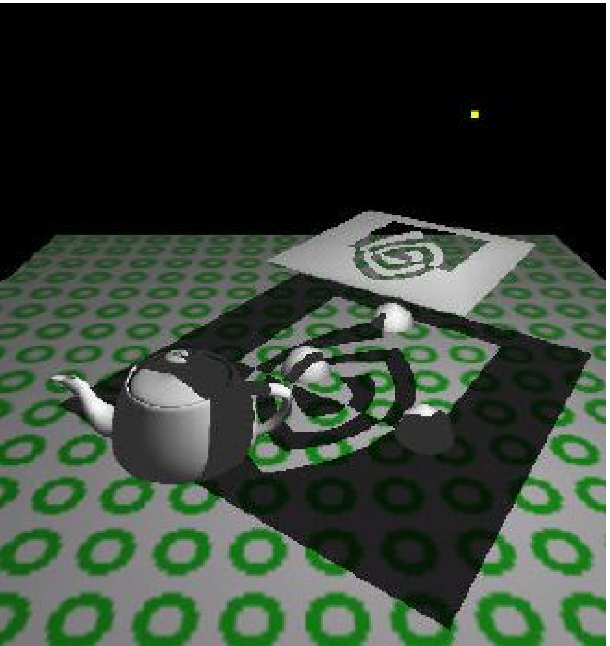


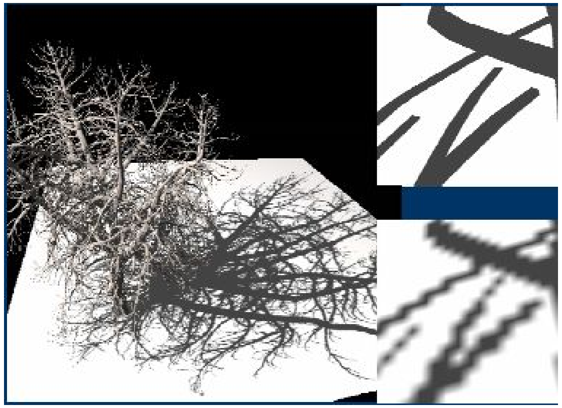


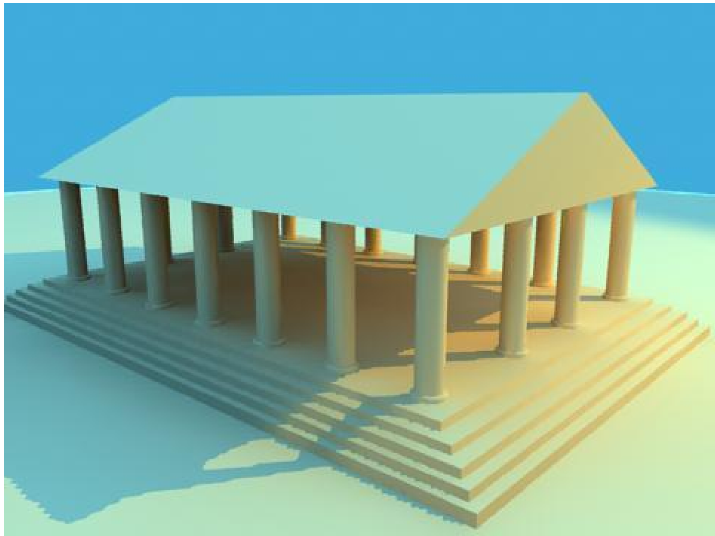
Shadows



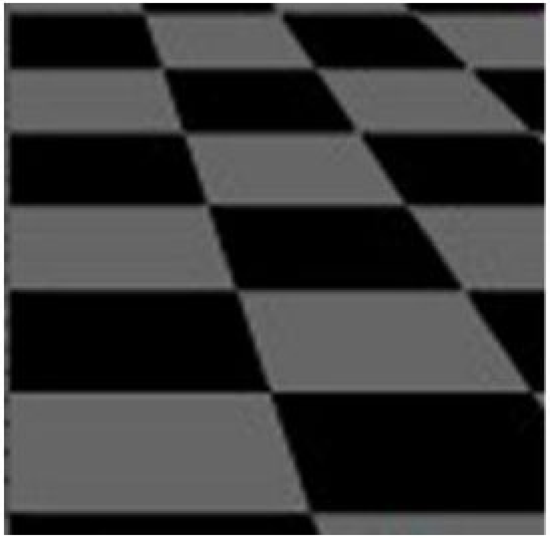


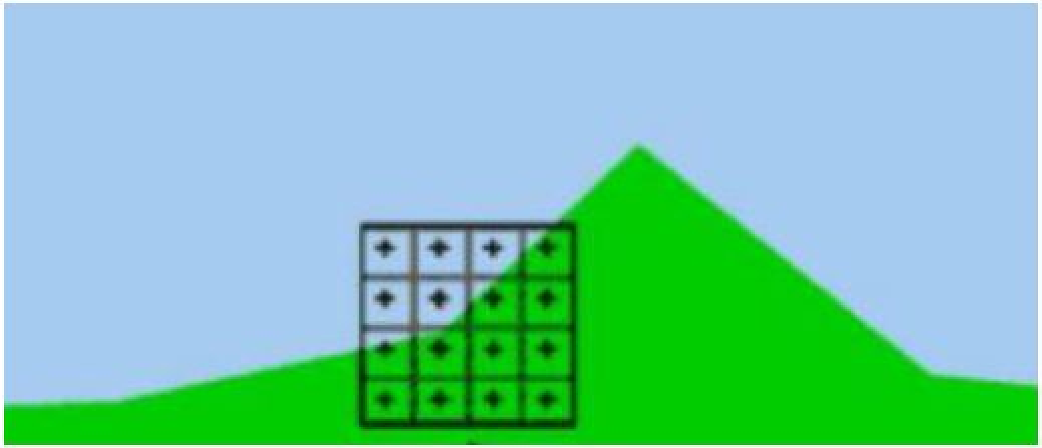


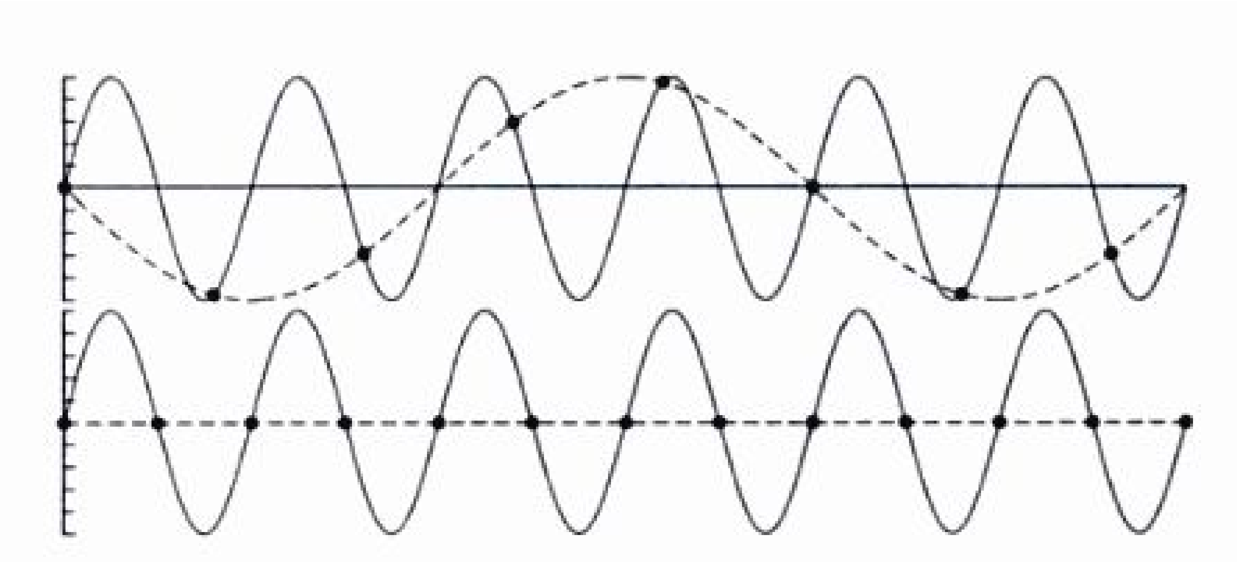


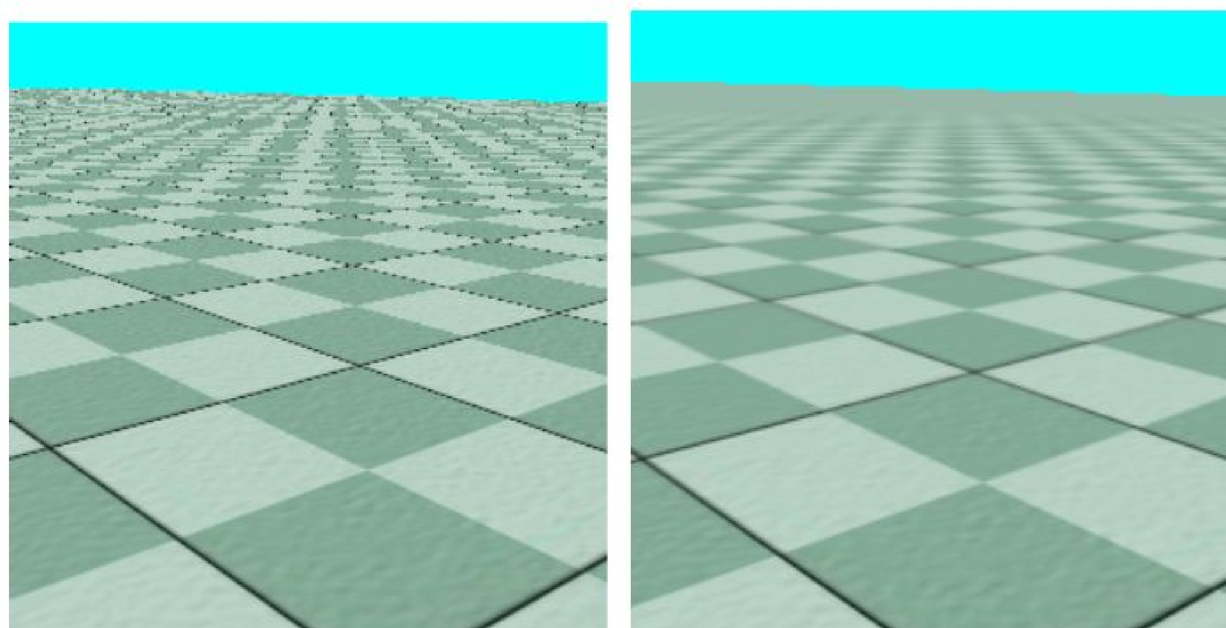


Anti-aliasing

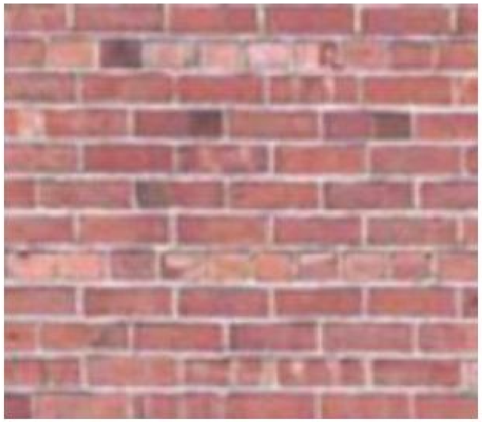




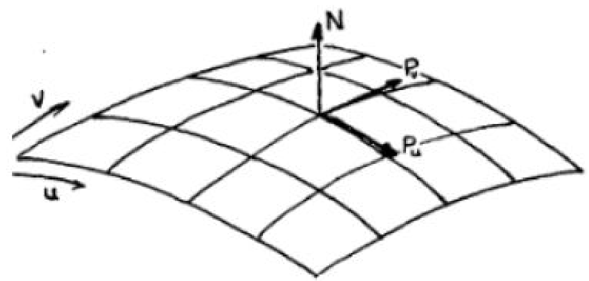


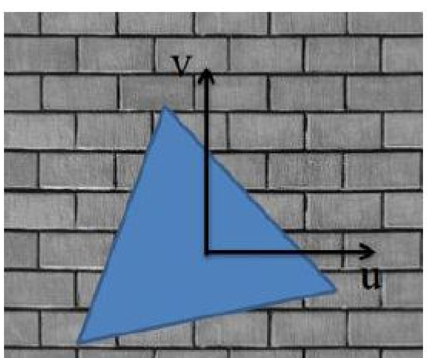


Bump mapping

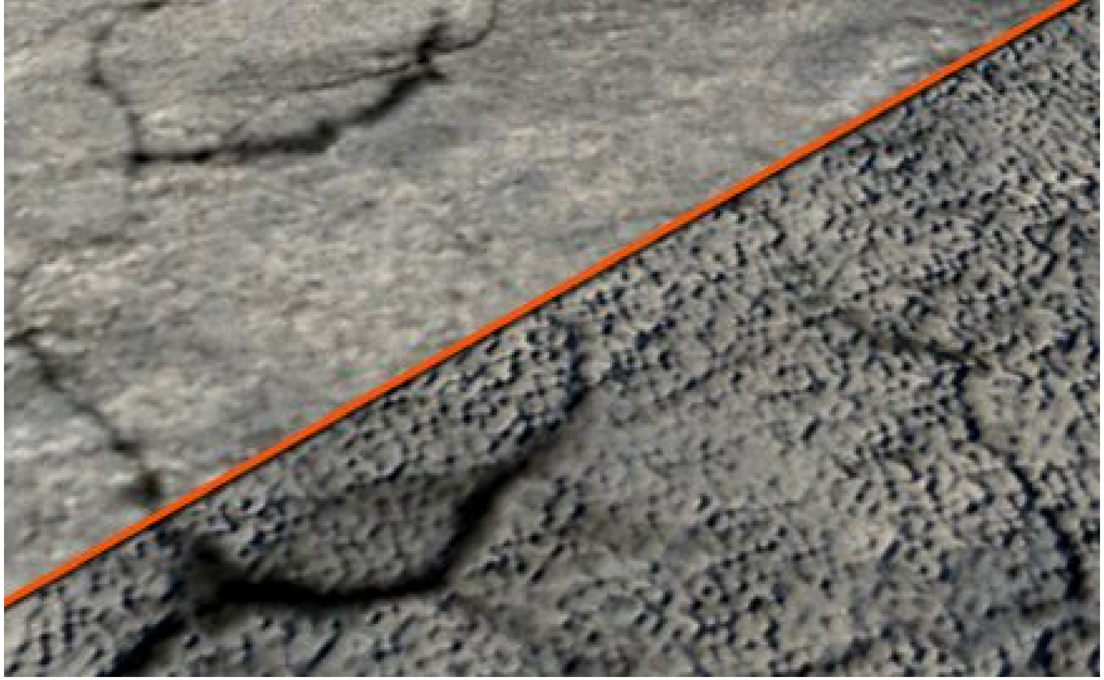


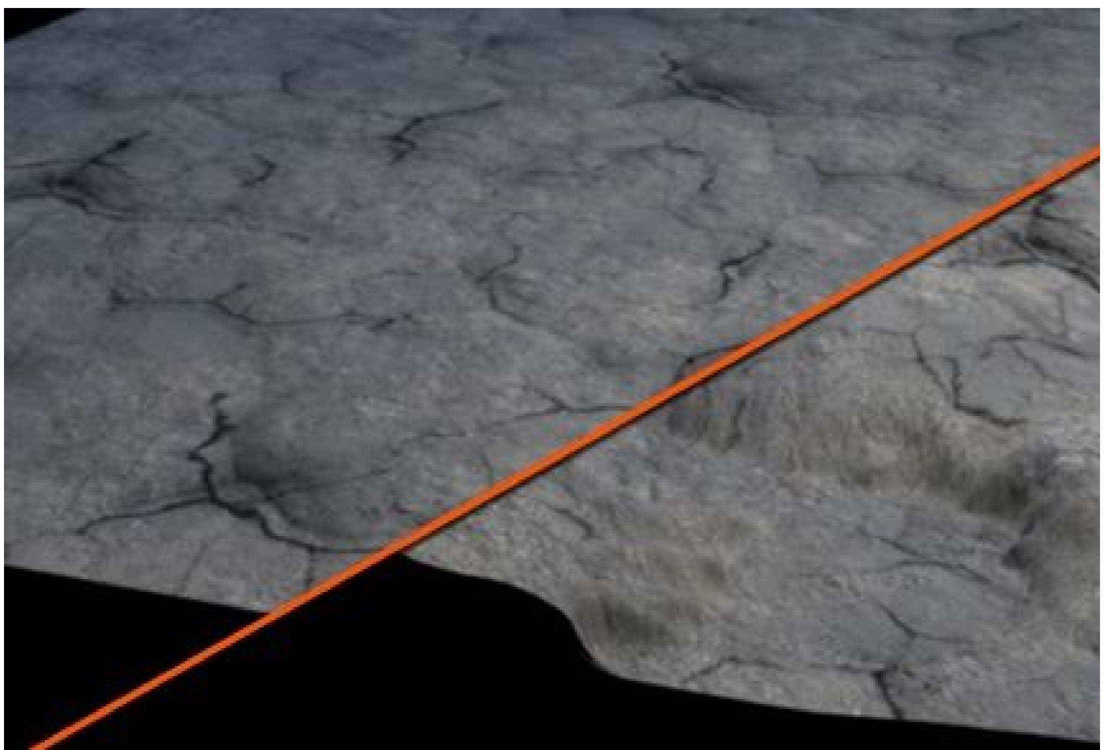
$$\mathbf{n}' = \mathbf{n} + \frac{F_u(\mathbf{n} \times \mathbf{P_v}) - F_v(\mathbf{n} \times \mathbf{P_u})}{||\mathbf{n}||}$$





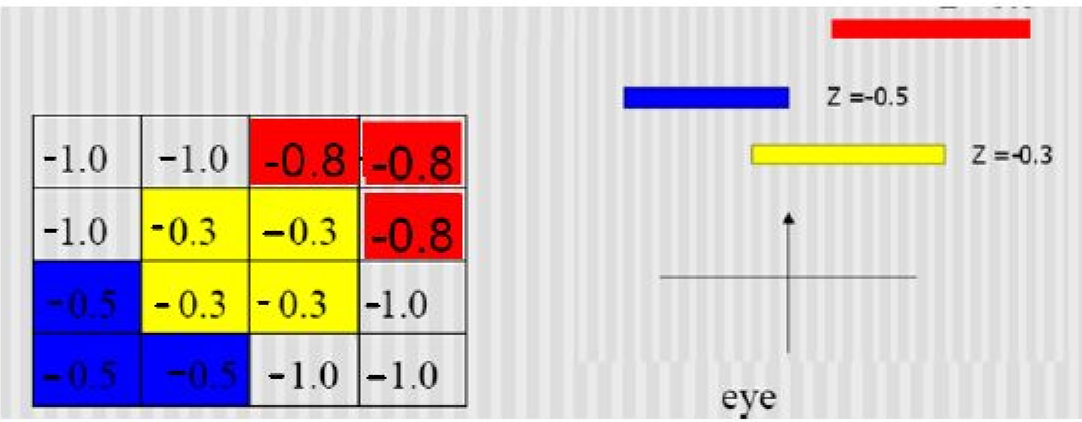
$$\frac{\partial P}{\partial x} = \frac{\partial P}{\partial u}\frac{\partial u}{\partial x} + \frac{\partial P}{\partial v}\frac{\partial v}{\partial x}$$
$$\frac{\partial P}{\partial y} = \frac{\partial P}{\partial u}\frac{\partial u}{\partial y} + \frac{\partial P}{\partial v}\frac{\partial v}{\partial y}.$$

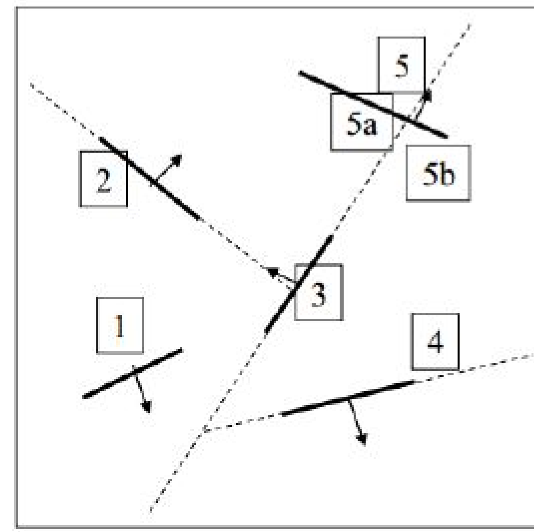


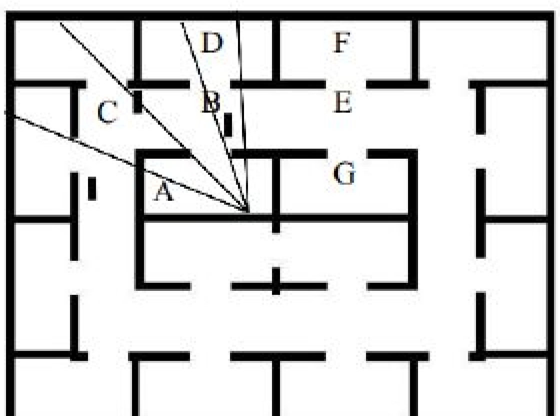


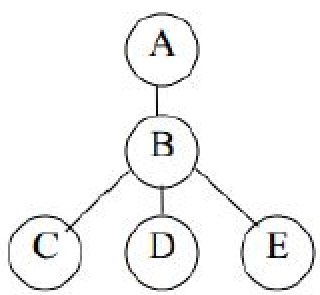
Hidden Surface Removal

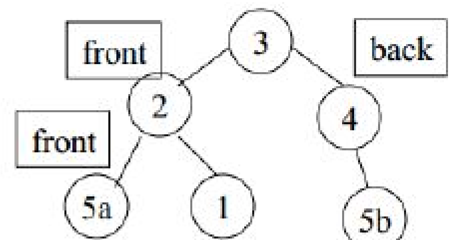
Z-buffer, BSP trees, Portal culling

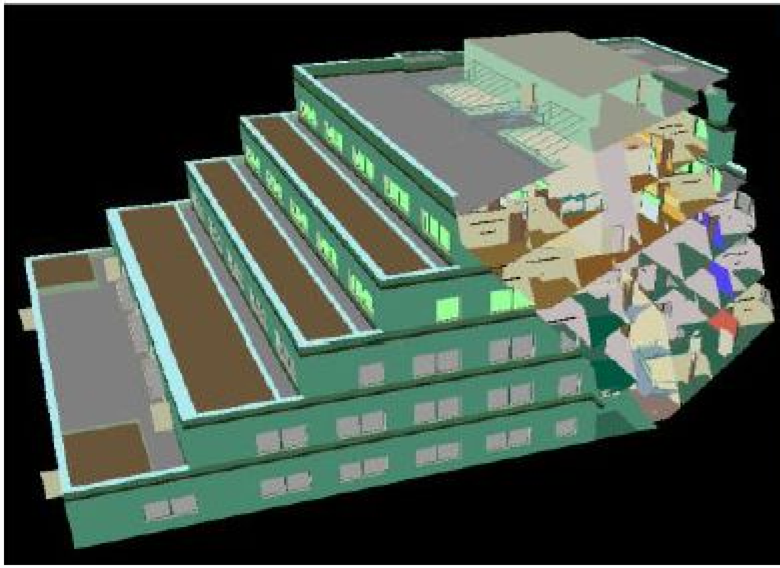


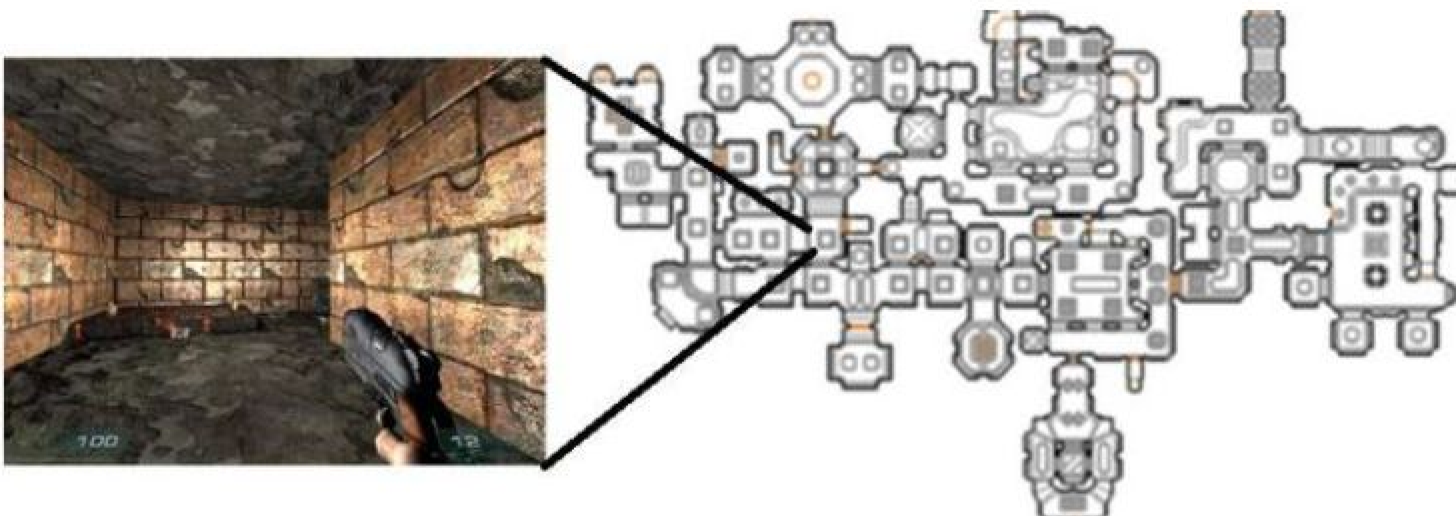




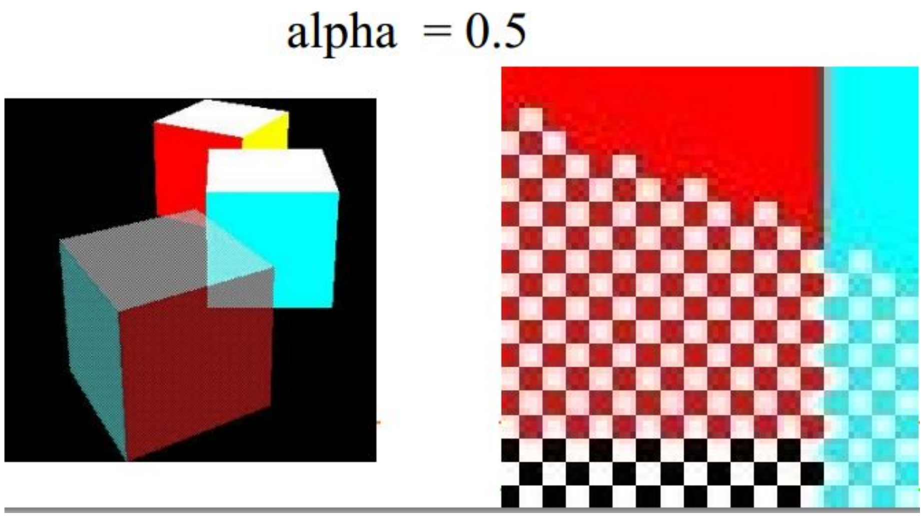


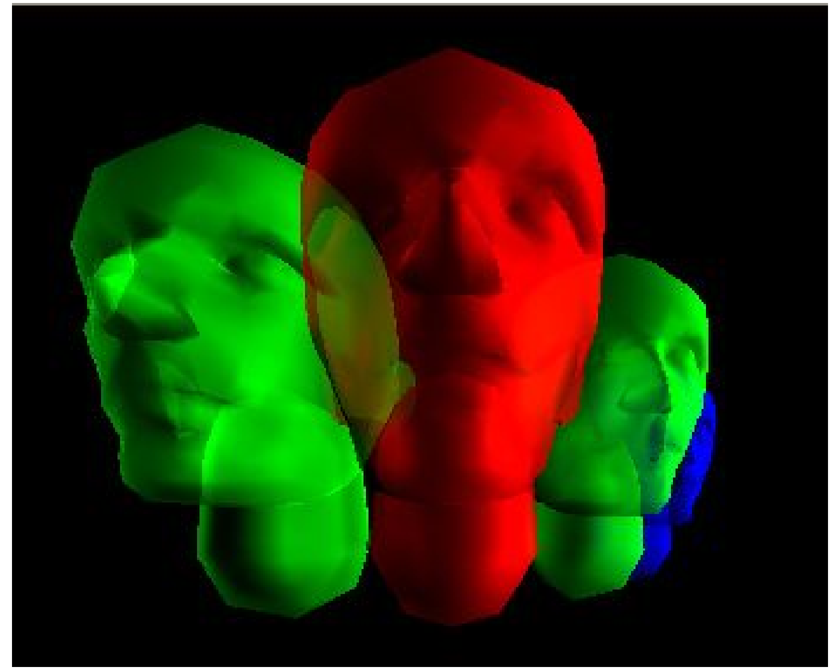


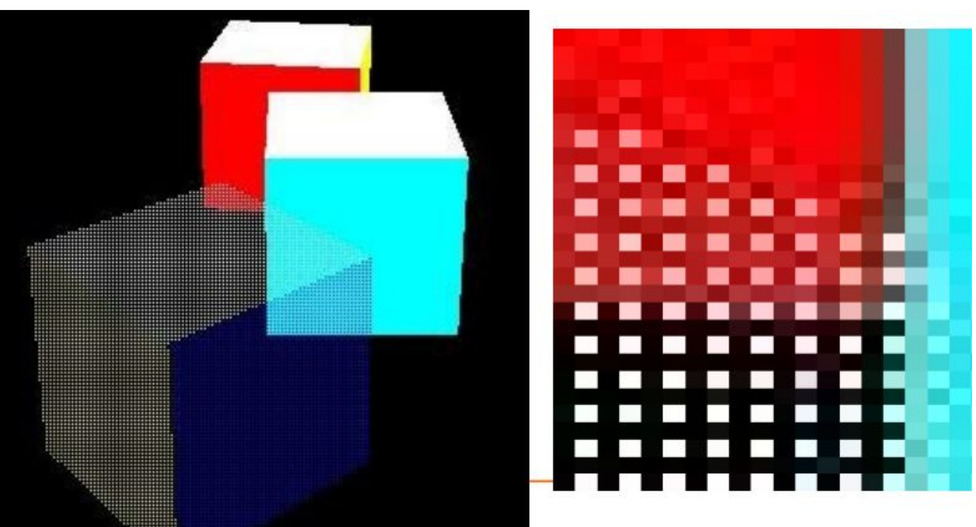


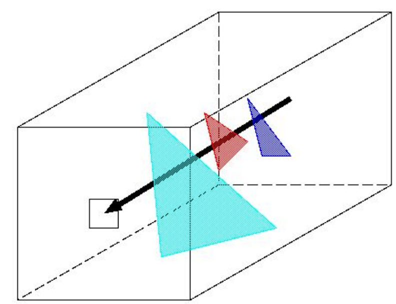

100
12

Transparency

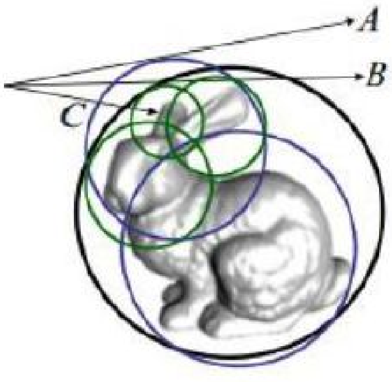


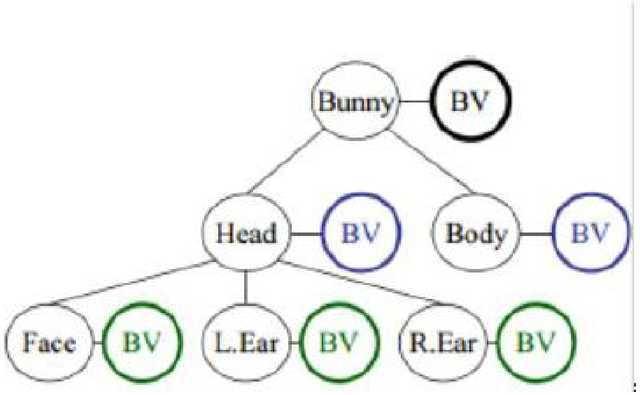


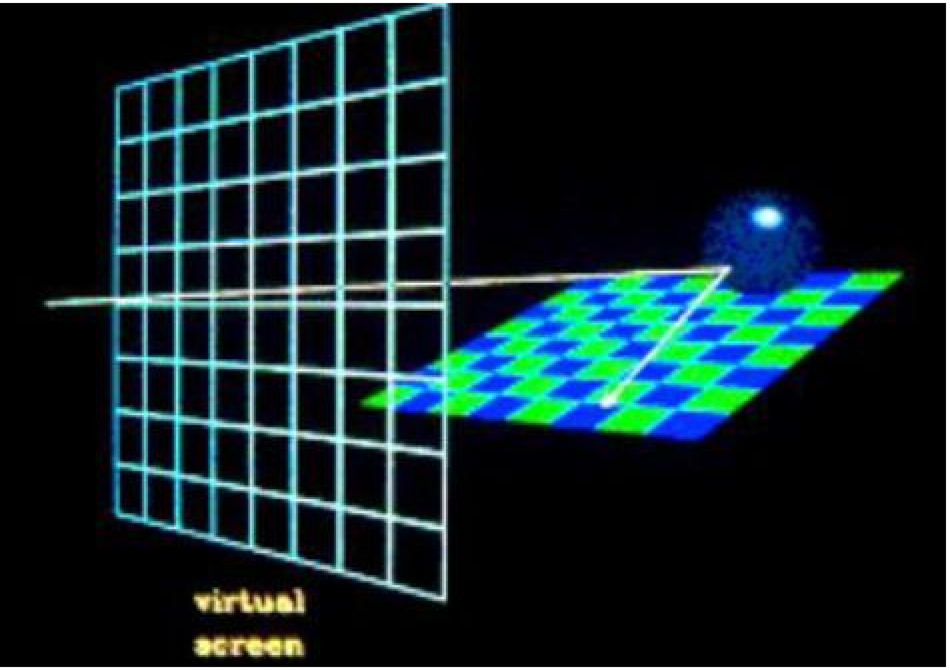




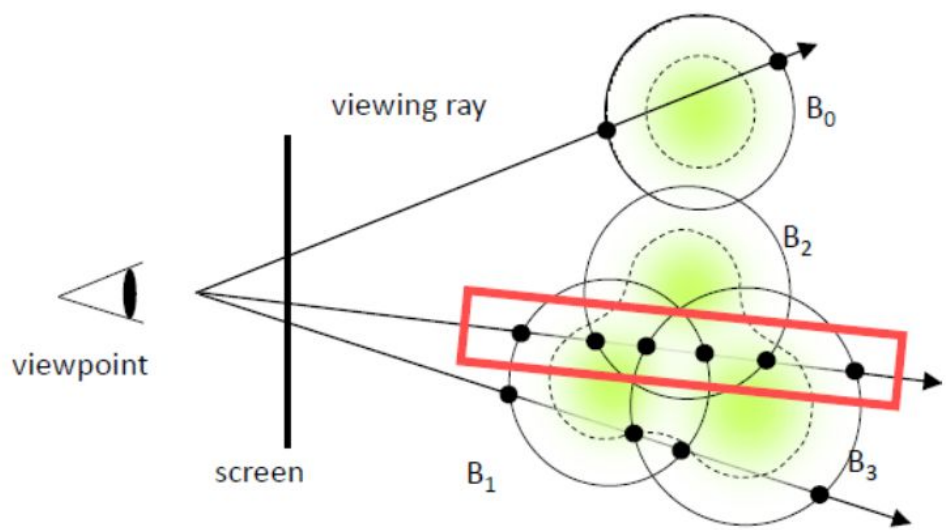
Ray Tracing







- How to make a bounding sphere hierarchy?



viewing ray
B_0
B_2
viewpoint
screen
B_1
B_3

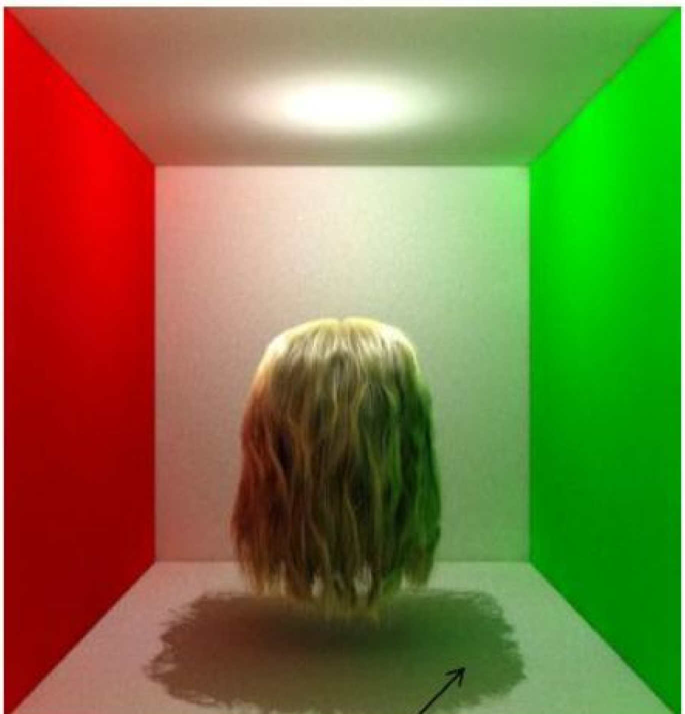
Light Transport Notations

L a light source

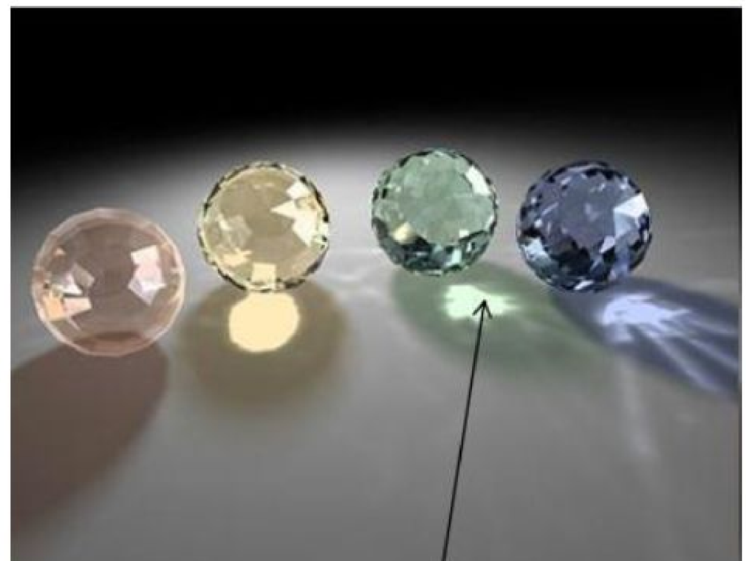
E the eye

S a specular reflection

D a diffuse reflection

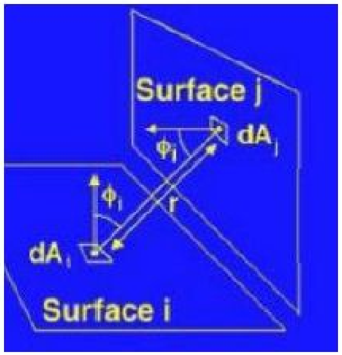


LDDE



LSDE

Radiosity



$$B_j = E_j + \rho_j \sum_{i=1}^{N} B_i F_{i,j}$$

(a)

$$\begin{pmatrix} 1-\rho_1 F_{11} & -\rho_1 F_{12} & \dots & -\rho_1 F_{1N} \\ -\rho_2 F_{21} & 1-\rho_2 F_{22} & \dots & -\rho_2 F_{2N} \\ \vdots & \vdots & \dots & \vdots \\ -\rho_N F_{N1} & -\rho_N F_{N2} & \dots & 1-\rho_N F_{NN} \end{pmatrix} \begin{pmatrix} B_1 \\ B_2 \\ \vdots \\ B_N \end{pmatrix} = \begin{pmatrix} E_1 \\ E_2 \\ \vdots \\ E_N \end{pmatrix}$$

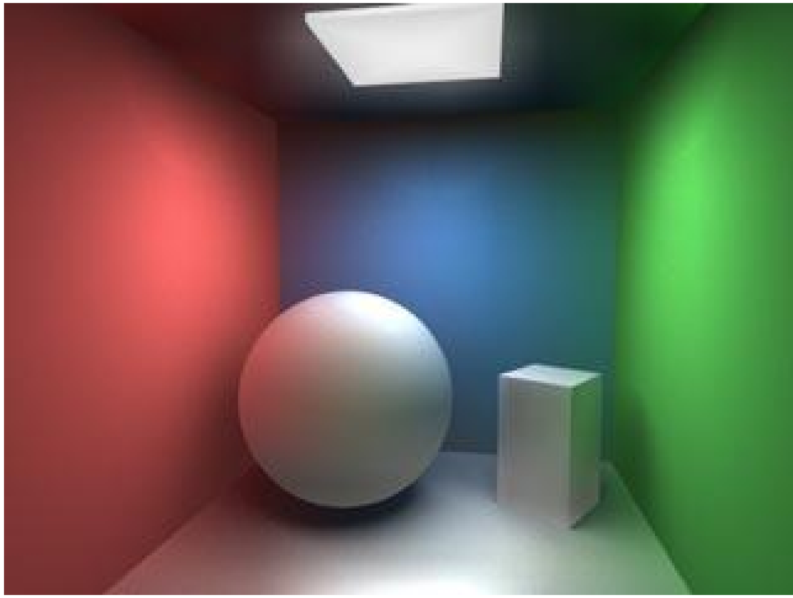
For computing the radiosity, you use an iterative approach

$$B_j = E_j + \rho_j \sum_{i=1}^{N} B_i F_{i,j}$$

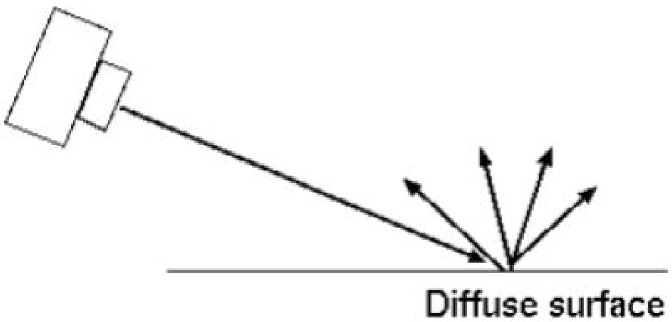
$$B_j^0 = E_j$$

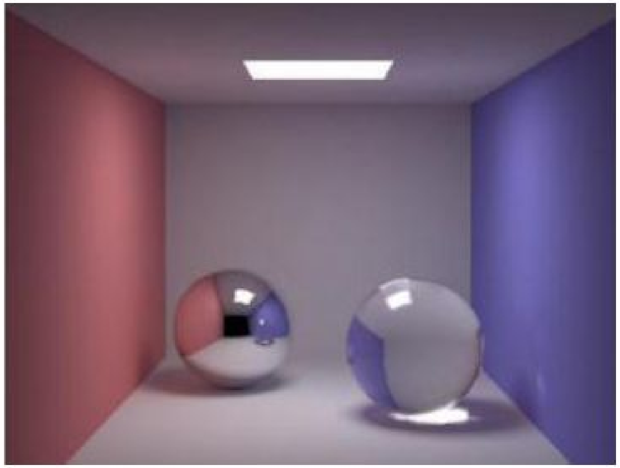
$$B_j^{k+1} = \rho_j \sum_{i=1}^{N} B_i^k F_{i,j}$$

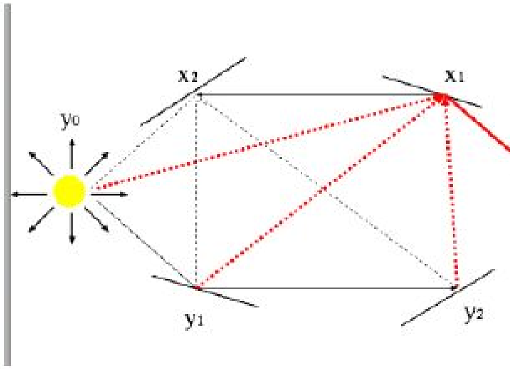
$$B = \sum_k B^k$$



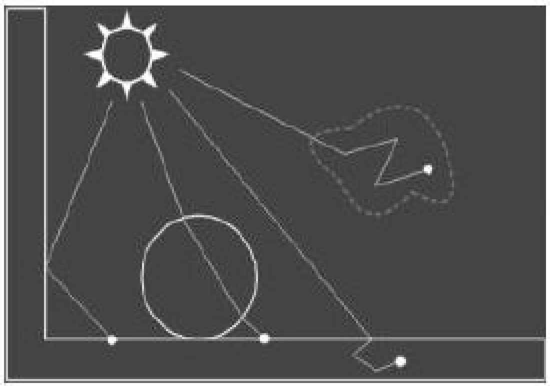
Path Tracing

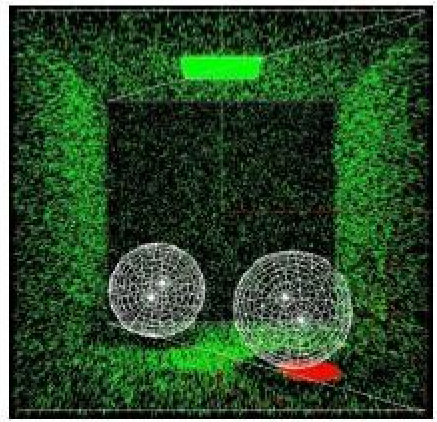


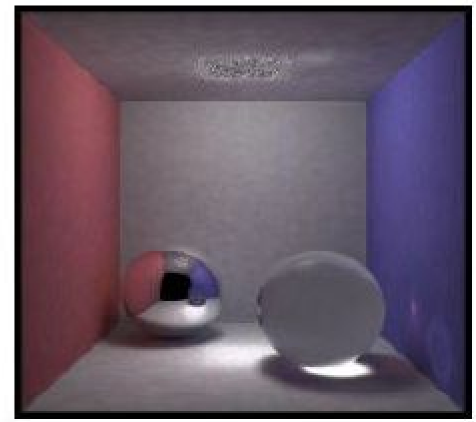


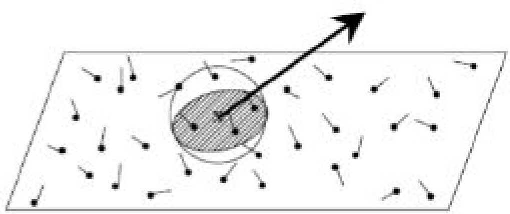


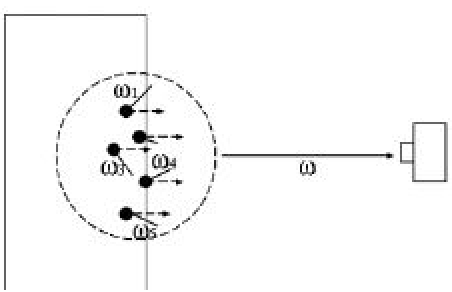
Photon Mapping











$$L_r(x,\vec{\omega}) = \sum_{p=1}^{N} f_r(x,\overrightarrow{\omega_p},\vec{\omega})\frac{\Delta\Phi_p(x,\overrightarrow{\omega_p})}{\Delta A}$$

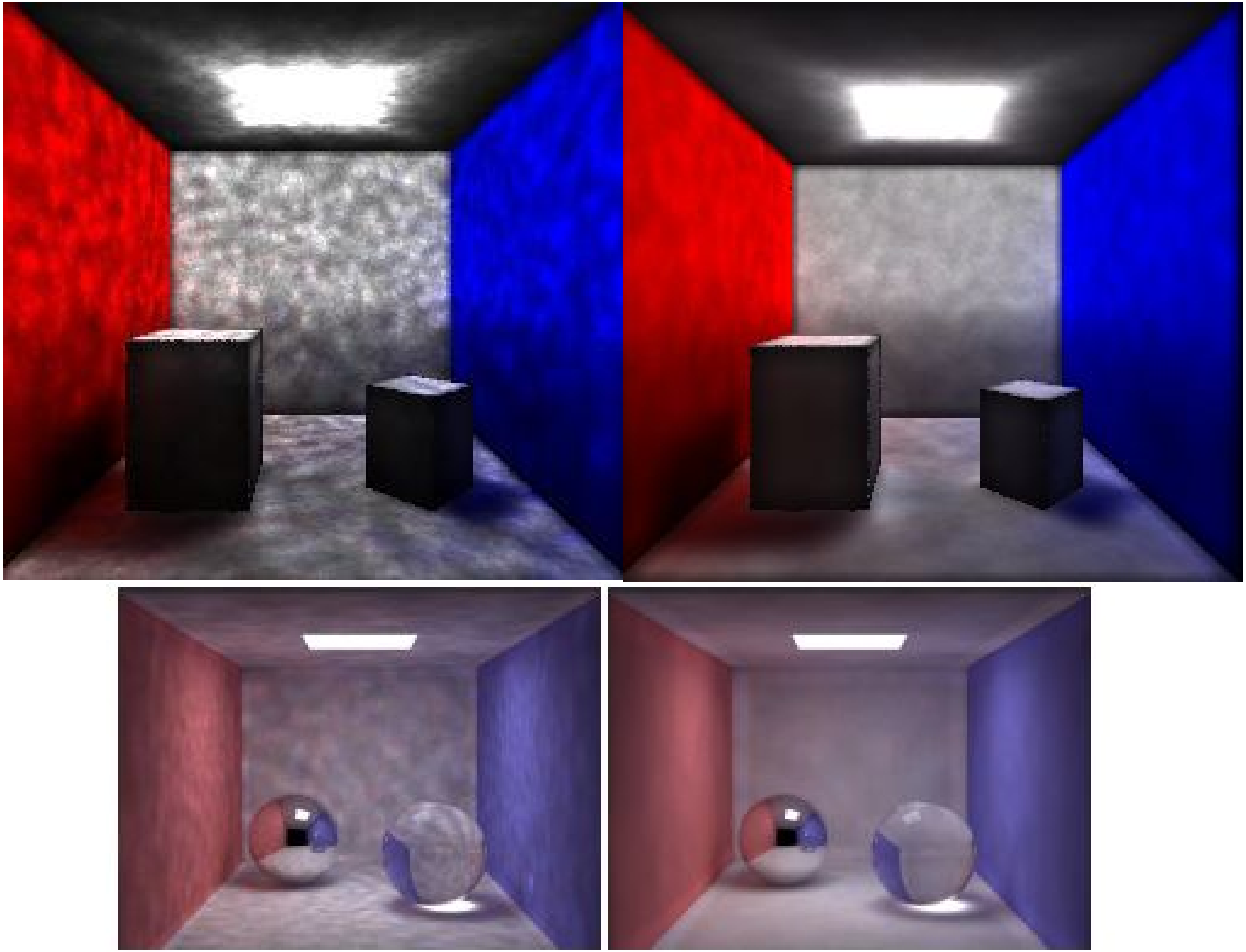
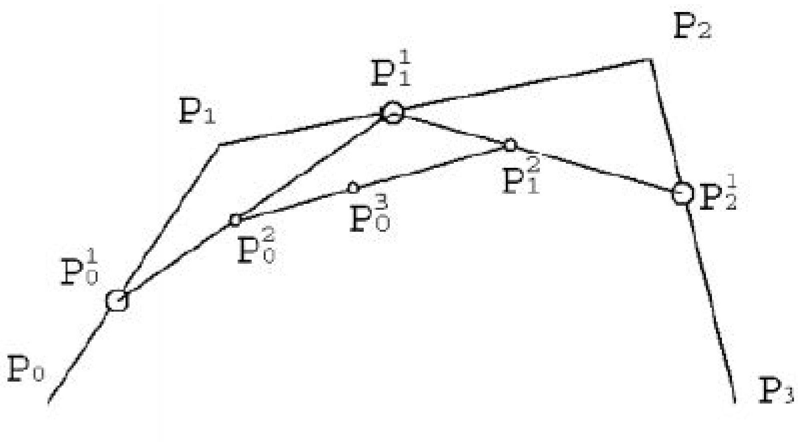
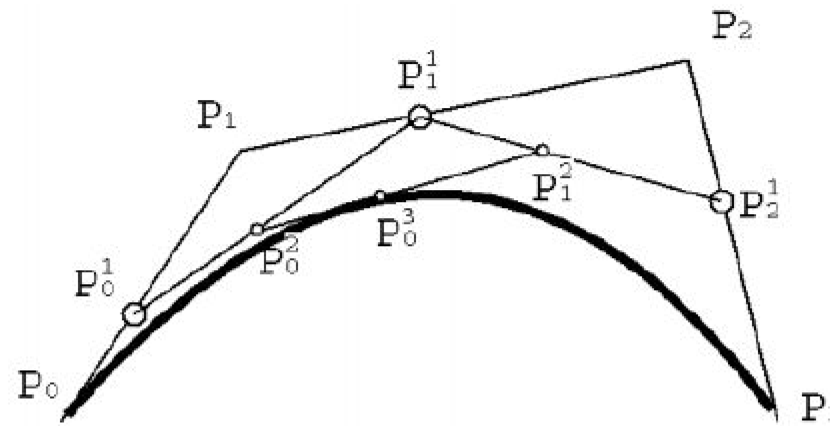
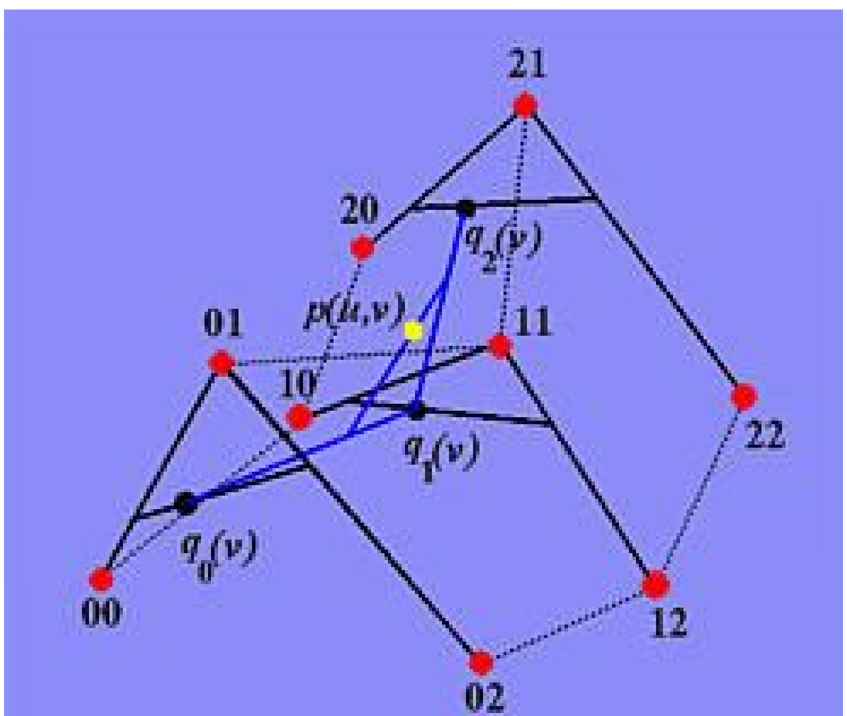


Figure 20: Global photon map radiance estimates visualized directly using 100 photons (left) and 500 photons (right) in the radiance estimate.

Parametric Curves and Surfaces

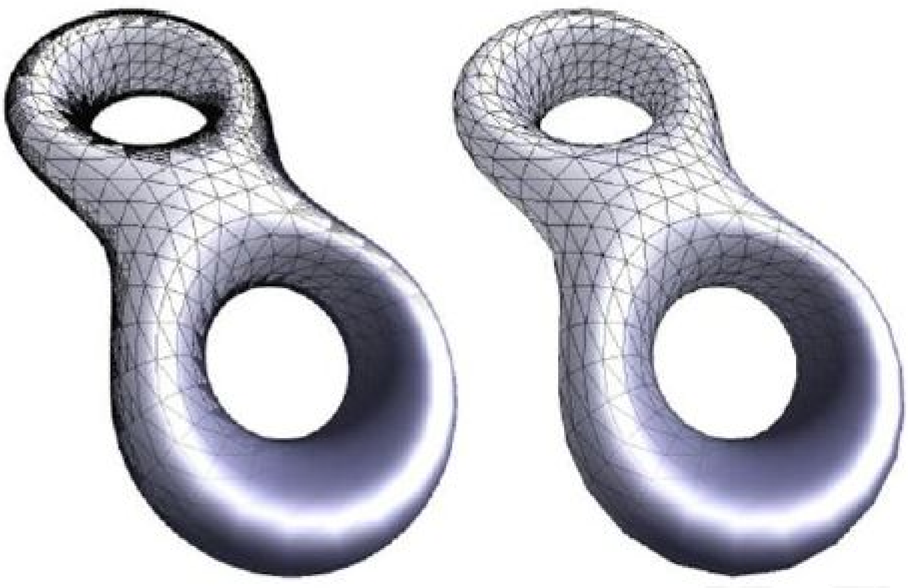


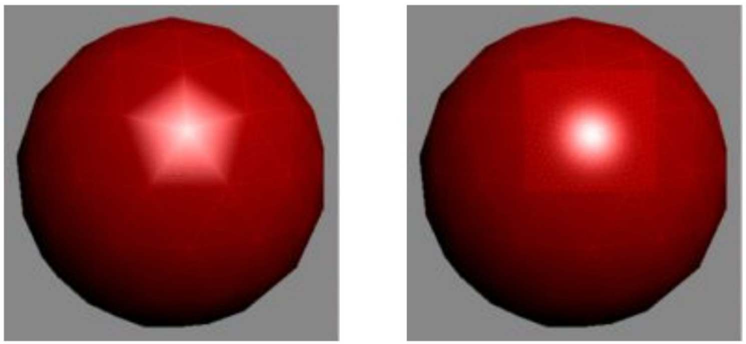


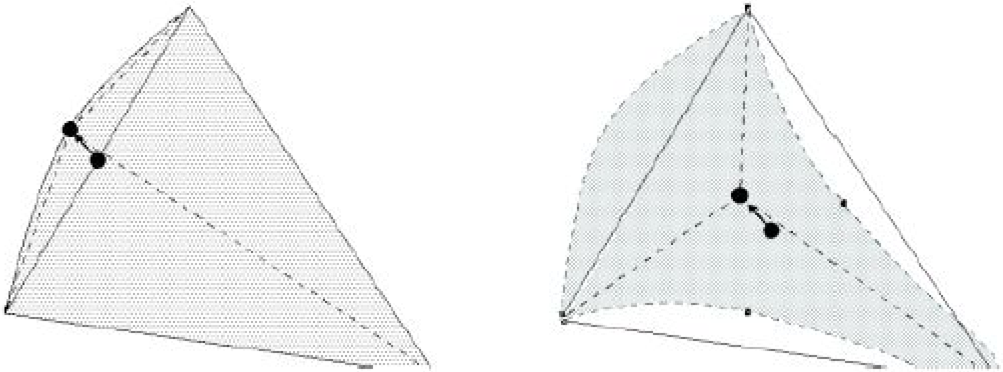


http://www.cs.mtu.edu/~shene/COURSES/cs3621/NOTES/surface/bezier-de-casteljau.html

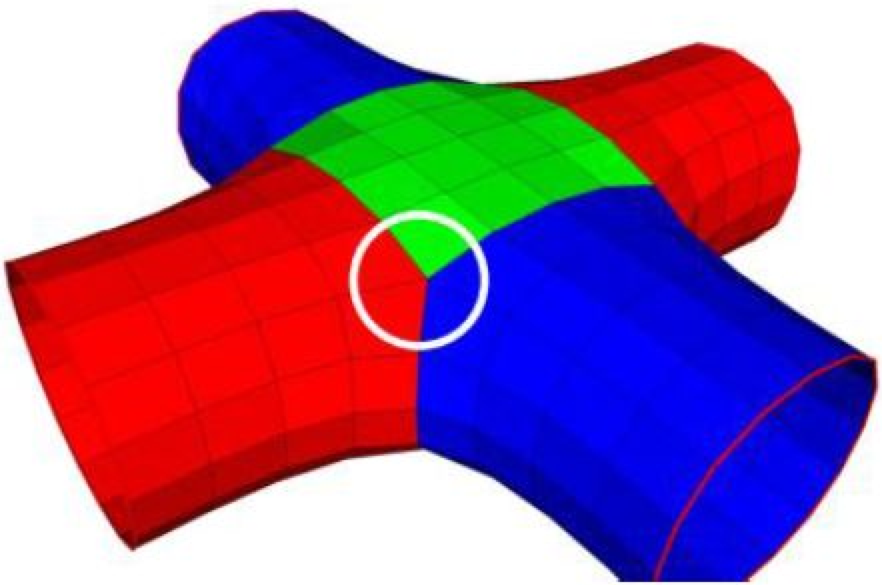
Adaptive Tesselation, On-the-fly Tesselation

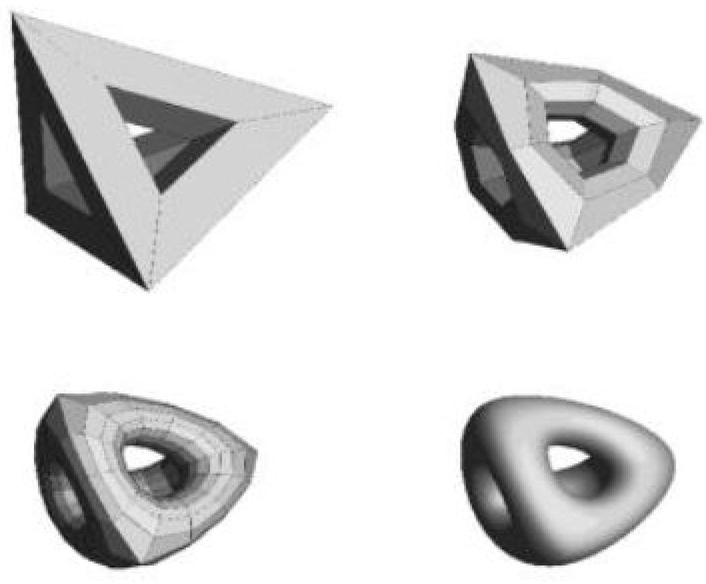






NURBS, Subdivision Surface






Good Luck!!