Advanced Concepts in Computer Graphics

Topics to be discussed:

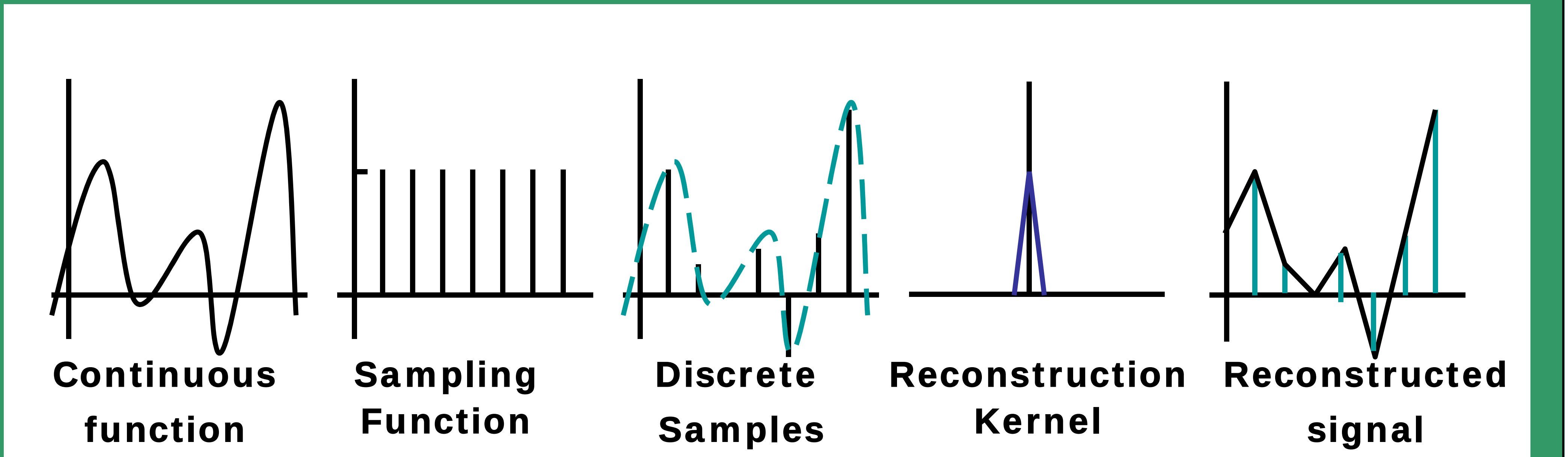
- Antialiasing
- Texture Bump Mapping
- Animation
- Soft Object Modeling
- Image-based rendering
- Visual Realism

ANTIALIASING

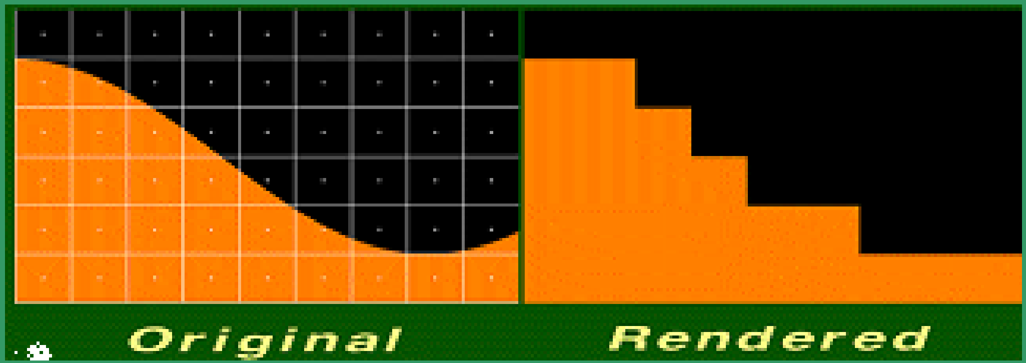
ALIASING

Aliasing occurs when signals are sampled too infrequently (coarse sampling), giving the illusion of a lower frequency signal.

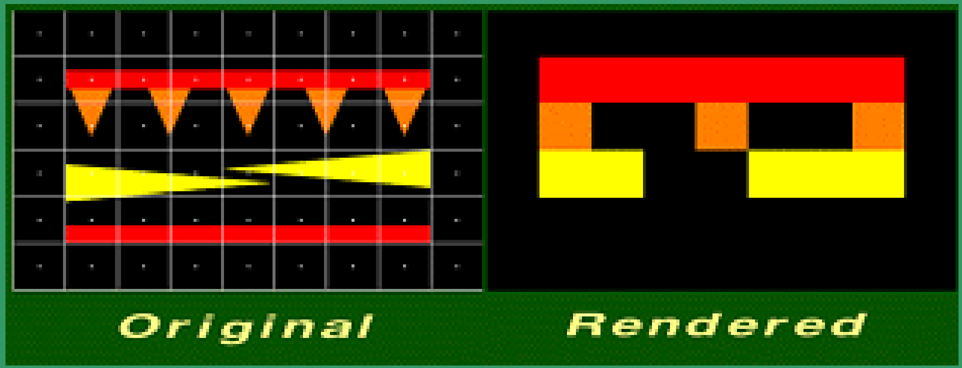
SAMPLING AND RECONSTRUCTION



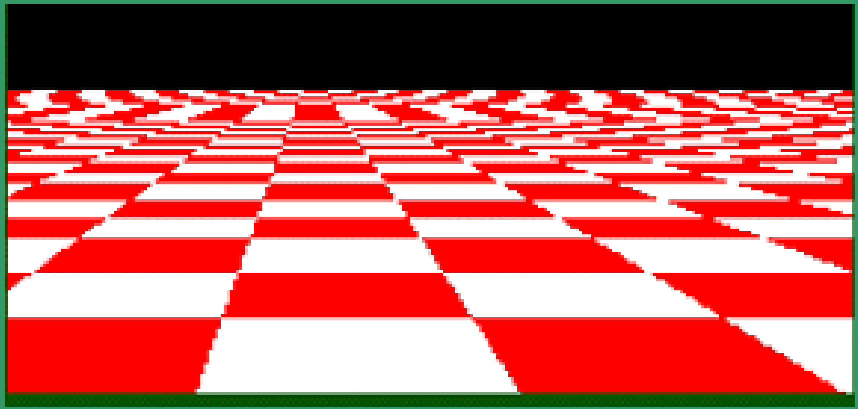
DRAWBACKS OF ALIASING



Jagged Profiles



Loss of Detail

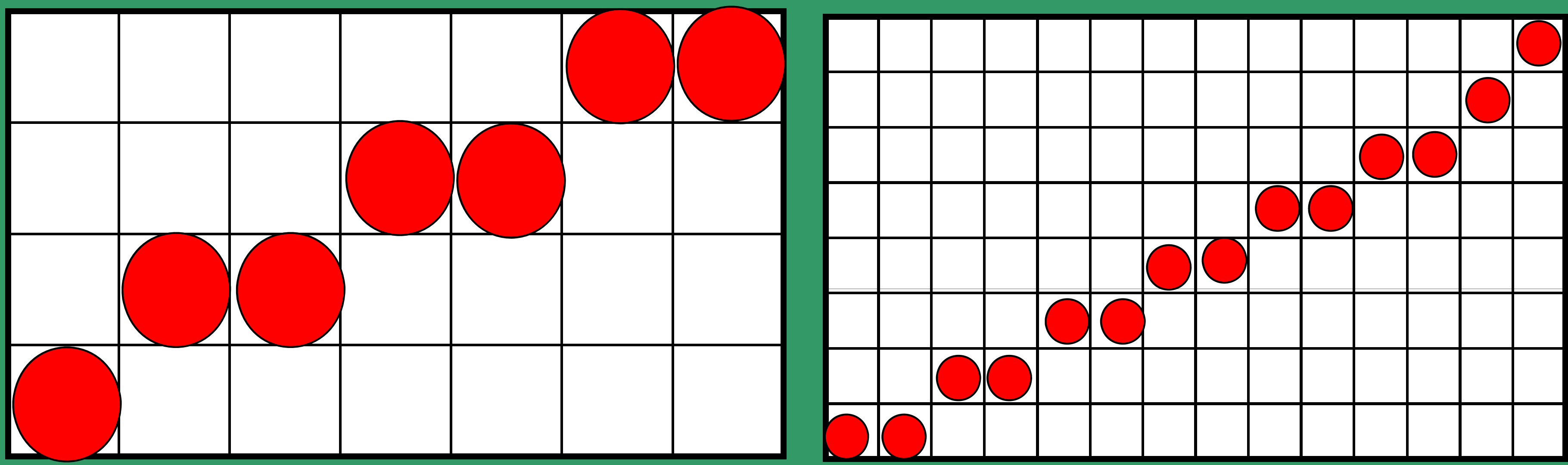


Disintegrating Textures

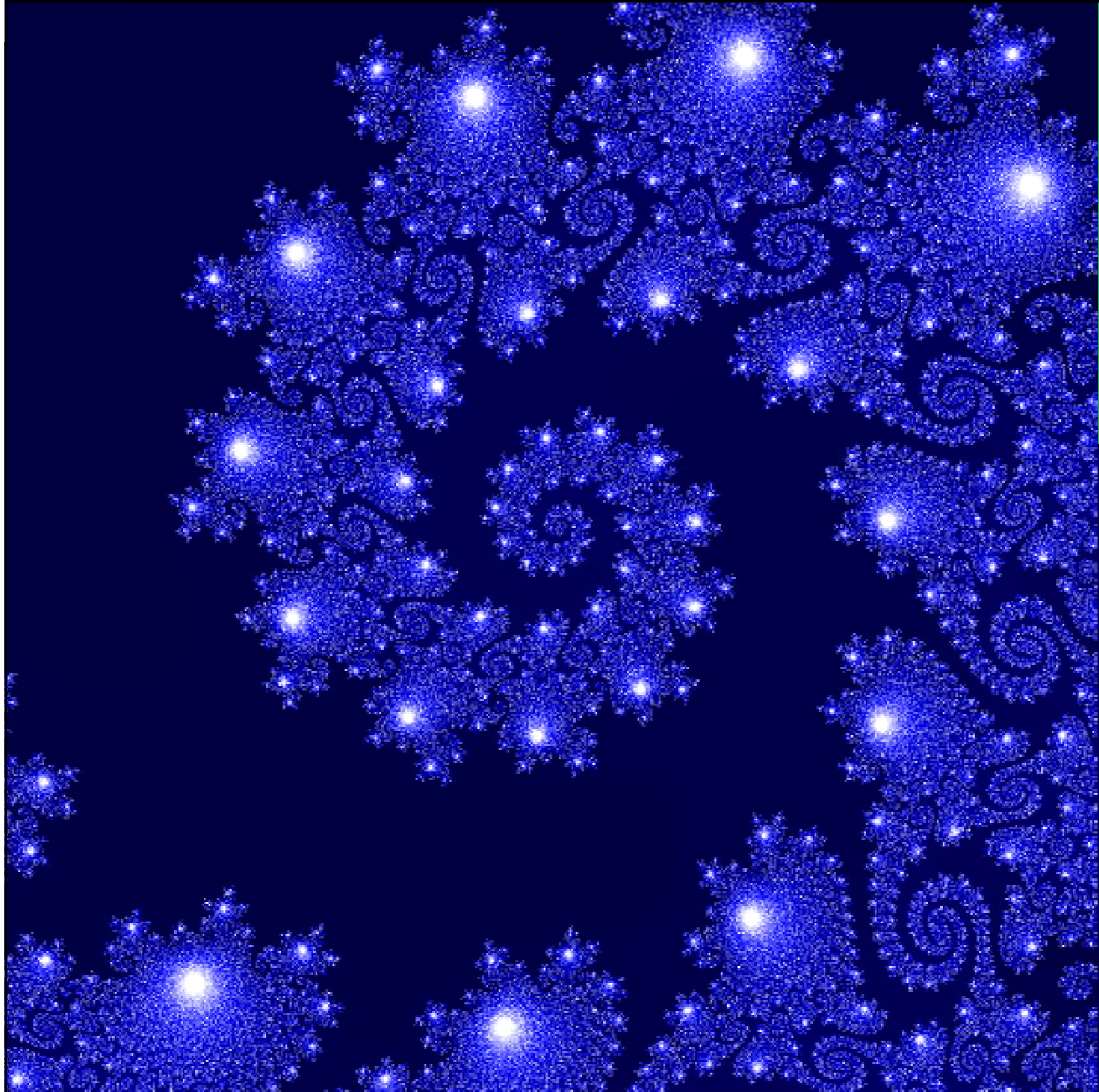
- **Techniques to reduce aliasing : Antialiasing**

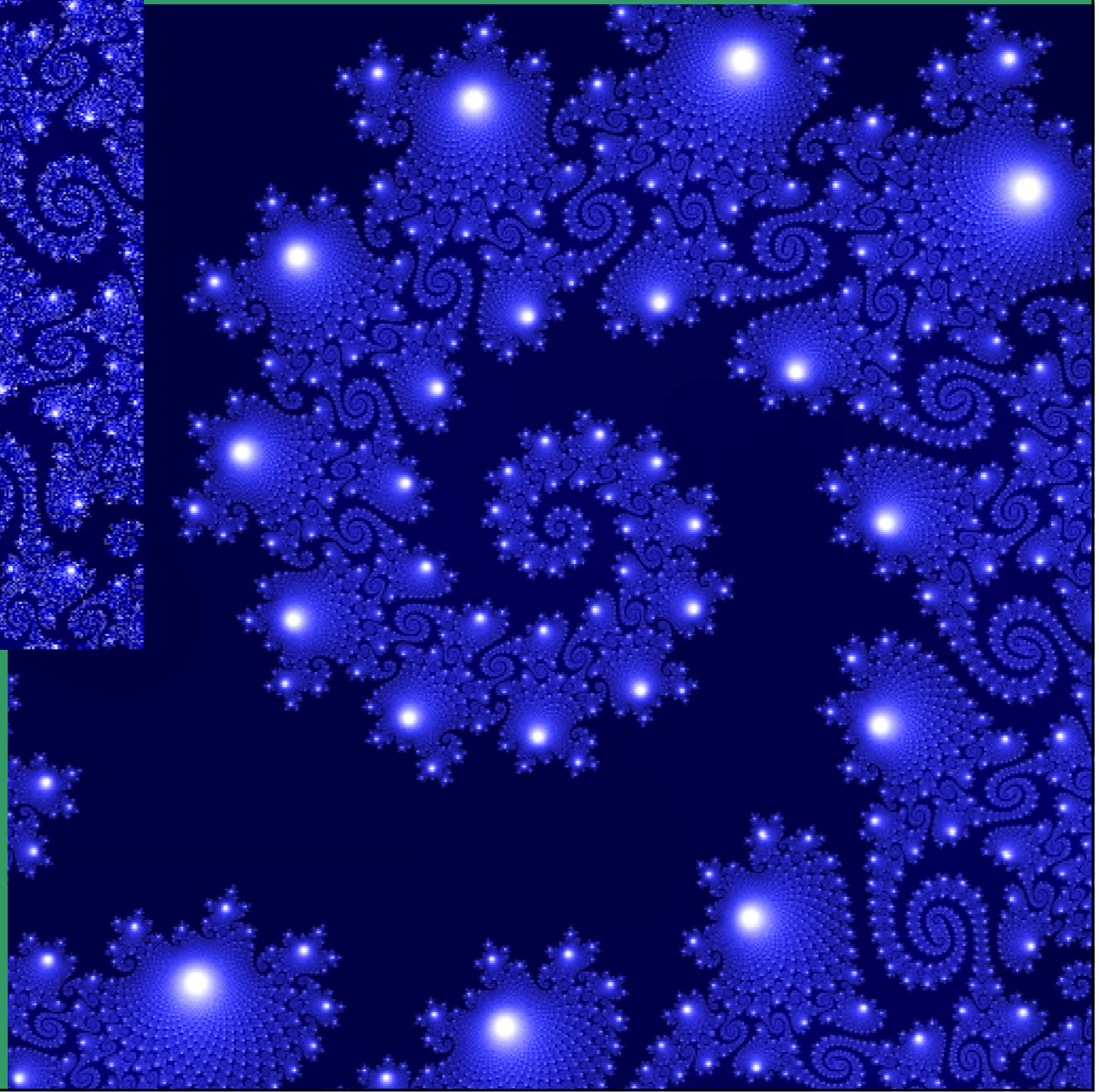
ANTIALIASING TECHNIQUES

Increasing Resolution



More memory cost, bandwidth and scan conversion time required.





ANTIALIASING TECHNIQUES (Cont.)

Area Sampling

- **Setting intensity proportional to amount of area covered.**

- **The intensity decreases as the distance between the pixel and the edge increases.**

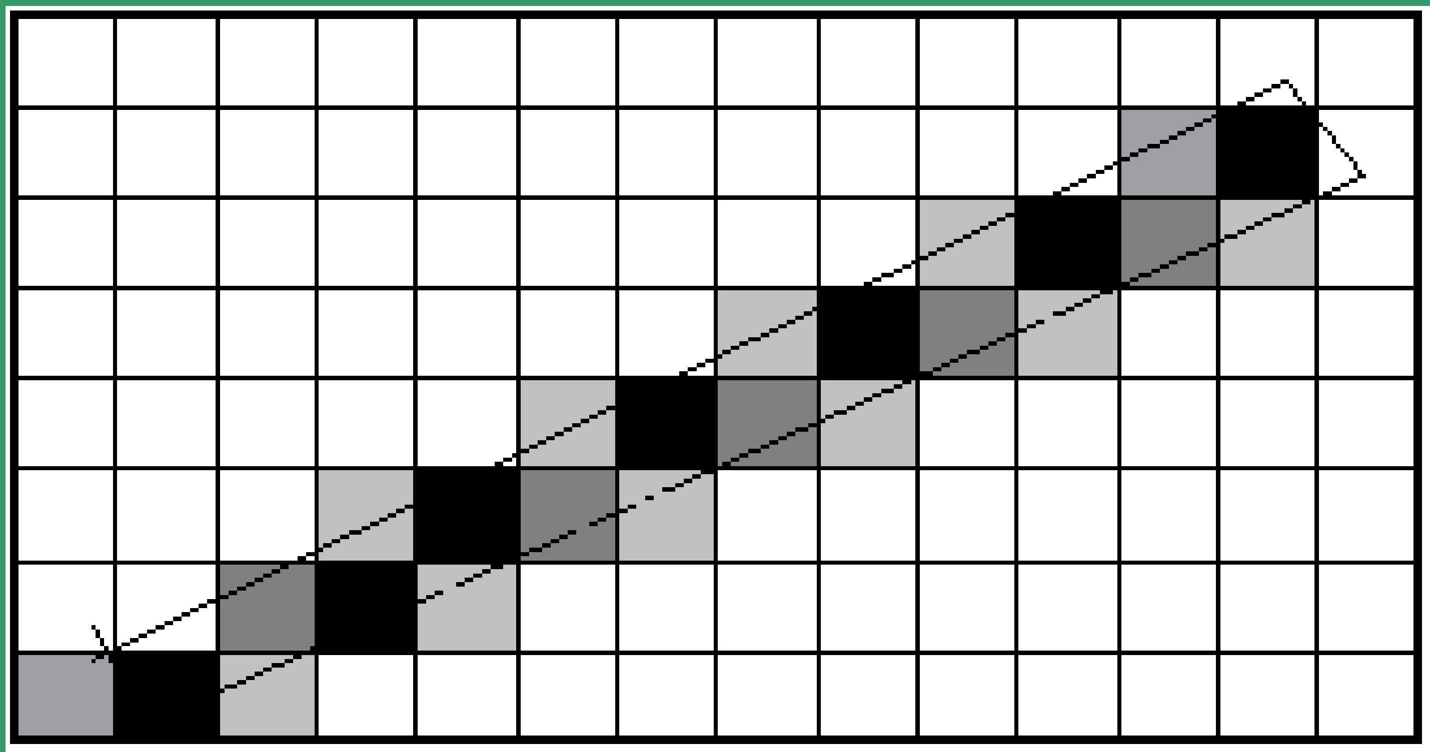
- **Unweighted Area Sampling :**

Equal areas contribute equal intensity, *regardless of distance* between the pixel's center and the area; only the total amount of overlapped area matters.

- **Weighted Area sampling:**

Equal areas contribute unequally.

A smaller area closer to the pixel center has a greater influence than does one at greater distance.



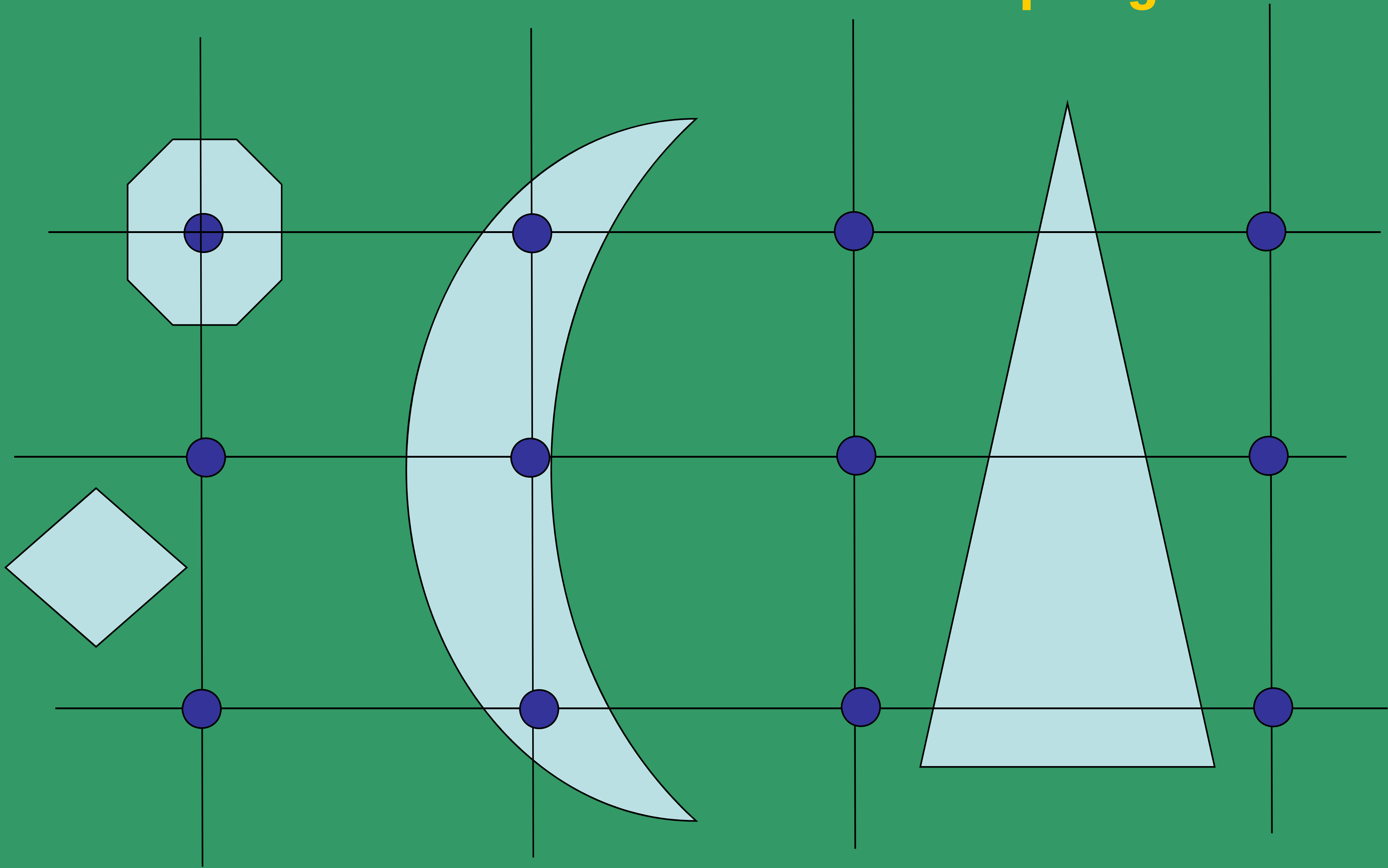
Intensity Proportional to Area Covered

ANTIALIASING TECHNIQUES (Cont.)

Point Sampling

- Select one point for each pixel, evaluate the original signal at this point and assign its value to the pixel.
- The projected vertices are not constrained to lie on a square grid.
- Because the signal's values at a finite set of points are sampled, important features of the signal may be missed.
- The approach of taking more than one sample for each pixel and combining them is known as **supersampling**.
- Supersampling corresponds to reconstructing the signal and resampling the reconstructed signal.

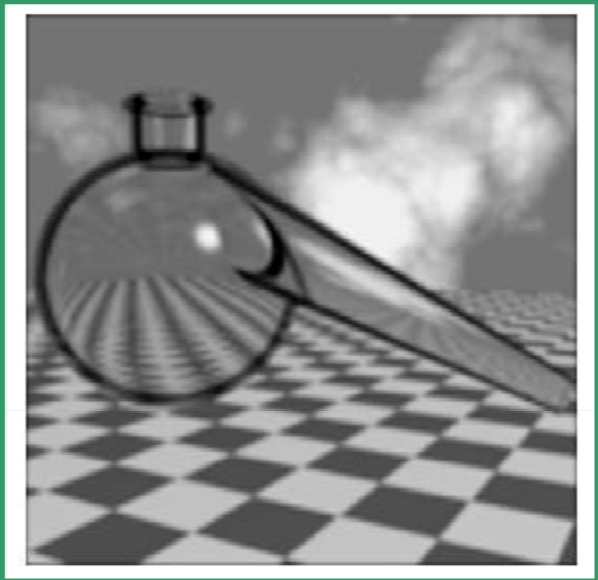
Problems in Point Sampling



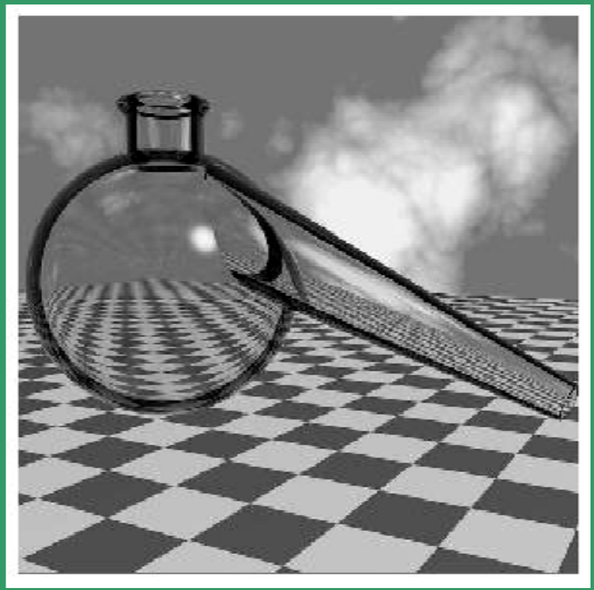
ANTIALIASING TECHNIQUES (Cont.)

Filtering

- By removing high frequency components from the original signal, the new signal can be reconstructed properly from a finite number of samples.

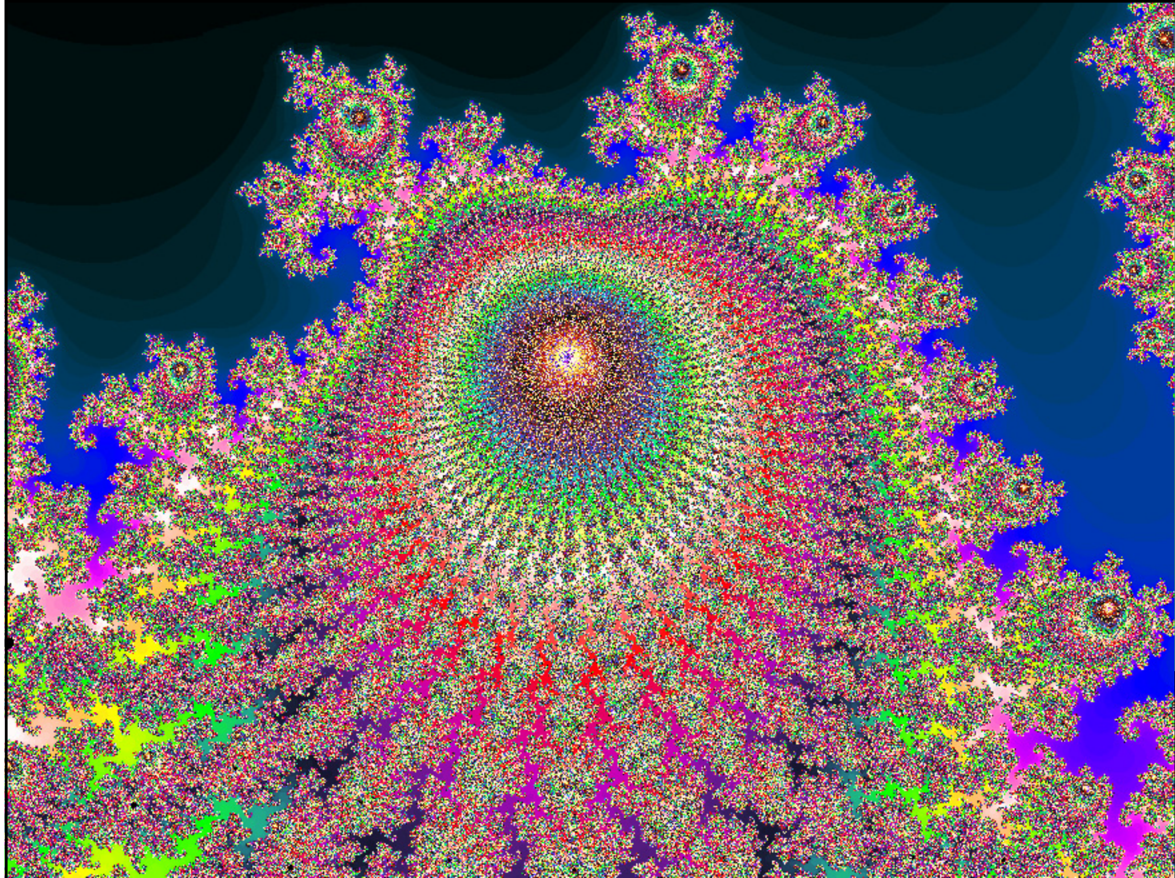


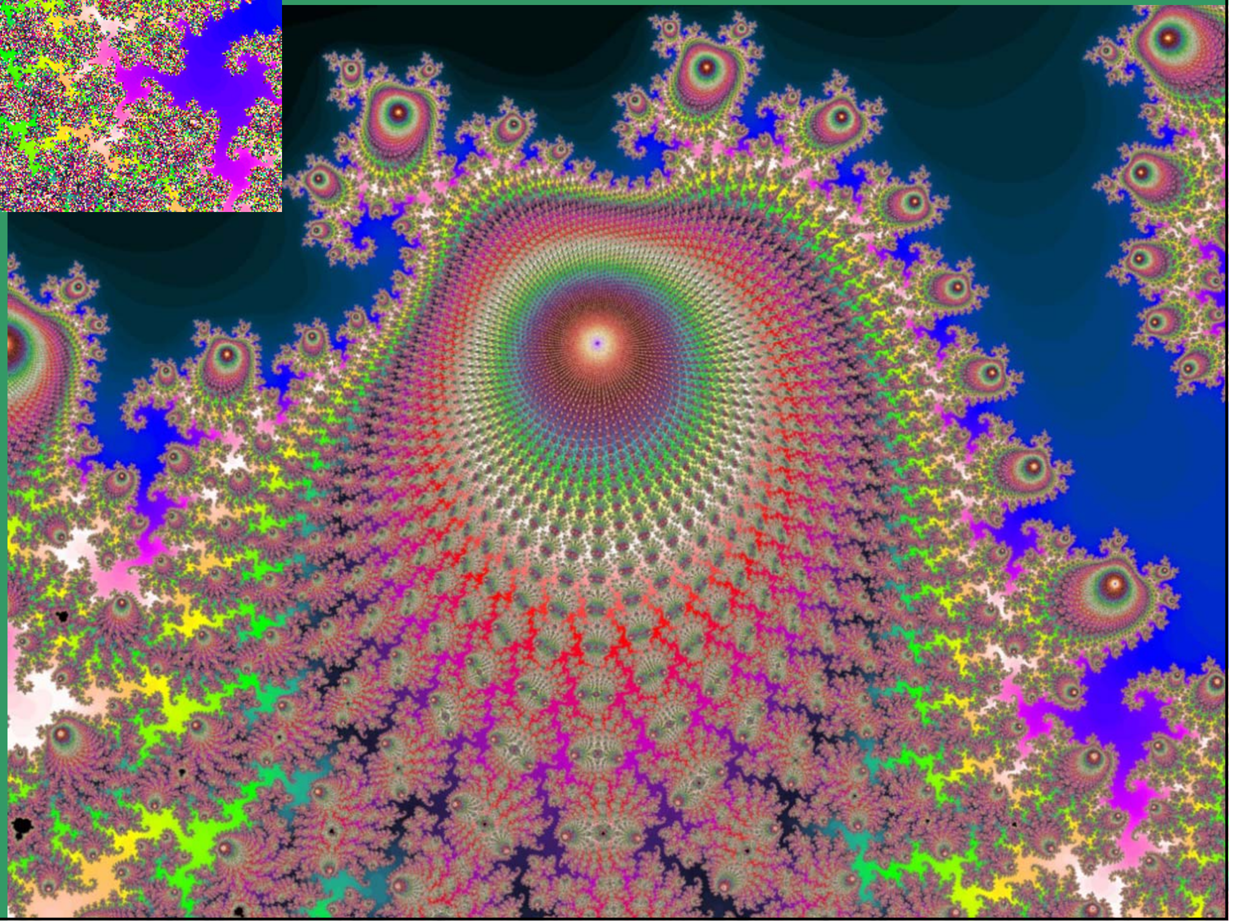
Result for Low Pass Filtering



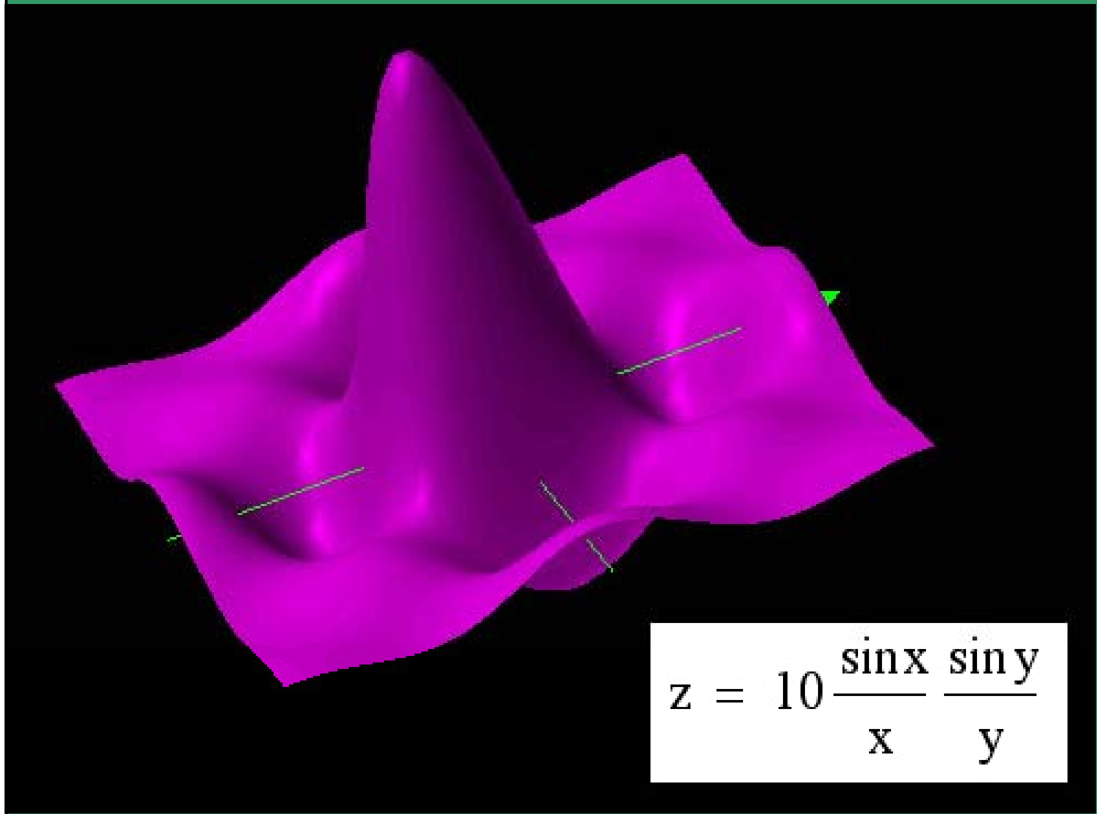
Original Image

Result for High Pass Filtering

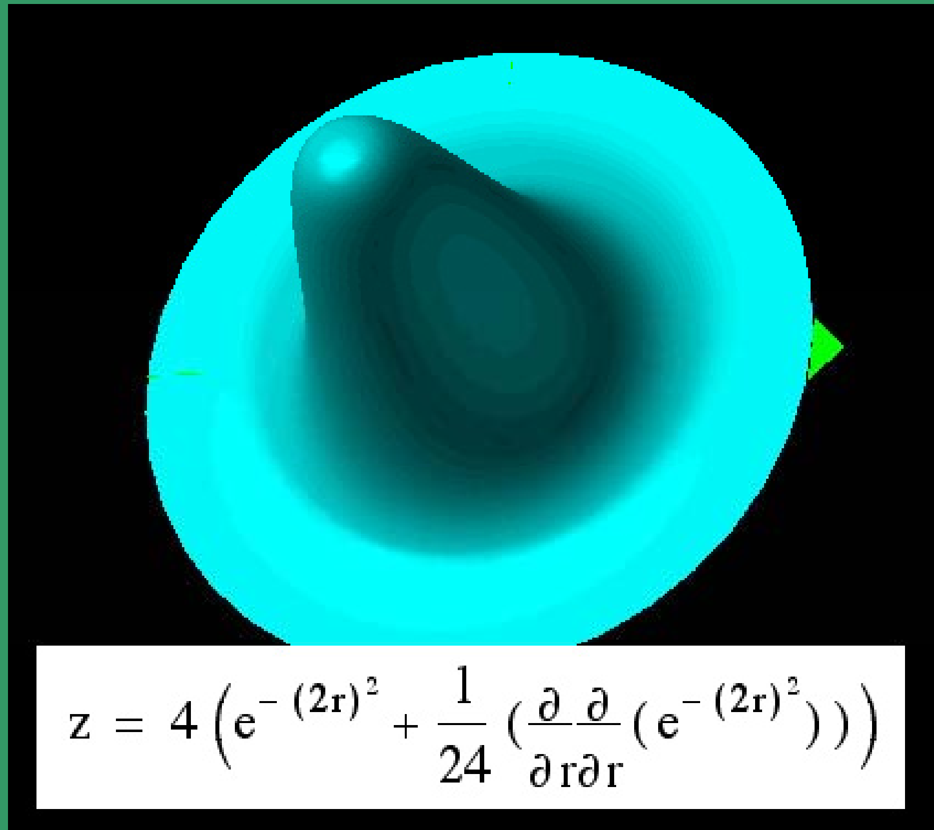




Functions (Gaussian-derived) for anti-aliasing



$$z = 10\frac{\sin x}{x}\frac{\sin y}{y}$$



$$z = 4\left(e^{-(2r)^2} + \frac{1}{24}\left(\frac{\partial}{\partial r}\frac{\partial}{\partial r}\left(e^{-(2r)^2}\right)\right)\right)$$

TEXTURE Mapping

& BUMP MAPPING

Texture Bump Mapping

Bump mapping, like texture mapping, is a technique to add more realism to synthetic images without adding a lot of geometry.

Texture mapping adds realism by attaching images to geometric surfaces.

Bump mapping adds per-pixel surface **relief shading**, increasing the apparent complexity of the surface.

RELIEF MAP IN DIGITAL CARTOGRAPHY

Texture Bump Mapping

Bump mapping is done for surfaces that should have a patterned roughness. Examples include oranges, strawberries, stucco, wood, etc.

An intuitive representation of surface bumpiness is formed by a 2D height field array, or ***bump map***.

Bump map is defined by the scalar difference $F(u, v)$ between the flat surface $P(u, v)$ and the desired bumpy surface $P'(u, v)$ along the normal N at each point (u, v).

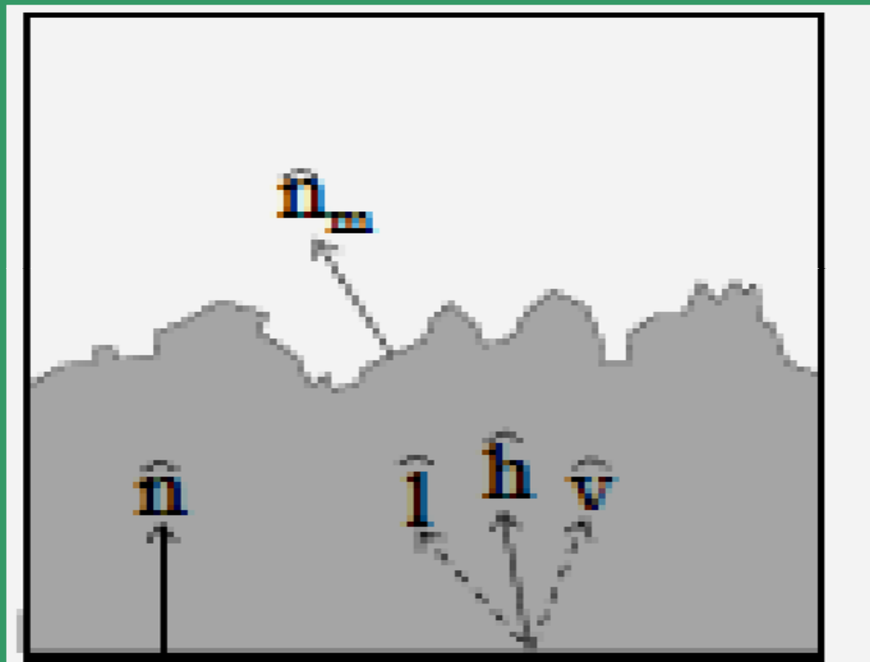
Texture Bump Mapping

A bump map is an array of values that represent an object's height variations on a small scale.

A custom renderer is used to map these height values into changes in the local surface normal.

These perturbed normals are combined with the surface normal, and the results are used to evaluate the lighting equation at each pixel.

Texture Bump Mapping

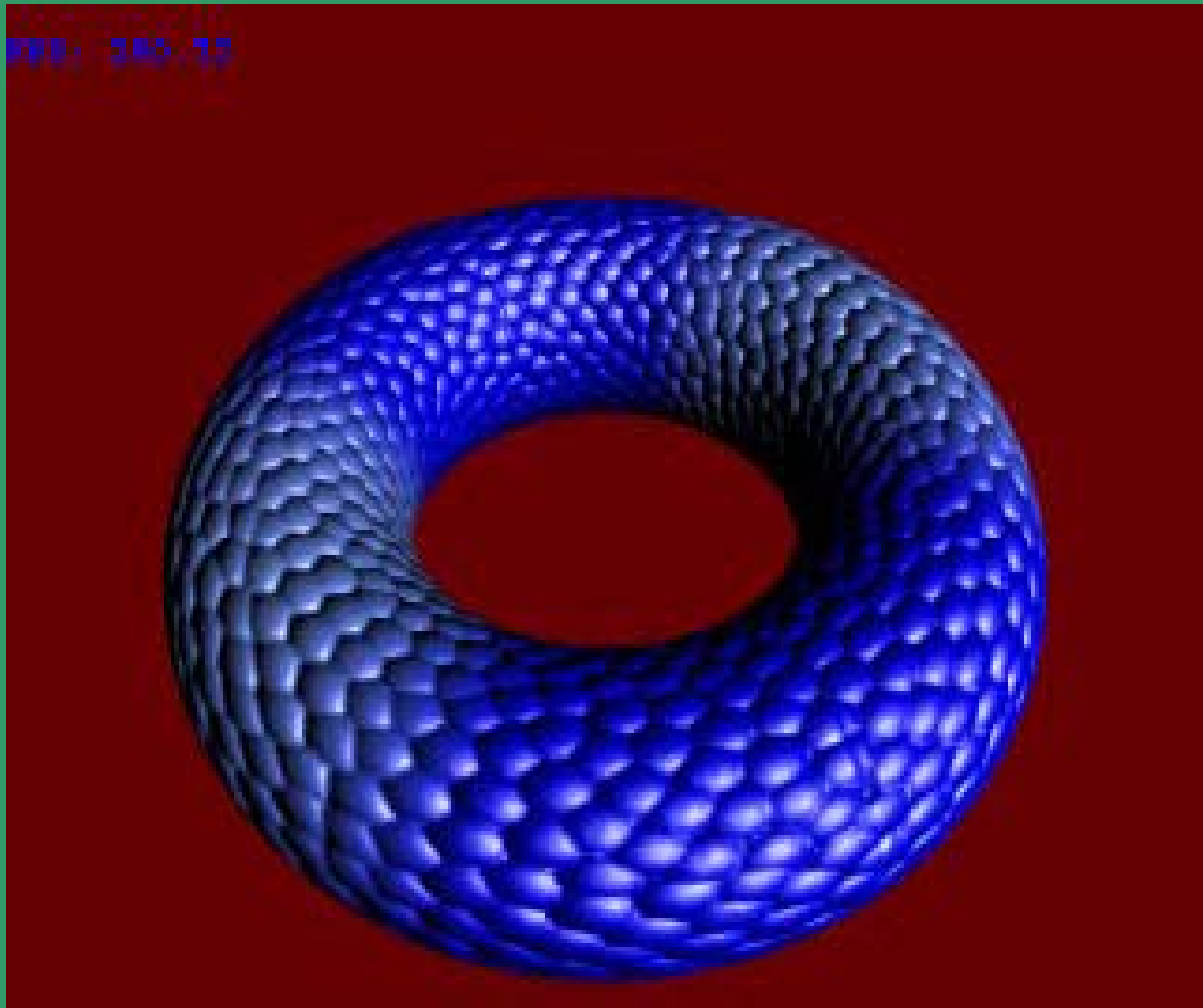


Texture Space:
(s, t)

Surface Space:
(u, v)

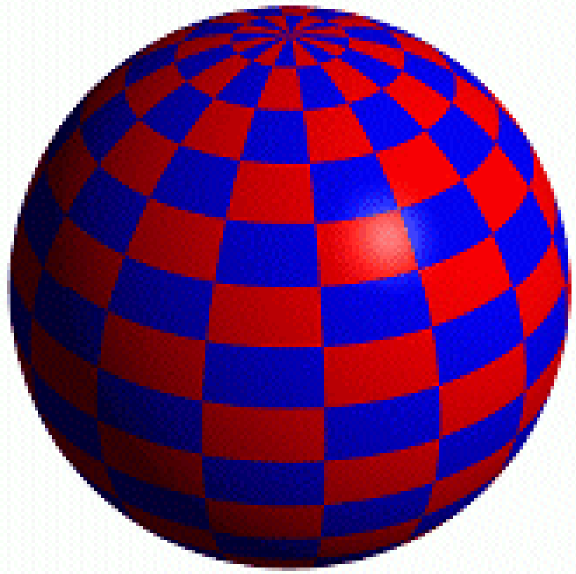
Image Space:
(x, y)

EXAMPLE



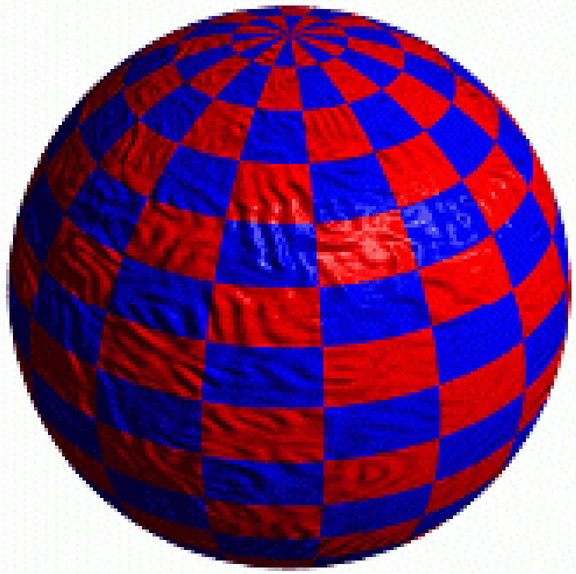
Bump Mapping

- Textures can be used to alter the surface normal of an object.
- This does not change the actual shape of the surface -- we are only shading it as if it were a different shape!



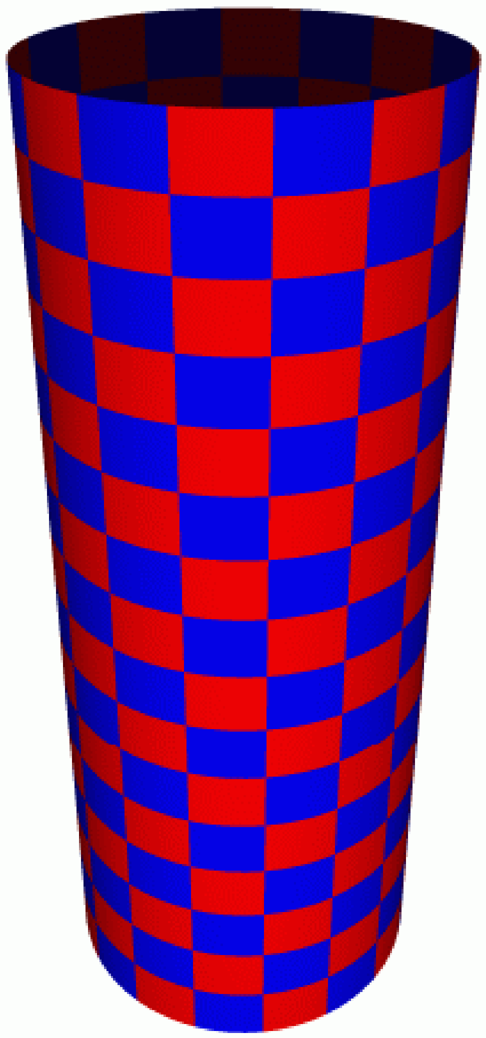
Sphere w/Diffuse Texture

Swirly Bump Map

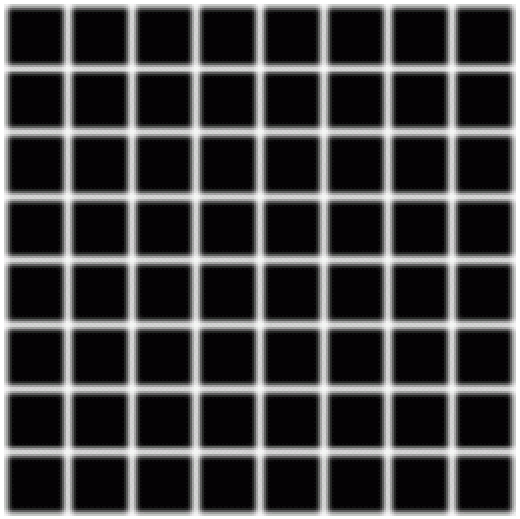


Sphere w/Diffuse Texture & Bump Map

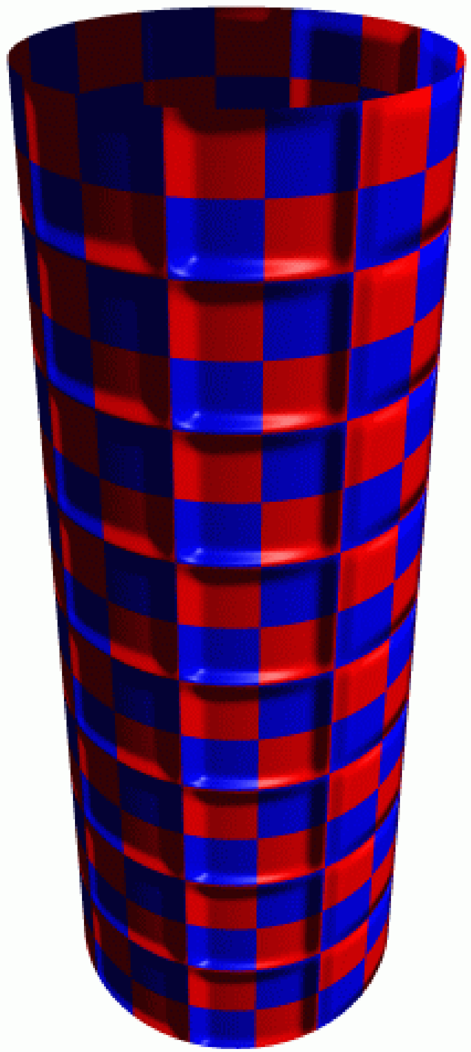
Another Bump Map Example



Cylinder w/Diffuse Texture Map

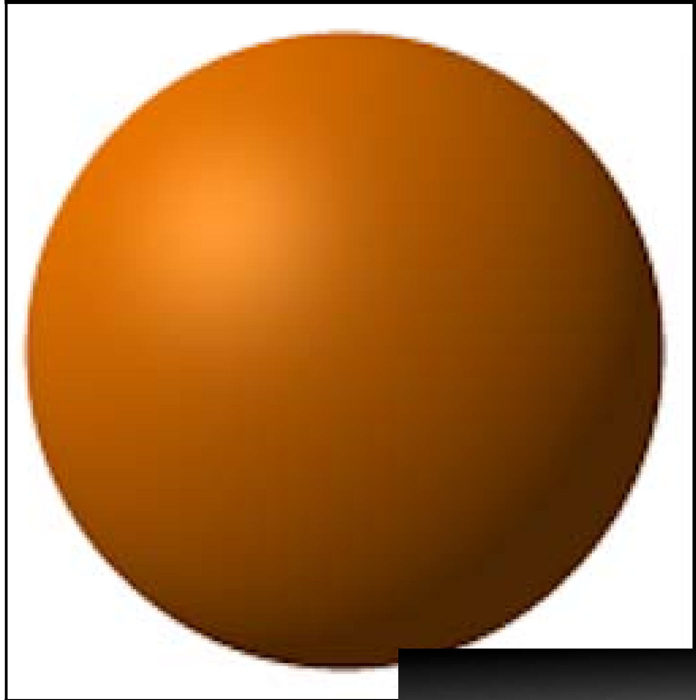
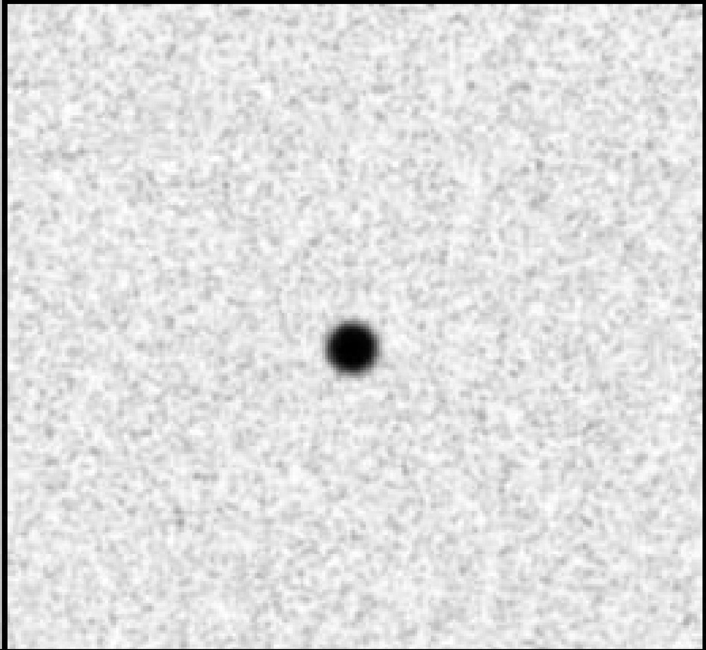
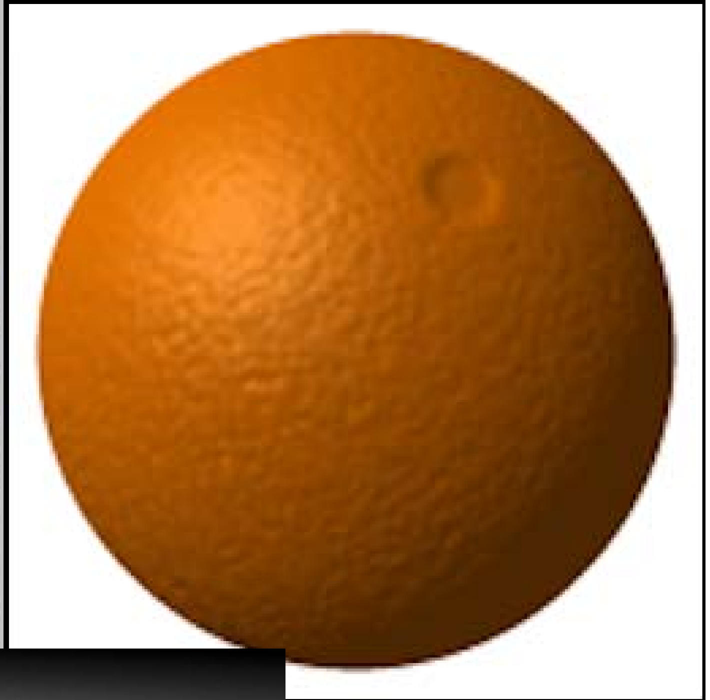
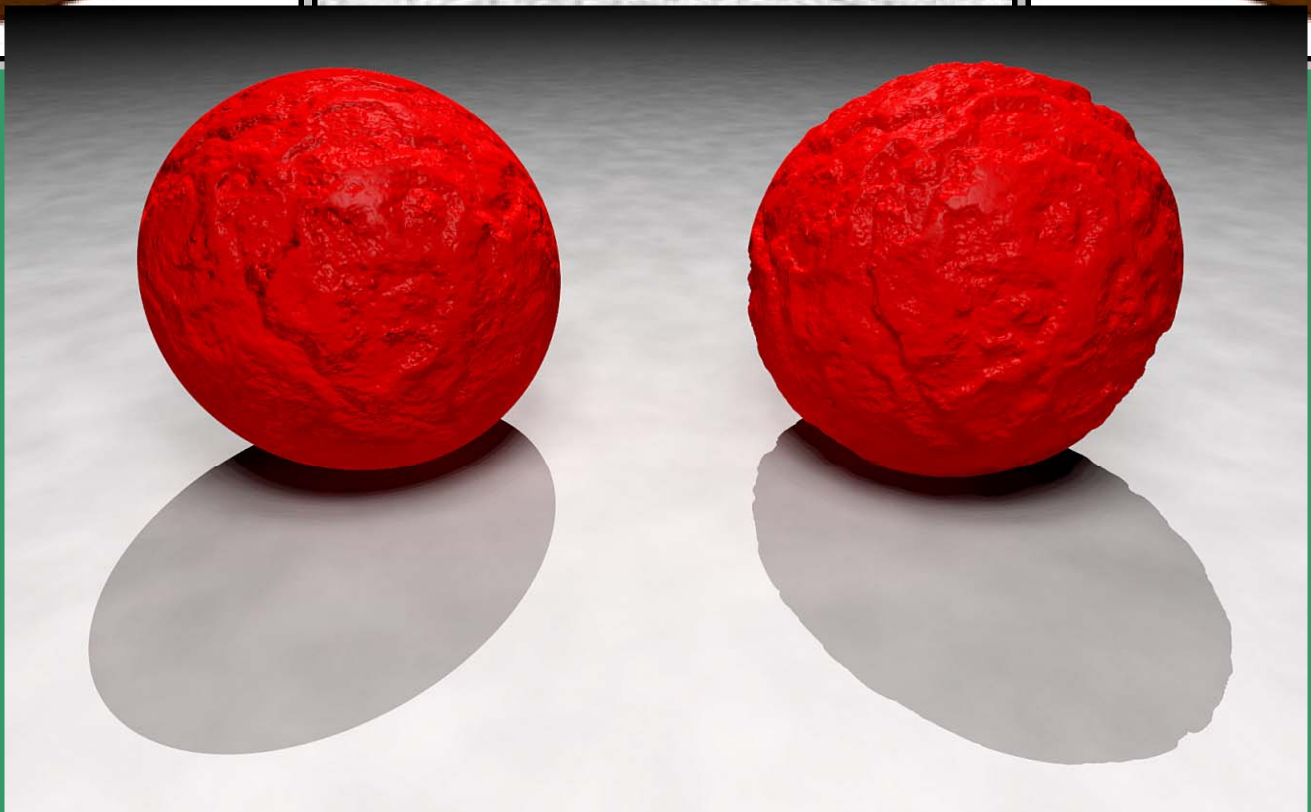


Bump Map

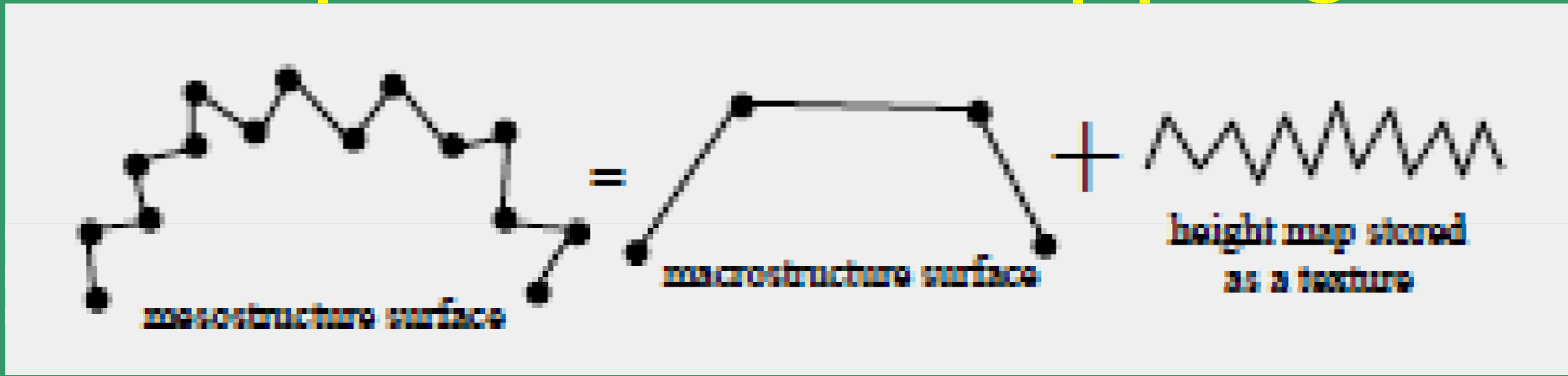


Cylinder w/Texture Map & Bump Map

Bump Map Example

Displacement Mapping



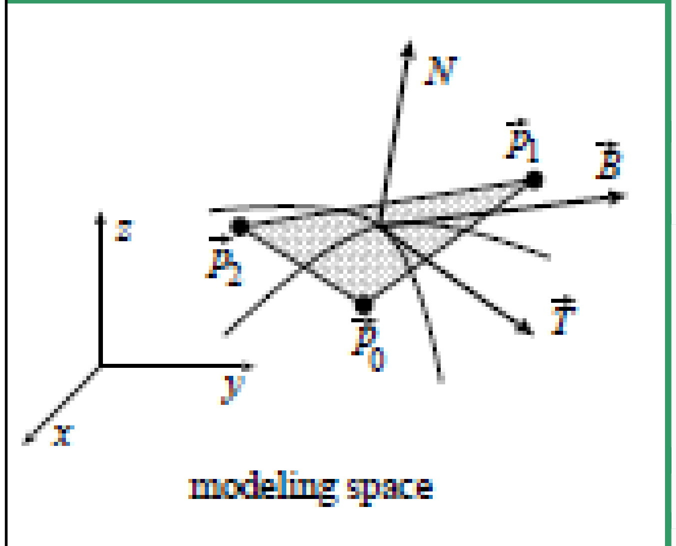
Displacement mapping algorithms take *sample points* and displace them perpendicularly to the normal of the macrostructure surface with the distance obtained from the height map.

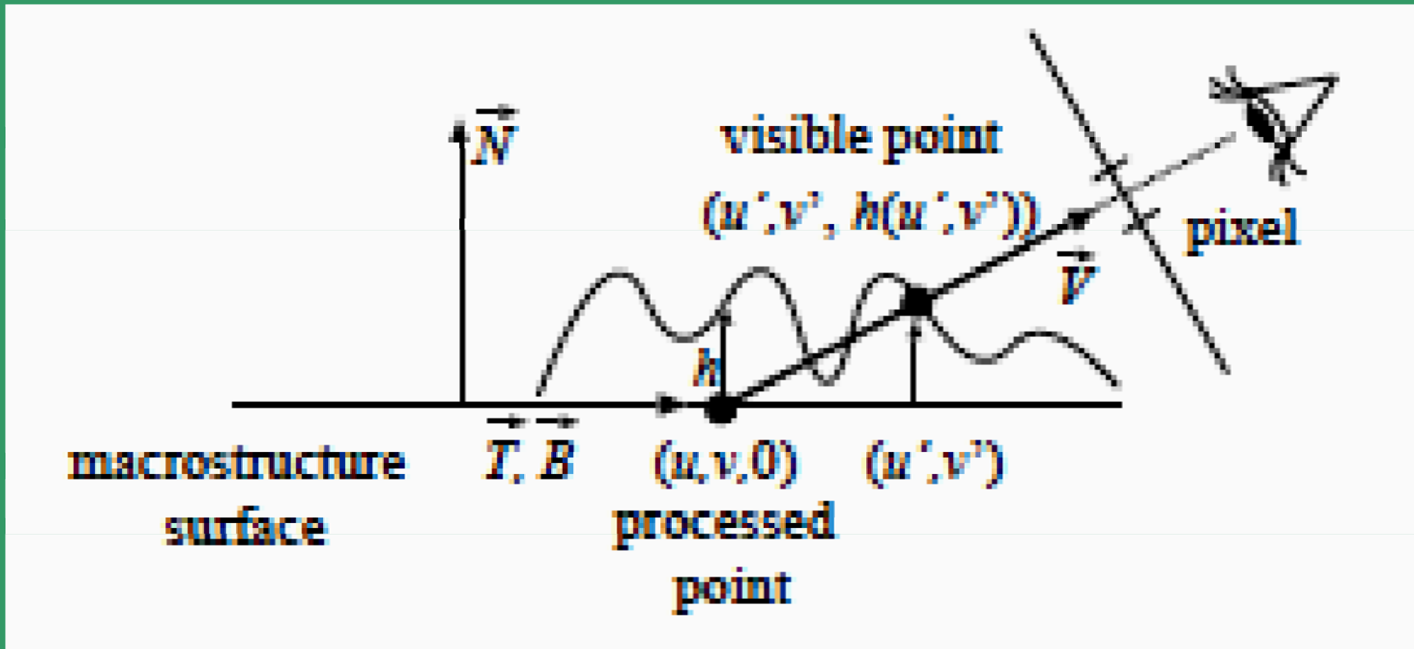
The sample points can be either the vertices of the original or tessellated mesh (*per-vertex displacement mapping) or the points corresponding to the texel centers* (*per-pixel displacement mapping).*

In case of per-vertex displacement mapping the modified geometry goes through the rendering pipeline. However, in per-pixel displacement mapping, surface details are added when color texturing takes place.

$$\vec{r}(u,v) = \vec{p}(u,v) + \vec{N}(u,v)h(u,v)$$

r – mesostructure; p – macrostructure;
N – unit normal; h – scalar height function / map

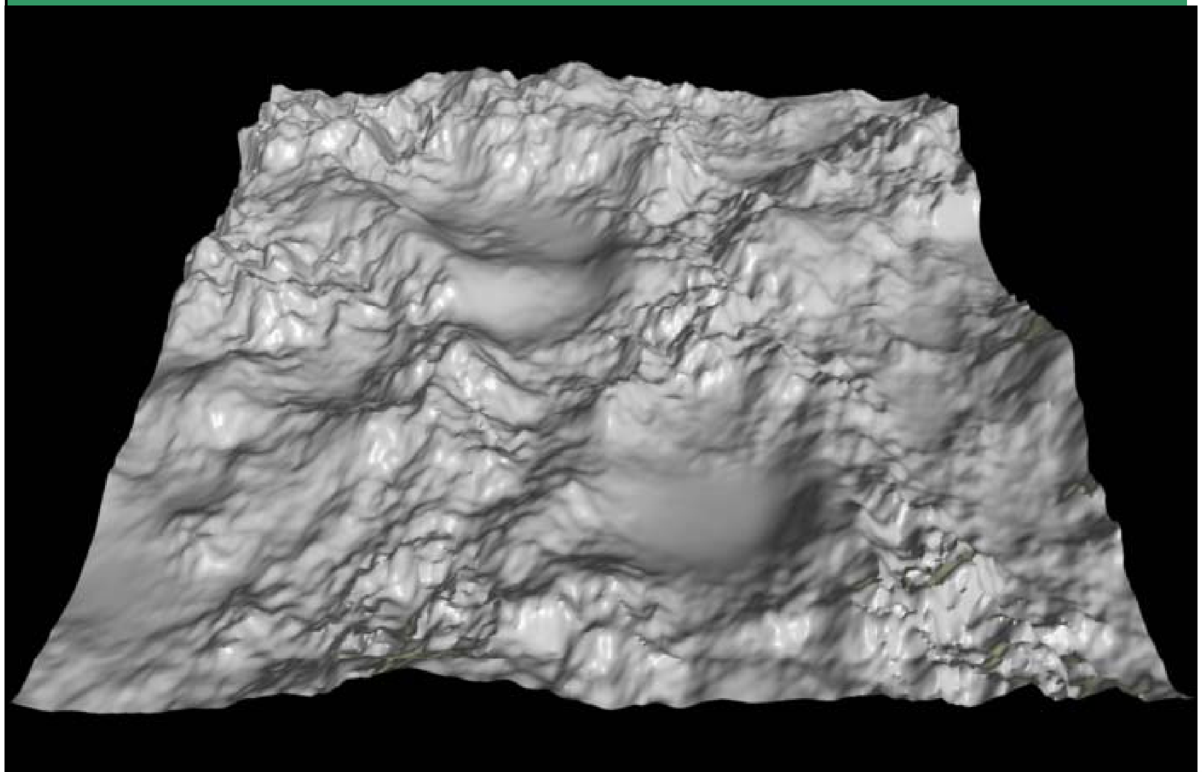


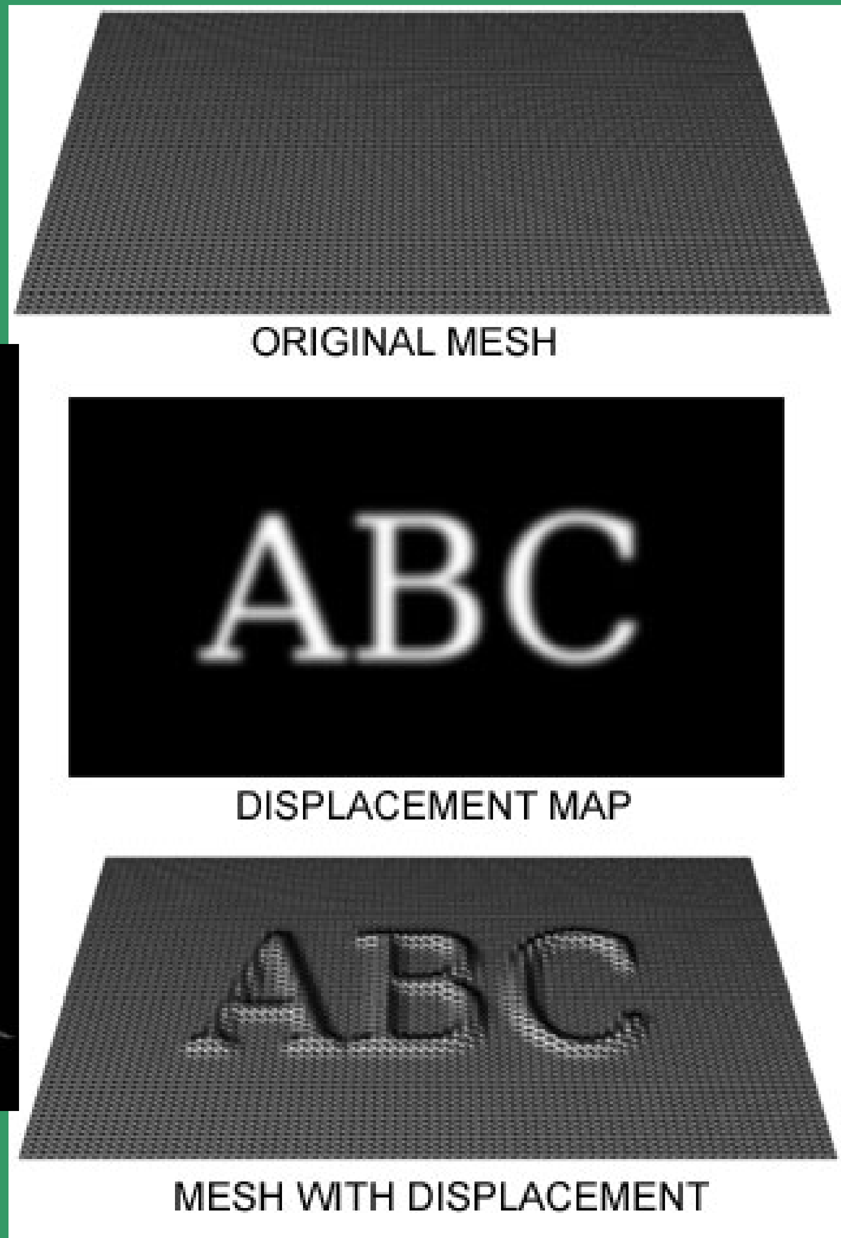


Solve for:

$$(u',v',h(u',v')) = (u,v,o) + \vec{V}.t$$

Displacement Mapping

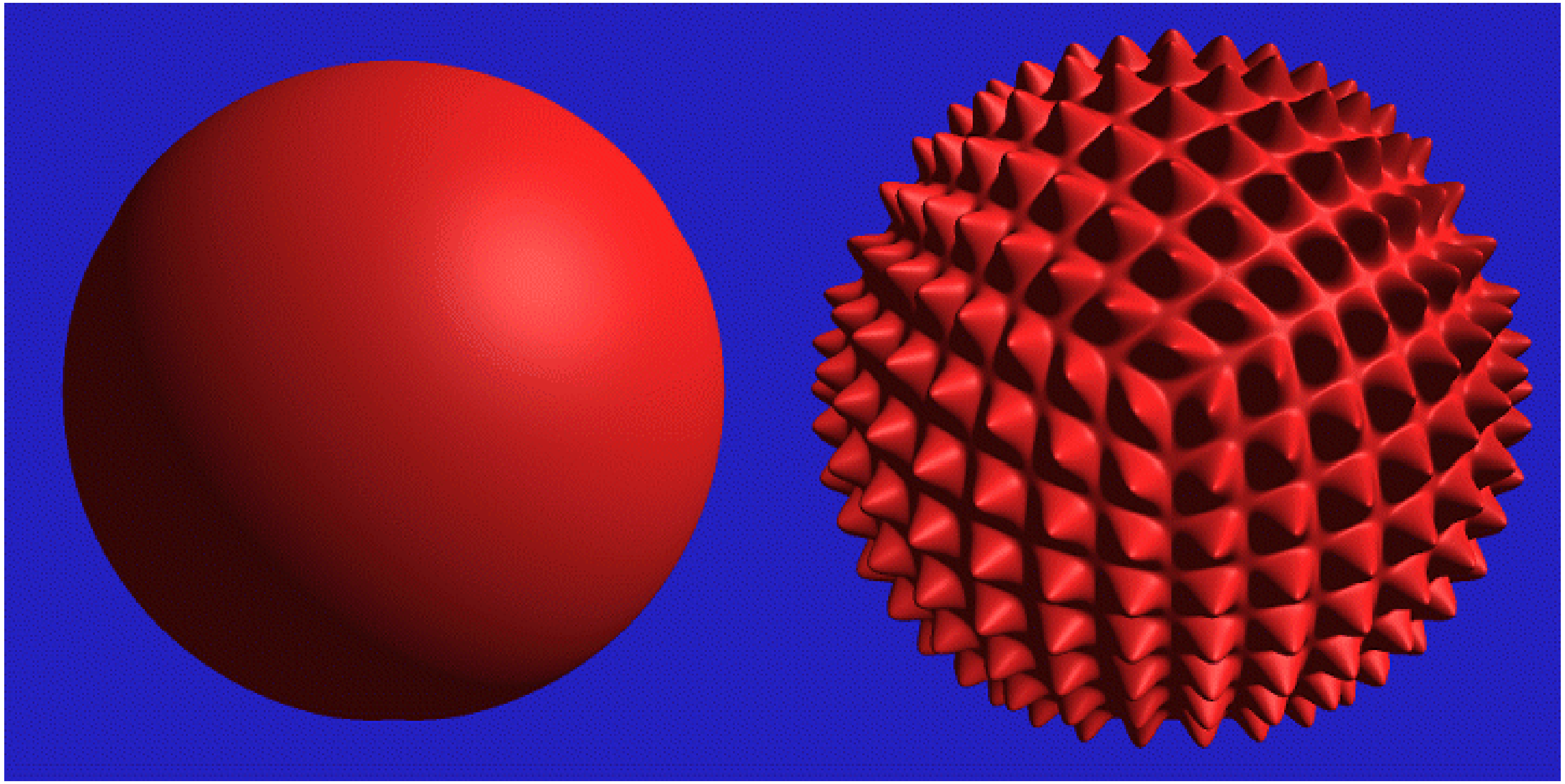




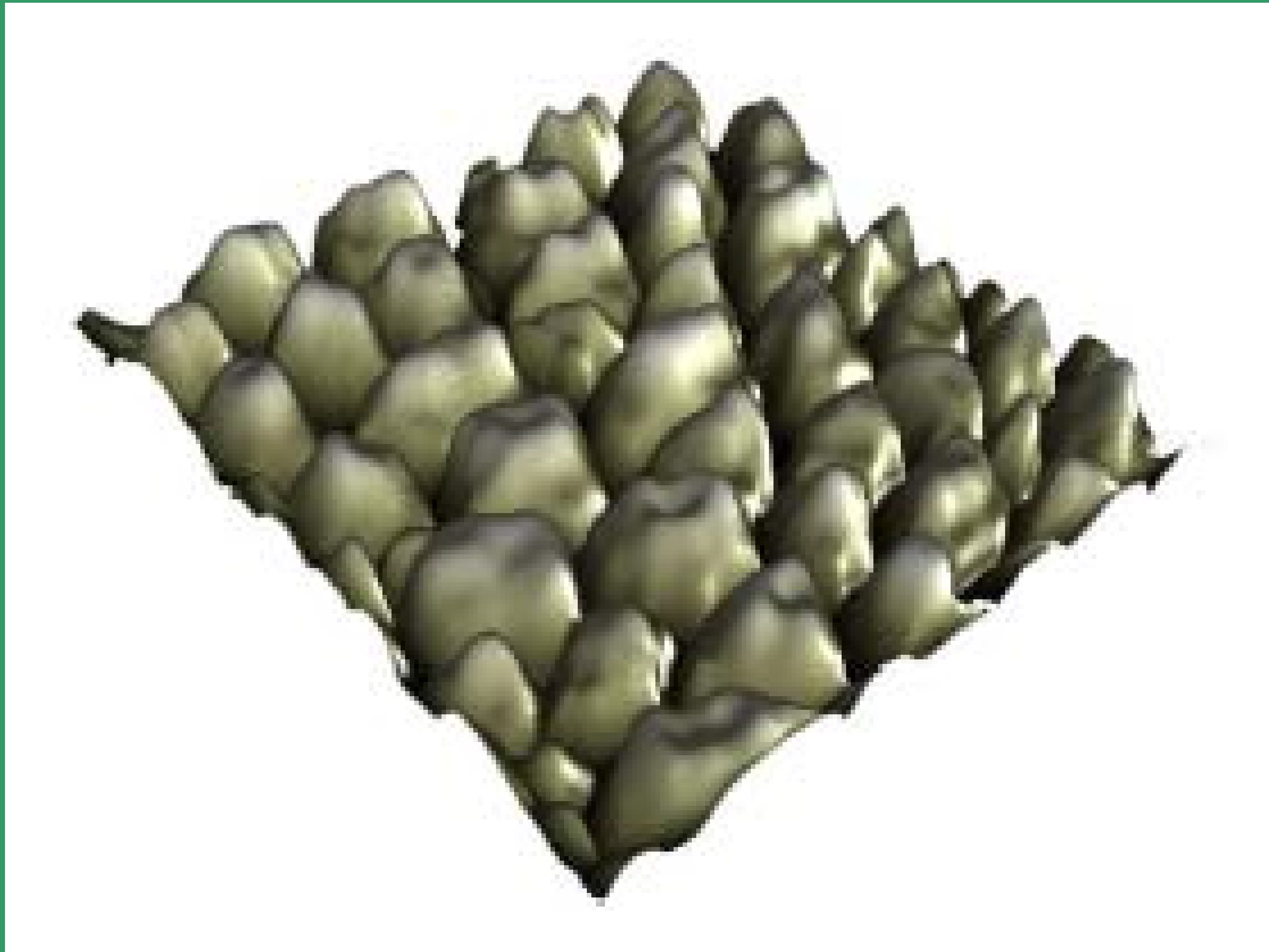
Displacement Mapping

- Use the texture map to actually move the surface point.

- The geometry must be displaced before visibility is determined.



Displacement Mapping

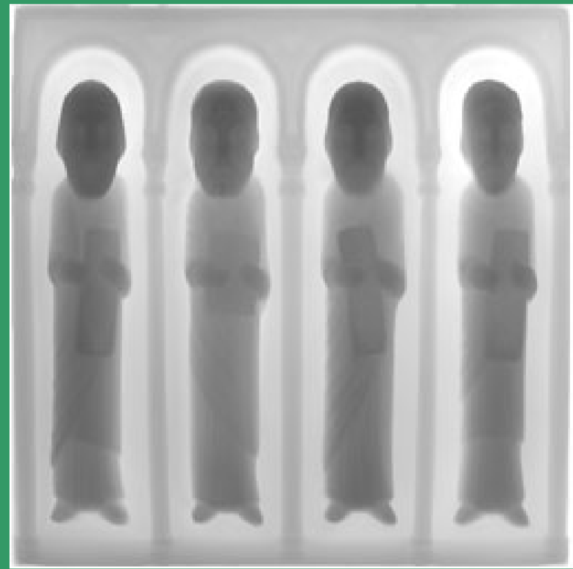


Environment Mapping Example

Terminator II

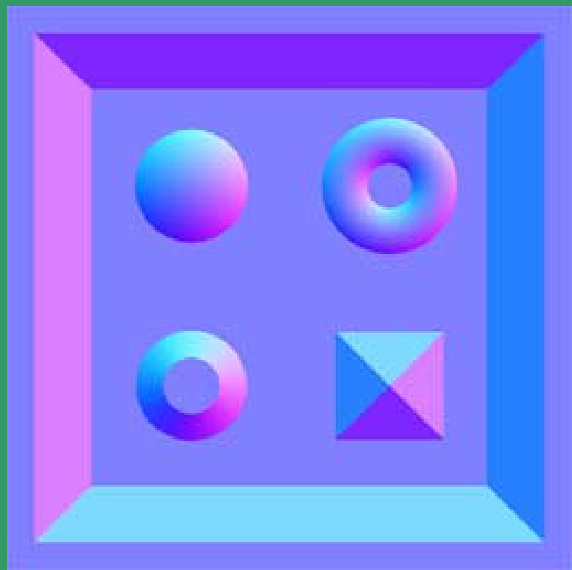
Environment Mapping Example

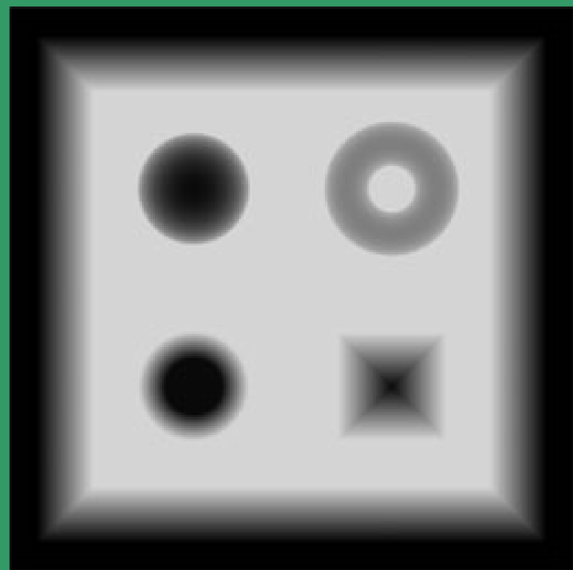
Relief Textures

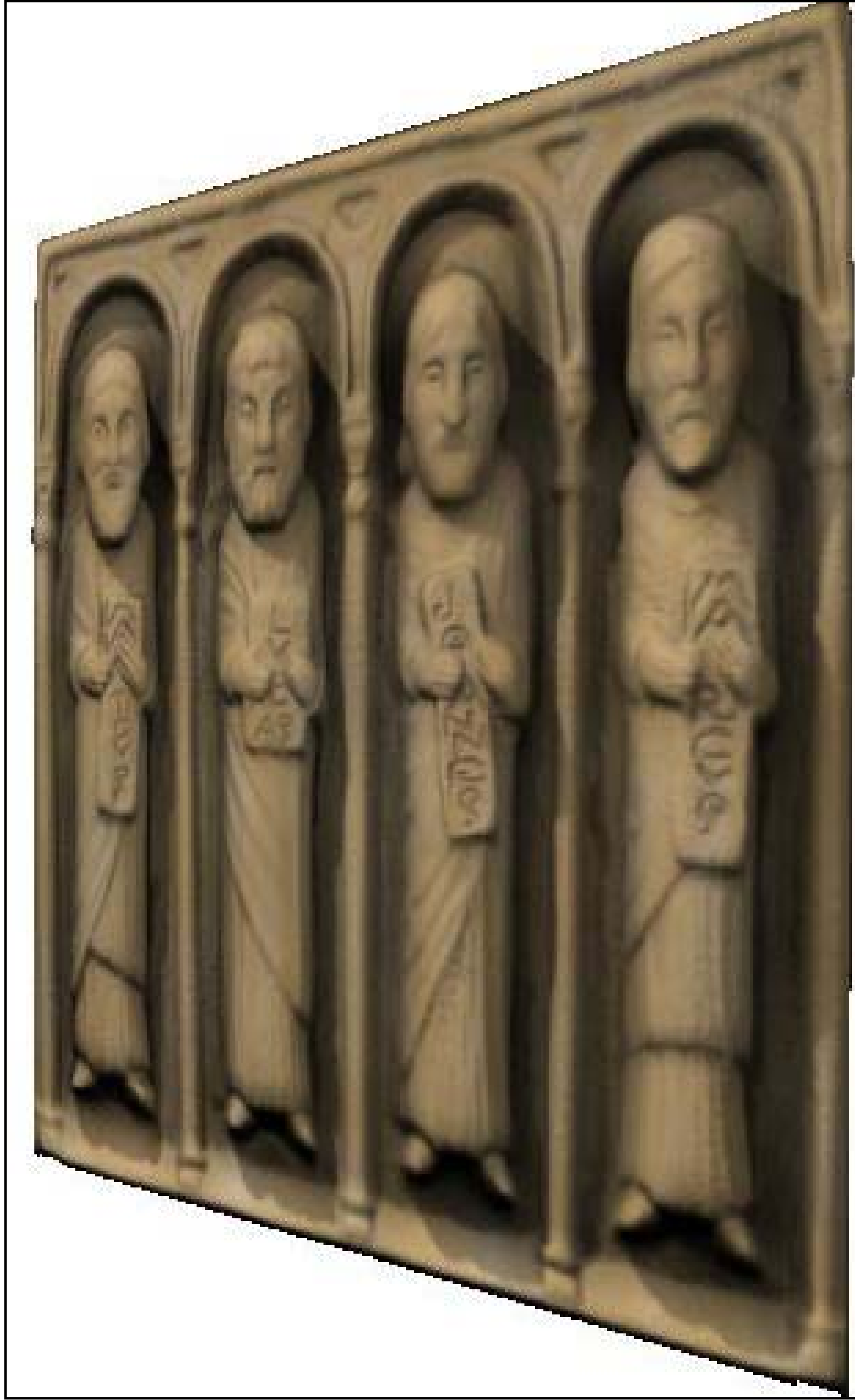


Color map

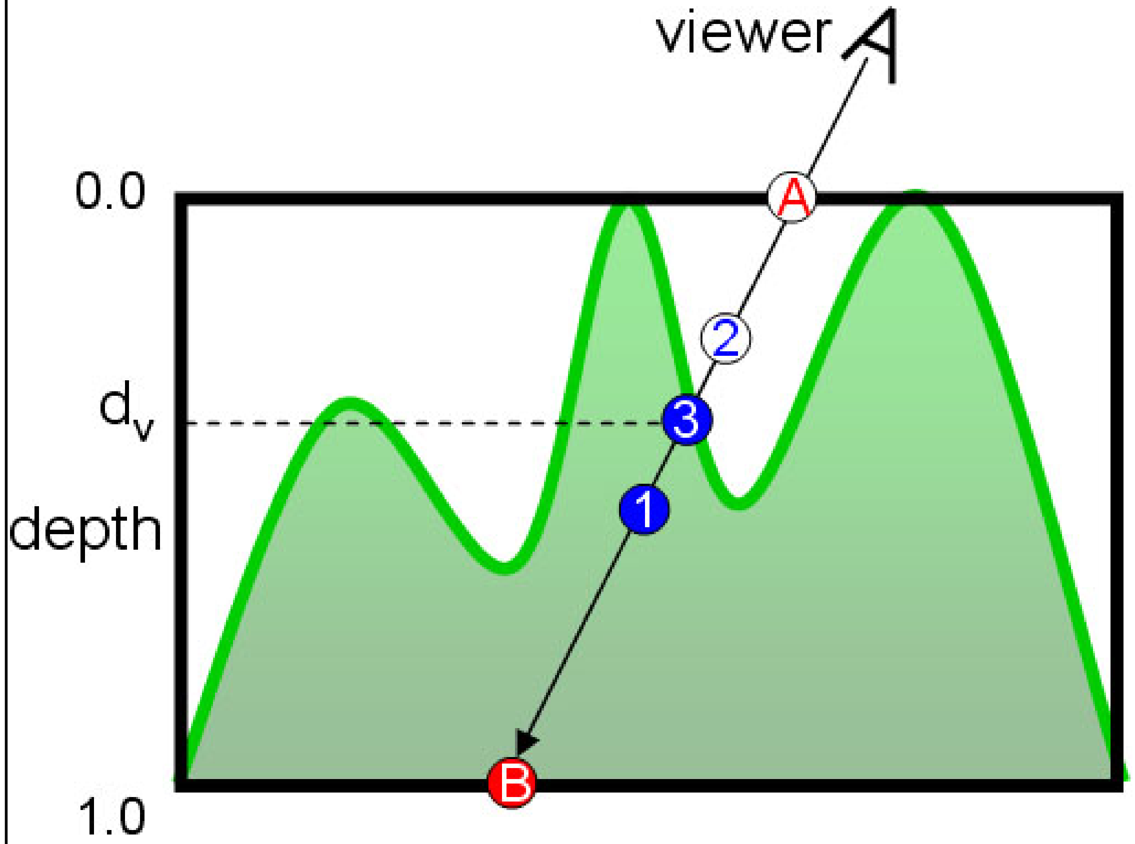
Depth Map

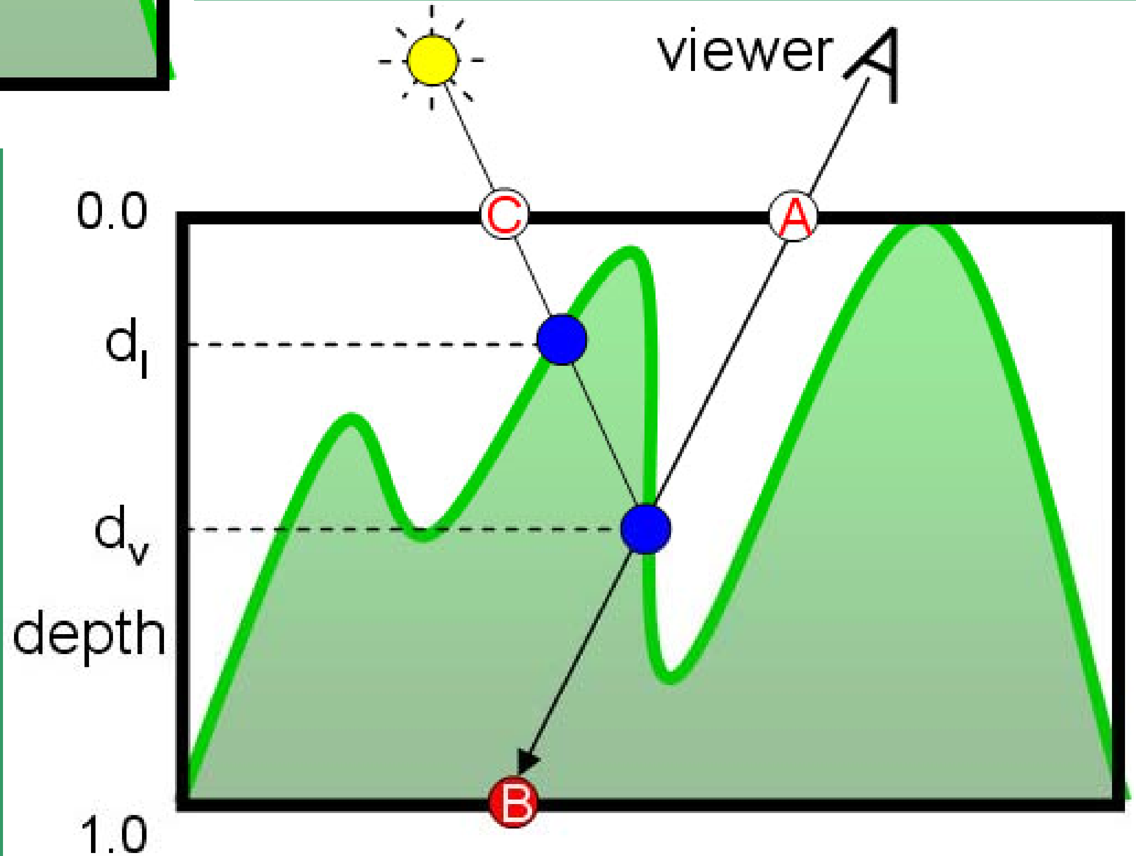


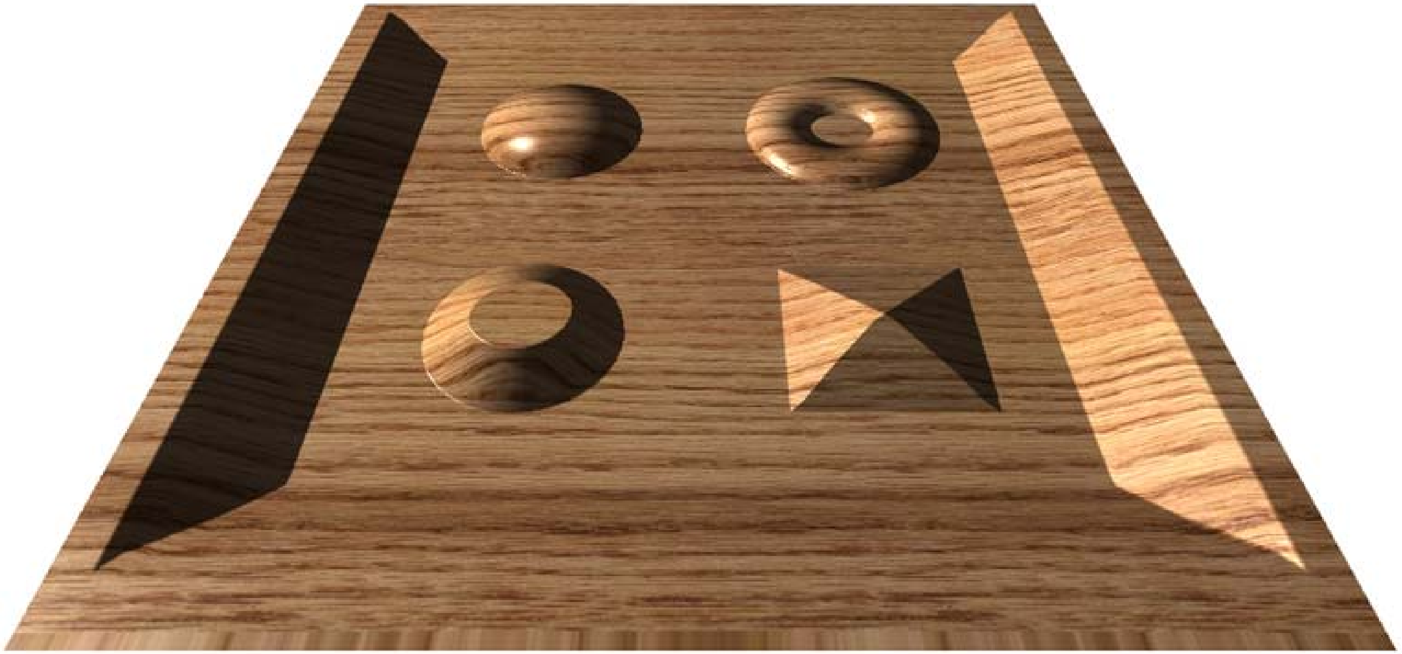





Relief Mapping on Polygonal Surfaces

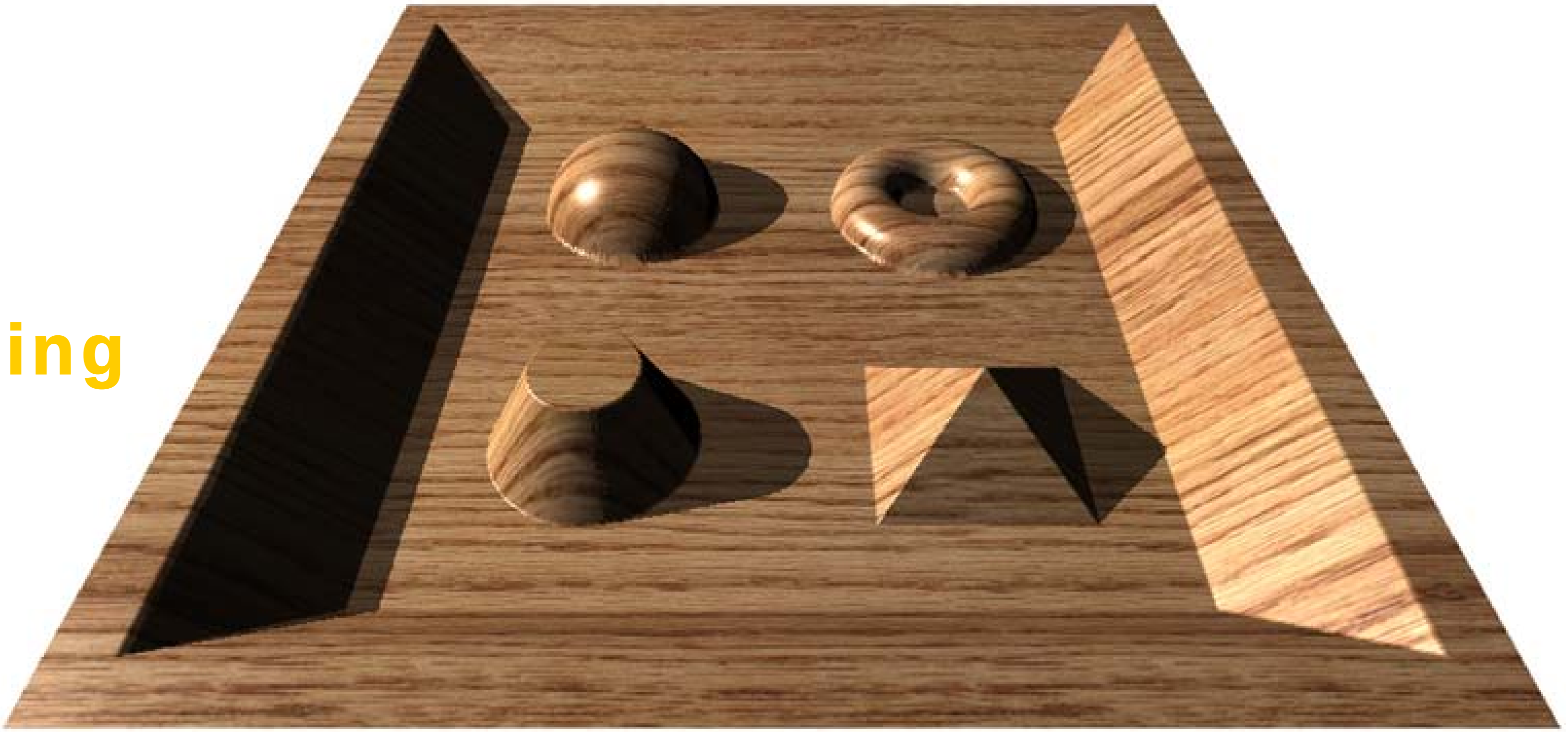


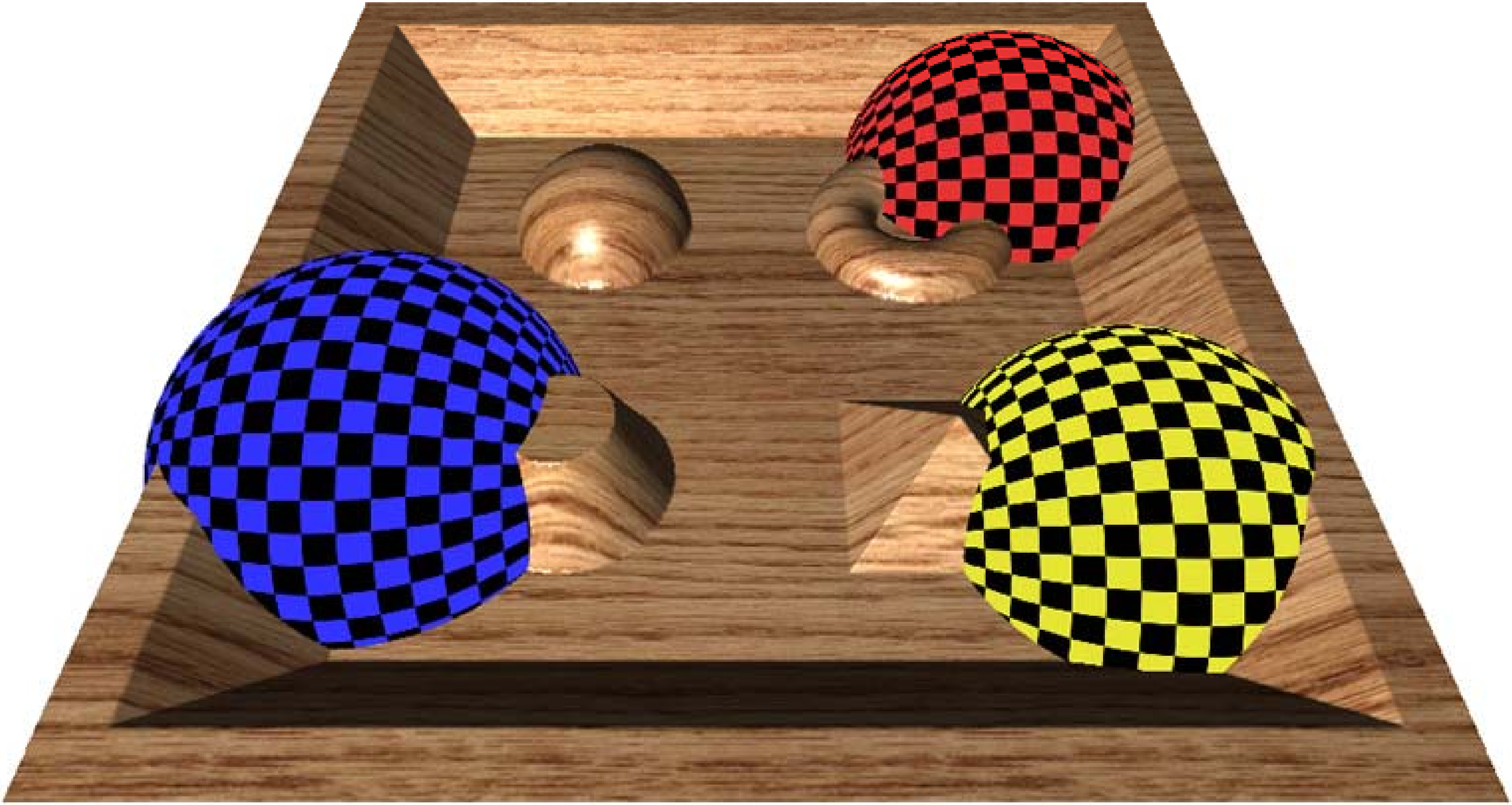




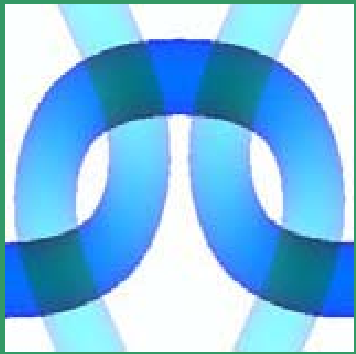
Bump / parallax mapping

Relief Mapping with Self-shadowing

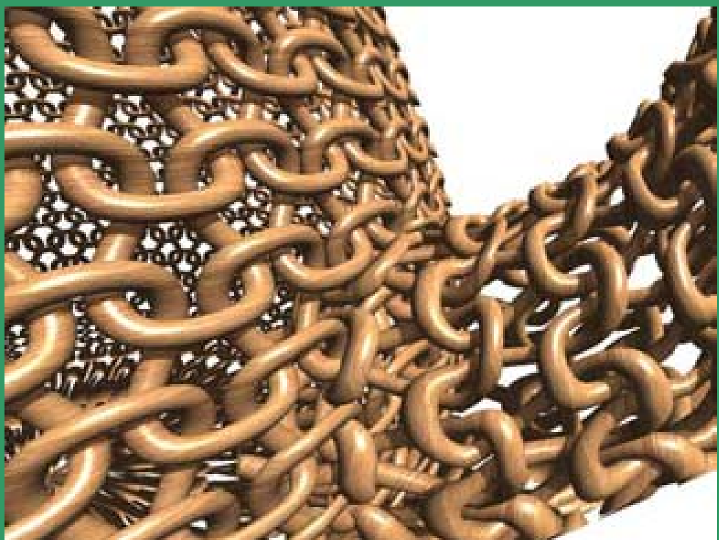


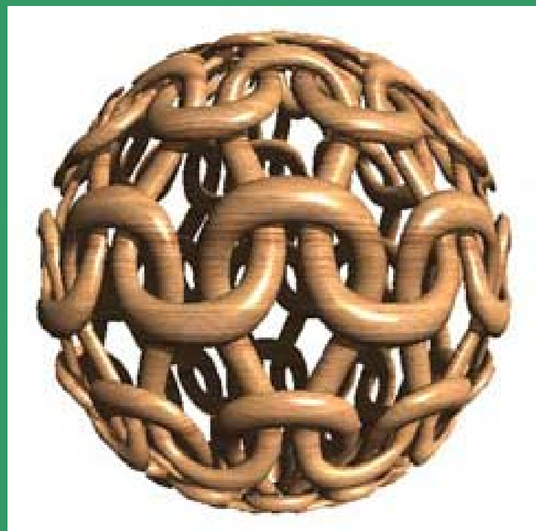


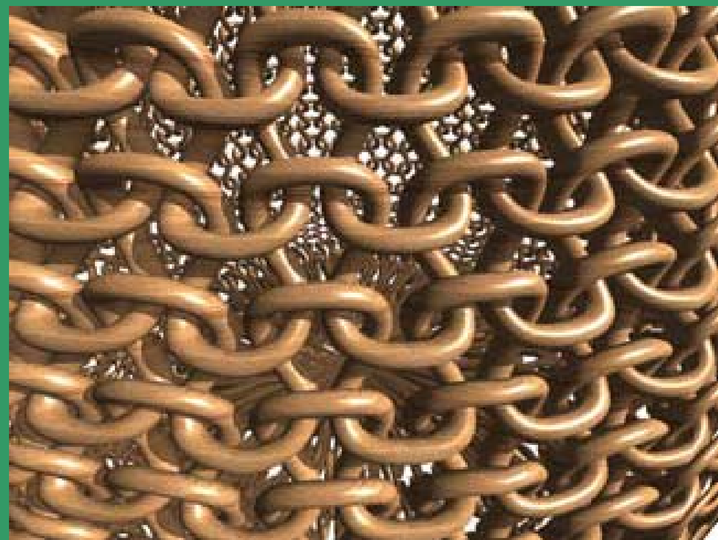
Interpenetration of
Relief map and texture mapped surfaces



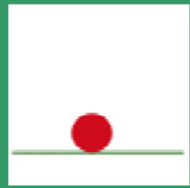
Relief Mapping of Non-height-field







A realistic scene implemented using:
NURBS (Non-uniform Rational B-Splines), image maps, bump maps, texture map, procedural noise and depth of field.
Courtesy: http://realsoft.fi/gallery/



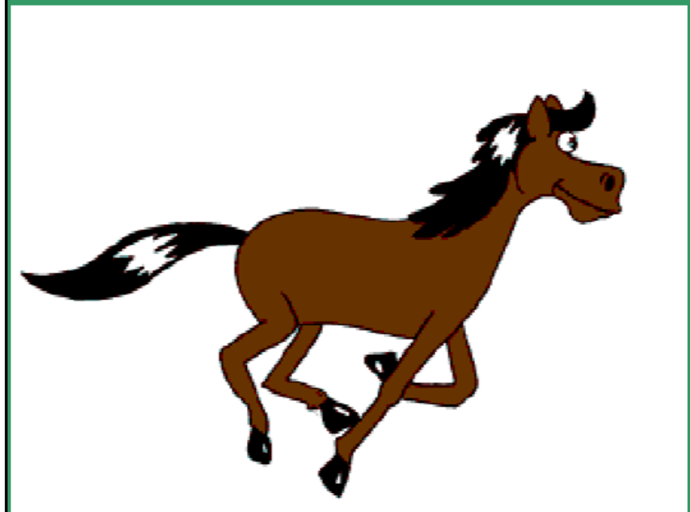
ANIMATION

APPLICATIONS OF ANIMATION

- **Special Effects (Movies, TV)**
- **Video Games**
- **Simulation, Training, Military**
- **Virtual Reality**
- **Medical**
- **Robotics, Animatronics**
- **Visualization**
- **Communication**

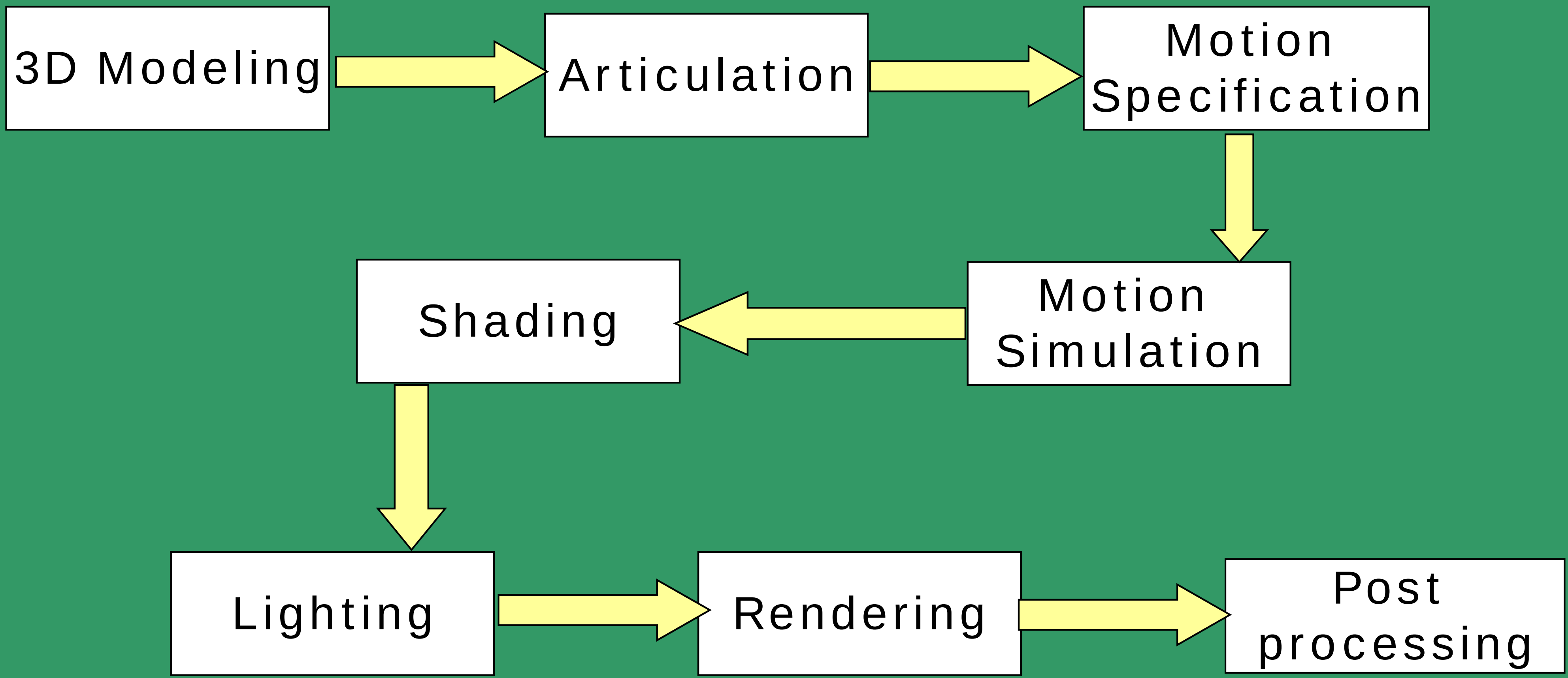
ANIMATION

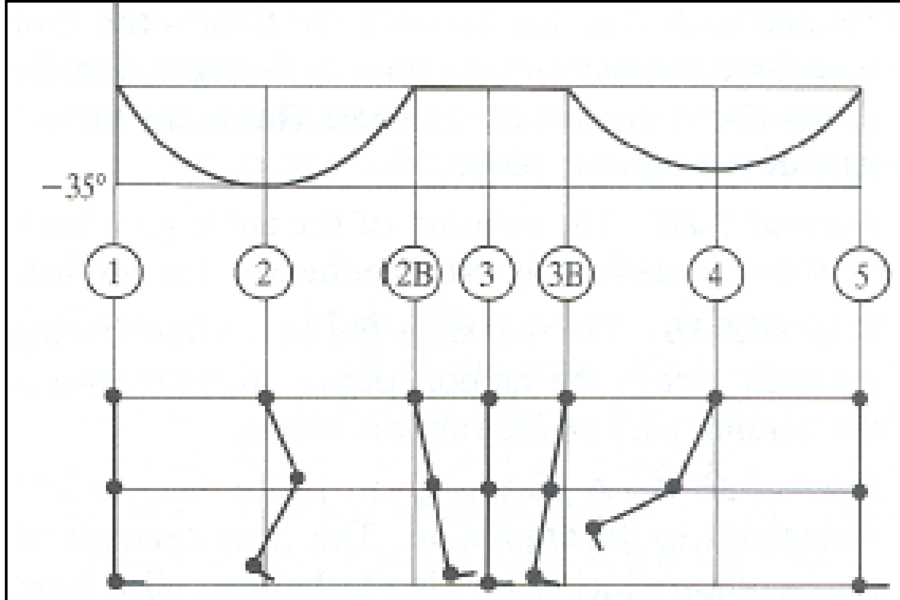
A technique in which the illusion of movement is created by photographing a series of individual drawings on successive frames of film (Cartoon production)

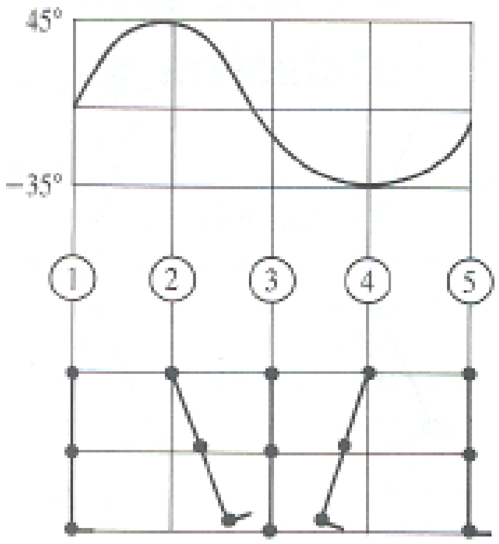


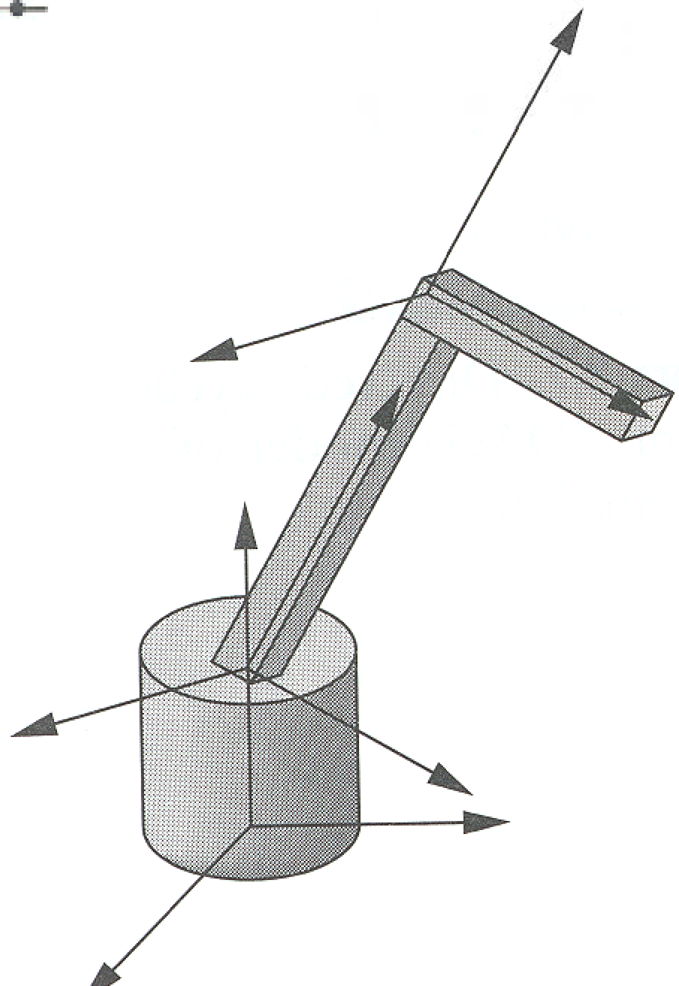
COMPUTER ANIMATION

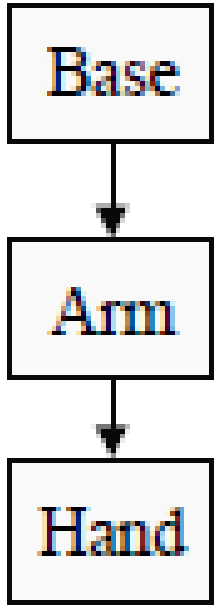
Animation Pipeline





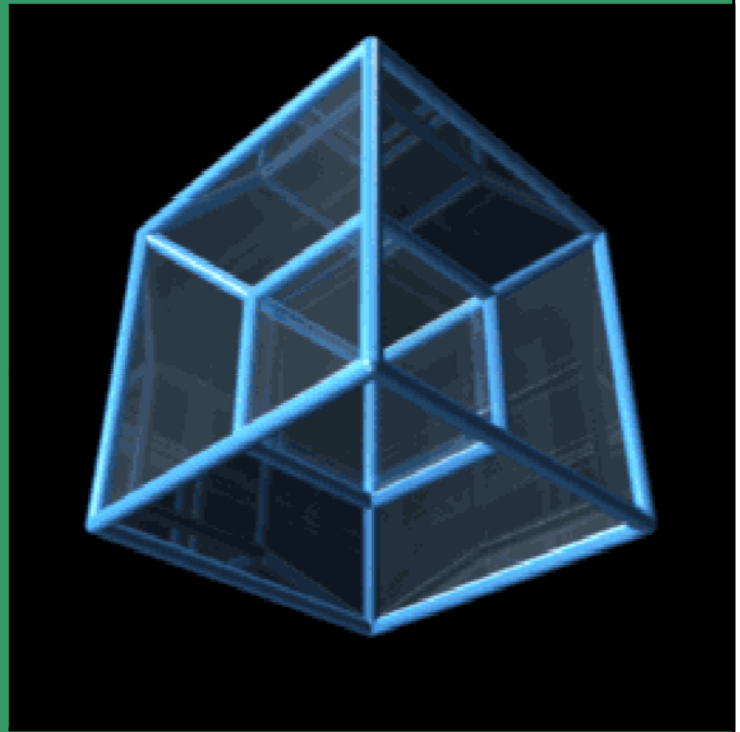






Scene Graph

2D AND 3D ANIMATION



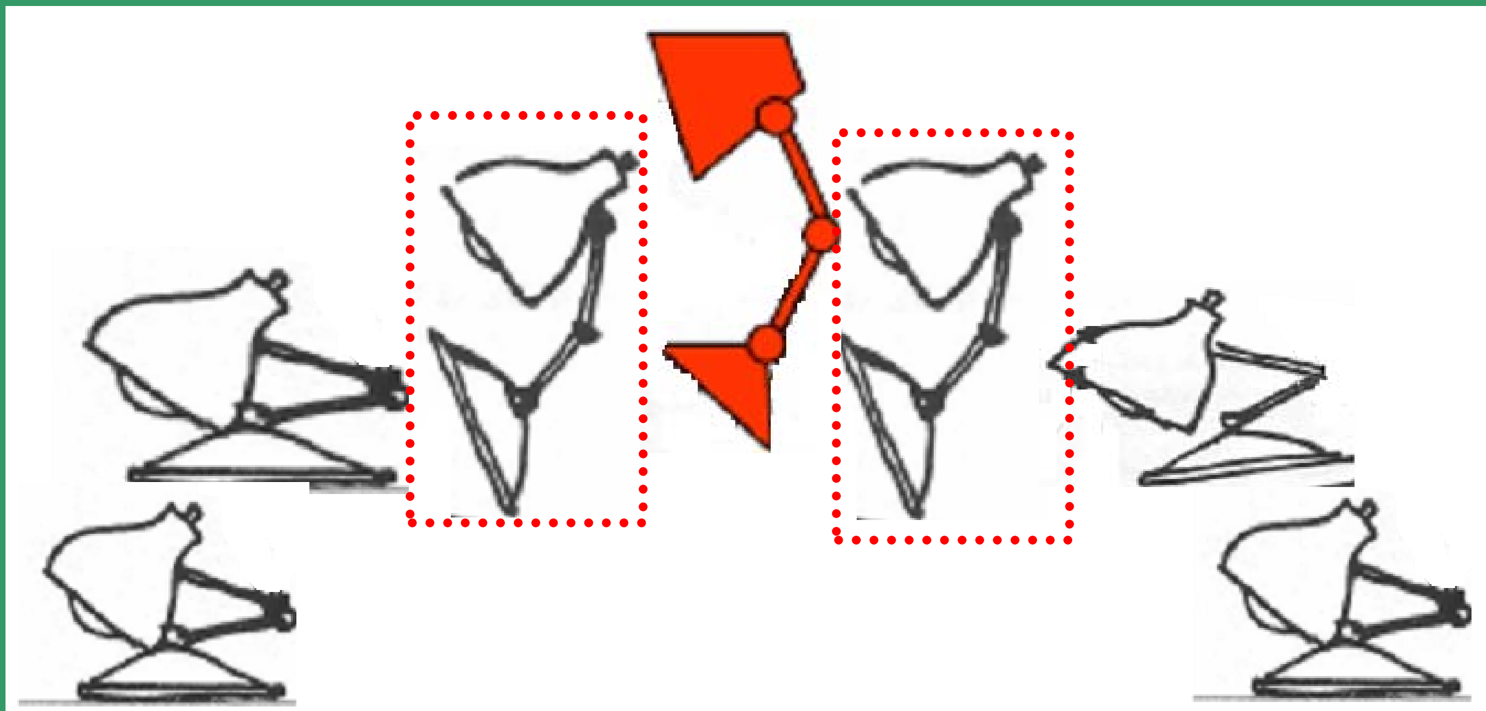
Animation characters in 2D and 3D

TYPES OF COMPUTER ANIMATION

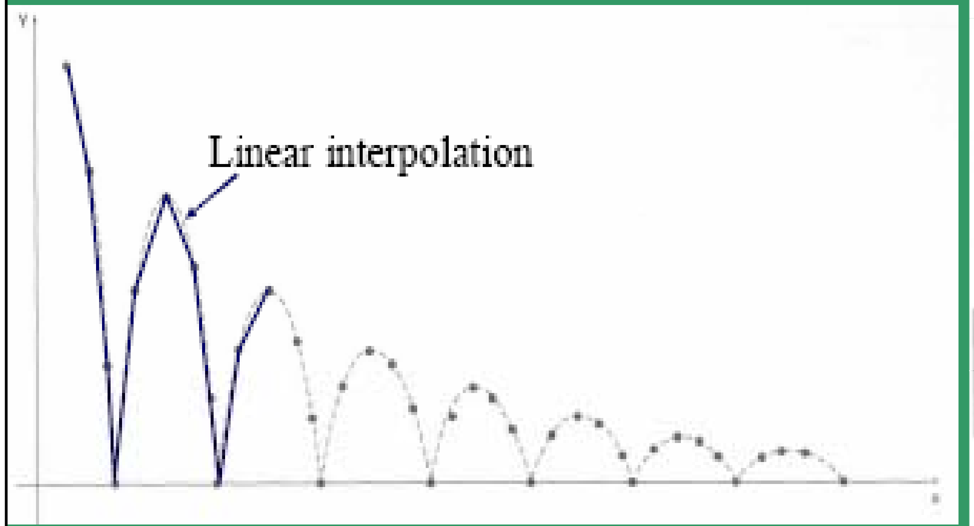
- **Keyframe Animation**
- **Procedural Animation**
- **Motion Captured Animation**
- **Kinematics**

KEYFRAME ANIMATION

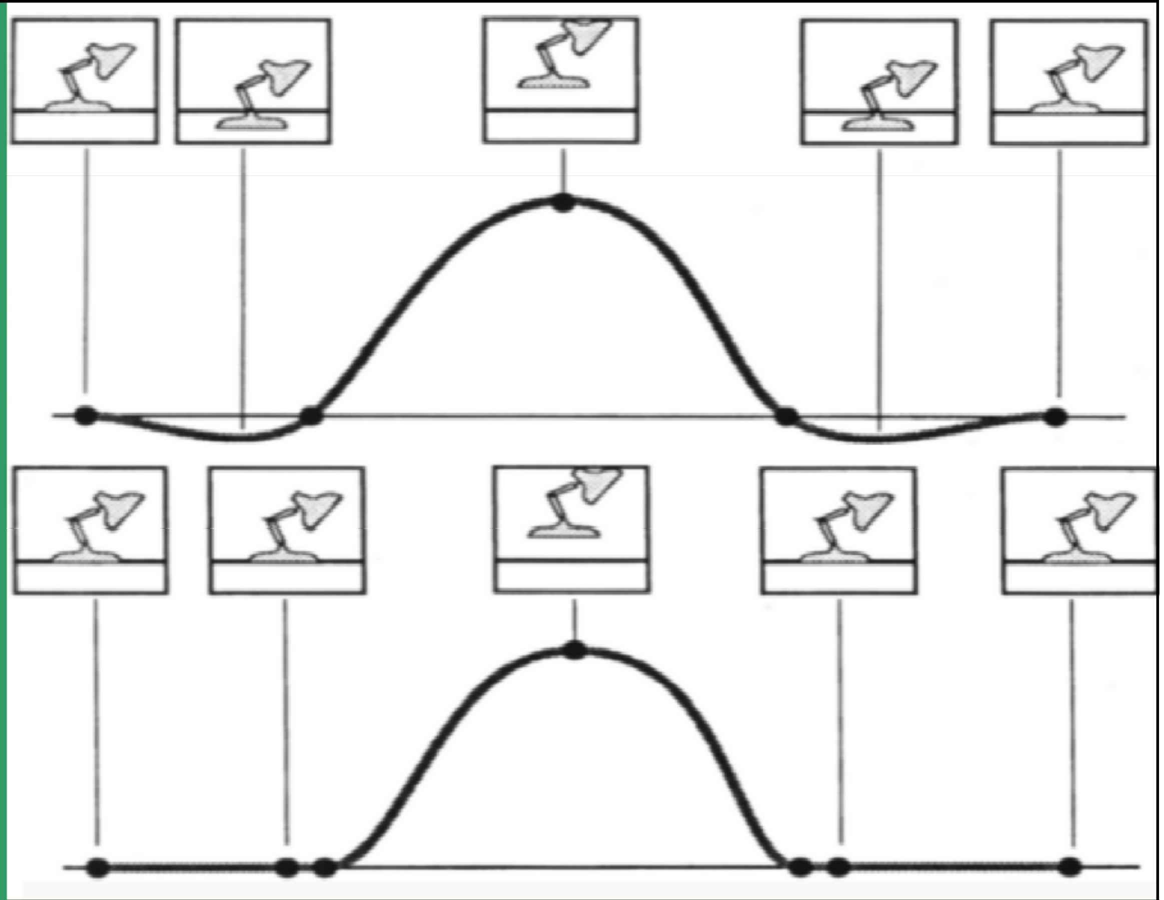
Define character poses at different time steps, called keyframes; and interpolate variables describing keyframes to determine poses of character - "inbetween".
Also called - Inverse Kinematics or dynamics



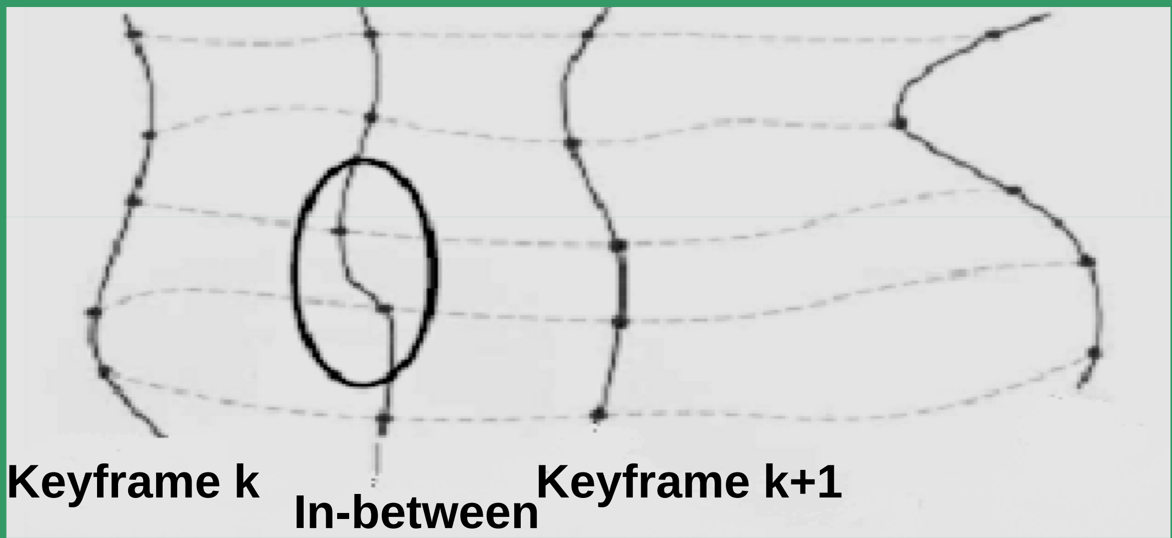
In-betweening



Linear Interpolation



Cubic Spline Interpolation

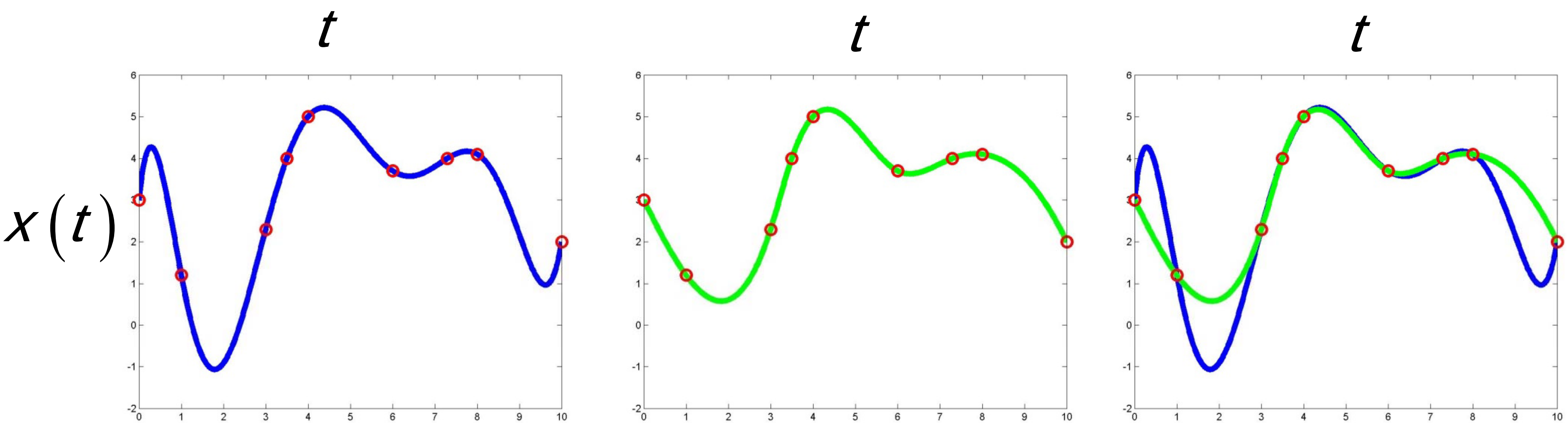


Spline Interpolation

Spline Interpolation

Lagrange polynomials of small degree are fine but high degree polynomials are too wiggly.

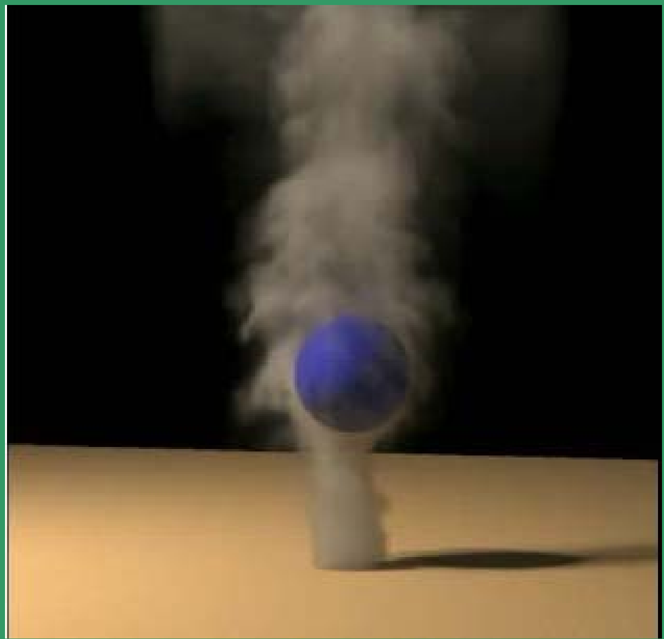
Spline (piecewise cubic polynomial) interpolation produces nicer interpolation.



8-degree polynomial | spline | spline vs. polynomial

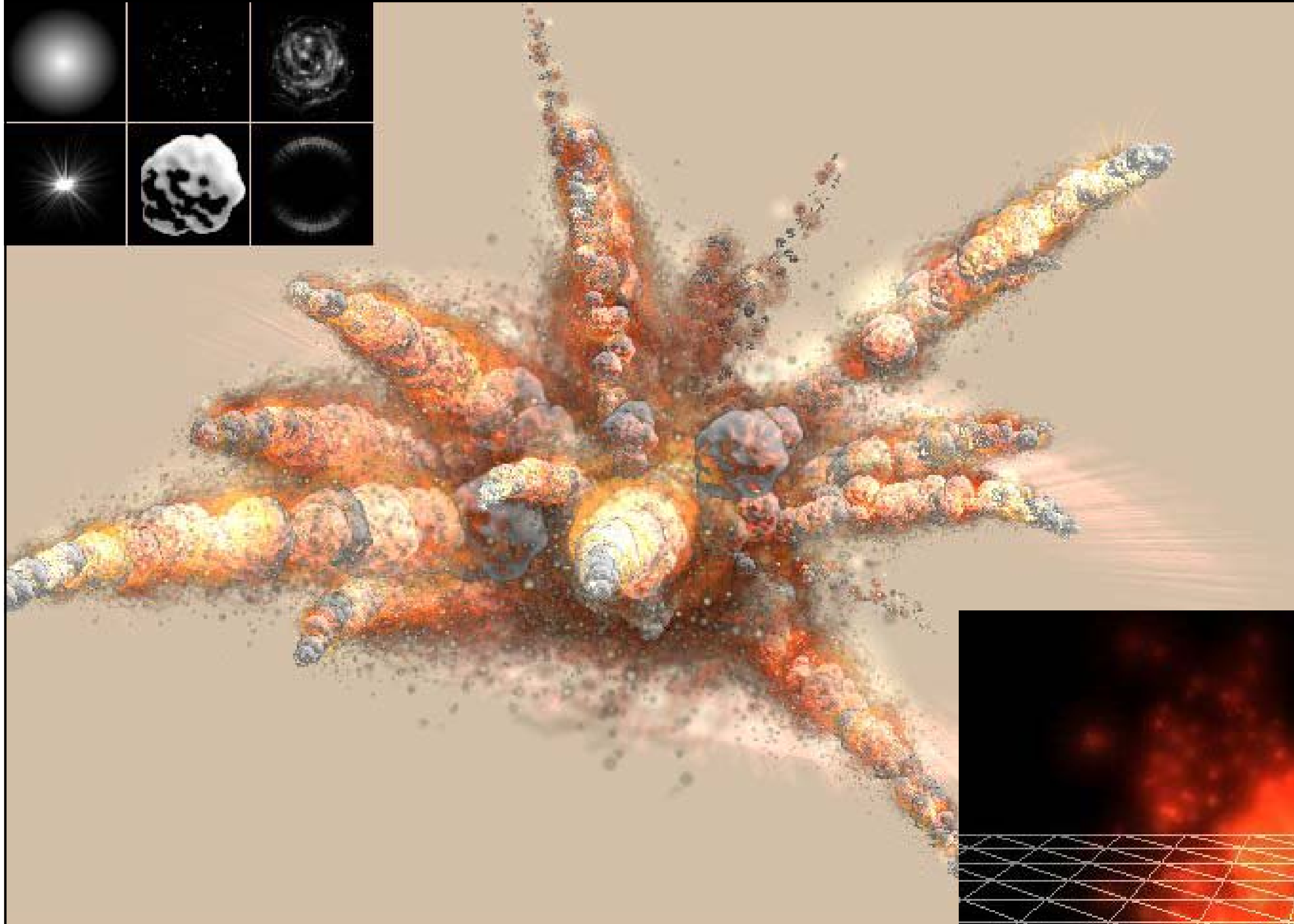
PROCEDURAL ANIMATION

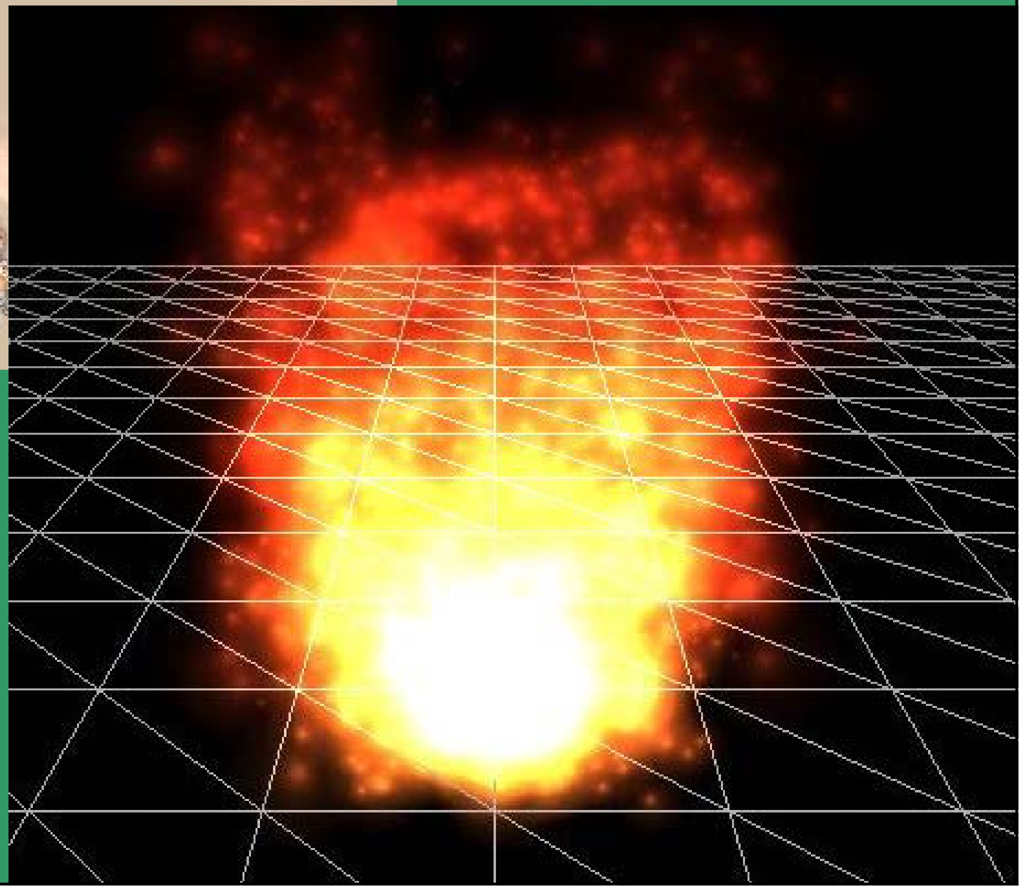
- **Most of the work is done by Computer**
- **Object positions and shapes are controlled by :**
  - **Particle, flocking and crowd systems**
  - **Cloth, Fire, Smoke and Water simulations**



Smoke simulation

Human and Cloth Animation

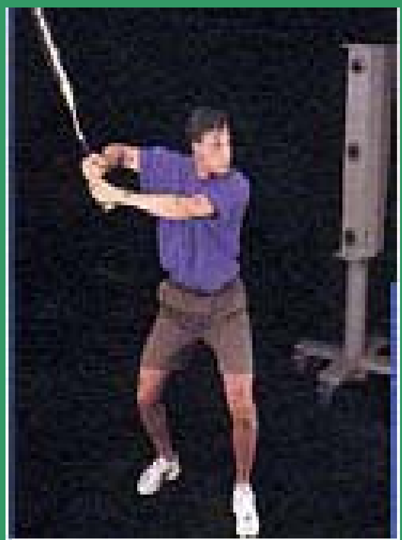


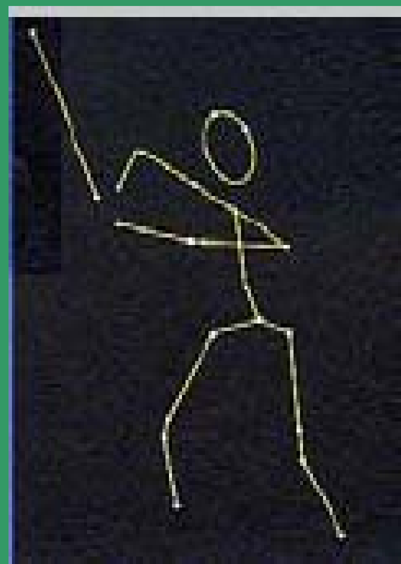


Particle System Applications

MOTION CAPTURED ANIMATION

- **Most of the work is done by Human Actor**
- **Human joint angles are taken from a live model via sensors on a motion capture suit**





Soft Modelling Of Objects

Need for Soft Modeling :

Various deformable parts such as cords, leather products and sheet metals are handled and manipulated in a lot of manufacturing processes.

Modeling of deformable objects is thus required so that the shape of the soft objects can be analyzed and can be evaluated on a computer.

Applications Of Soft Modeling :

Computer aided design and computer drawing applications

Deformable models are used to create and edit complex curves, surfaces and solids.

Computer aided apparel design

Used to simulate fabric draping and folding.

Image analysis

Used to segment images and to fit curved surfaces to noisy image data.

Surgical simulation and training systems

Techniques for modeling deformable models :

Non Physical Models :

Splines and Patches :

Bezier curves, double-quadratic curves,B-splines,

Non-uniform rotational B-Splines(NURBS) and

Beta-splines are used to represent planar and 3d curves.

Free-form deformation (FFD):

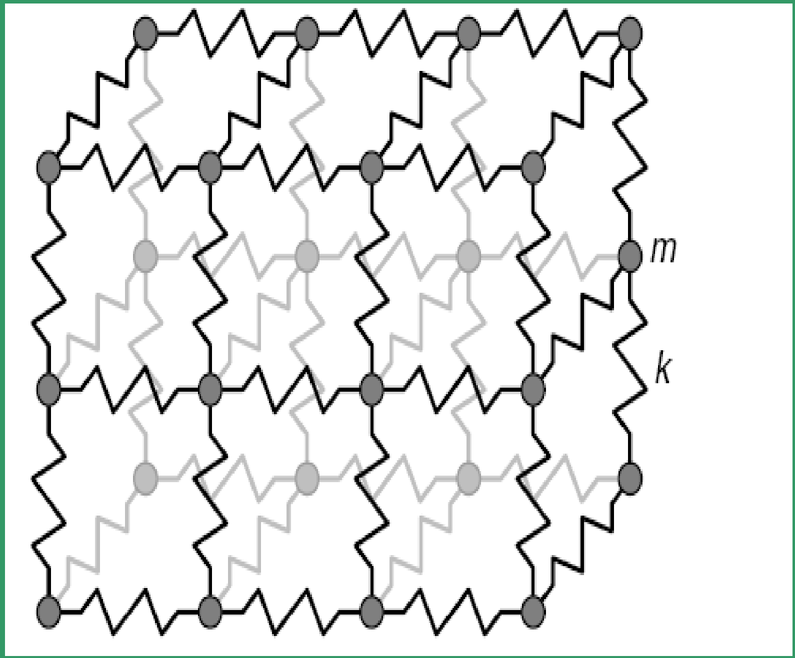
FFD is a general method for deforming objects that provide a higher and powerful level of control.

Techniques for modeling deformable models :

Physical Models :

Mass-Spring Models :

An object is modeled as a collection of point masses connected by springs in a lattice structure.



Widely used in face animation

The spring forces are often linear, but nonlinear springs can be used to model tissues such as human skin that has inelastic behavior.

Cloth Modeling

IMAGE BASED RENDERING

IMAGE BASED RENDERING (IBR)

IBR refers to a class of rendering methods. It takes a series of images as input and uses them to form a new image from different camera locations.

The images produced by IBR systems are often more realistic, when compared with classical rendering models.

Basic principle is to take some subset of the required viewpoints and from these synthesize the picture that we need to see from a new viewpoint.

Two Image based rendering methods

- **Mosaicing**

Matching multiple images by aligning and pasting images to a wider field of view image

- **Light field rendering (lumigraph)**

Light field rendering is the process of rendering novel views of a scene captured by the light field function.

Mosaicing

The top two images mosaiced together to form a panoramic view of a scene

Light field rendering (lumigraph)

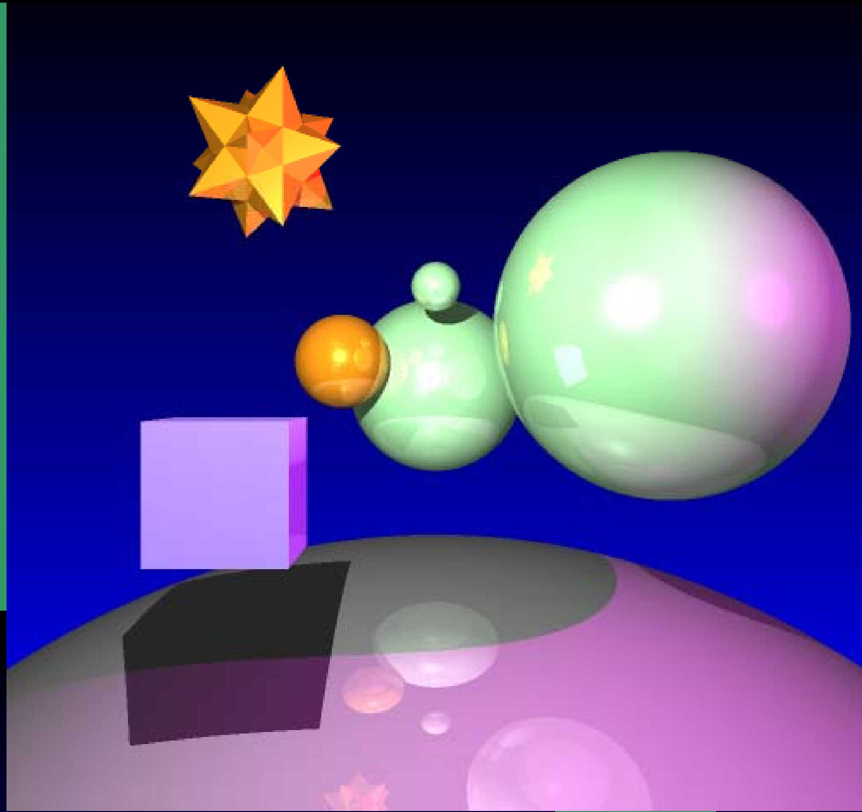
A light field is a 4D function describing the radiance across a boundary between the volume containing a scene, and the disjoint volume in which the eye point may be placed.

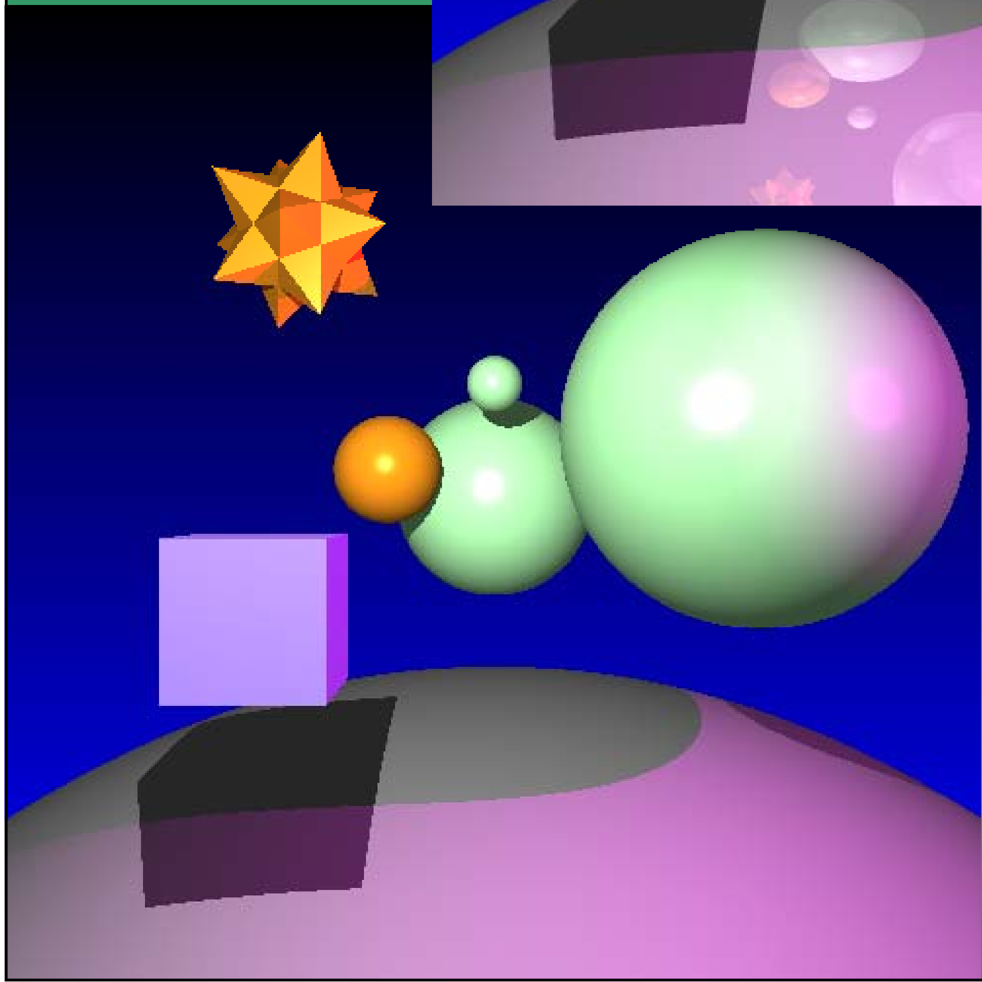
Visual Realism

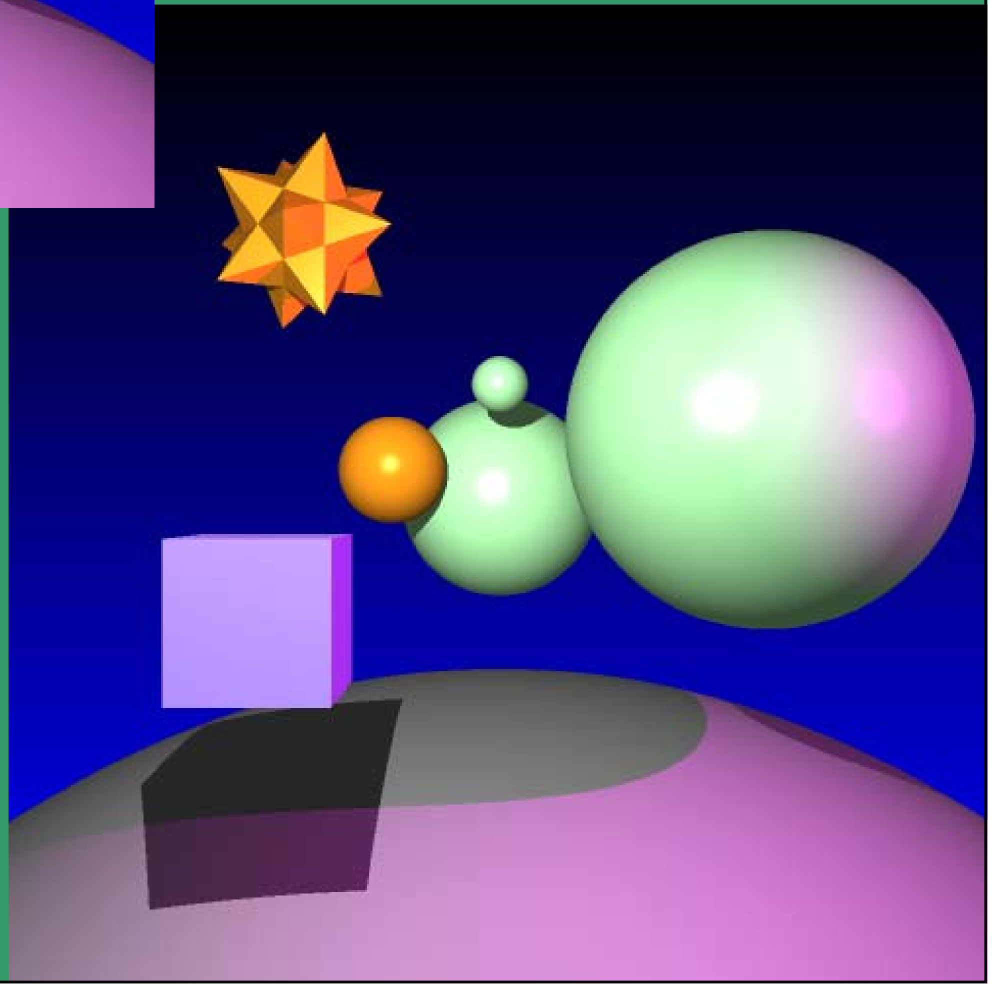
Objective - Creation of realistic pictures

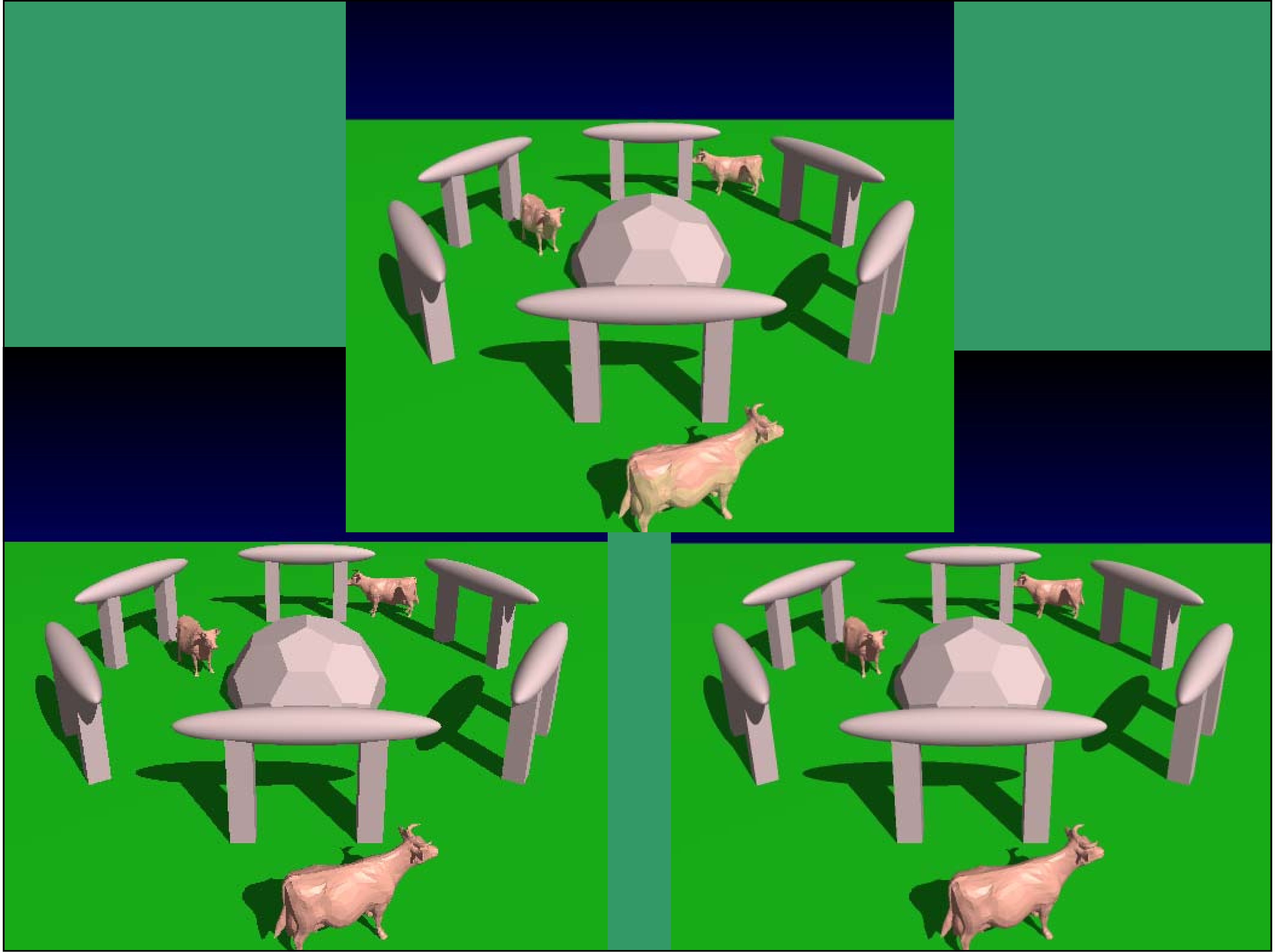
Techniques used are:

- **Effect of texture mapping**
- **Material properties**
- **Shadows, procedural texture / noise**
- **Transparency and Reflection**
- **Radiosity and photon mapping**
- **Stereopsis**
- **Dynamics**
- **Anti-aliasing**
- **Improved Displays**
- **Haptics (non-visual feedback) and use of other senses**
- **Image / Video based rendering**







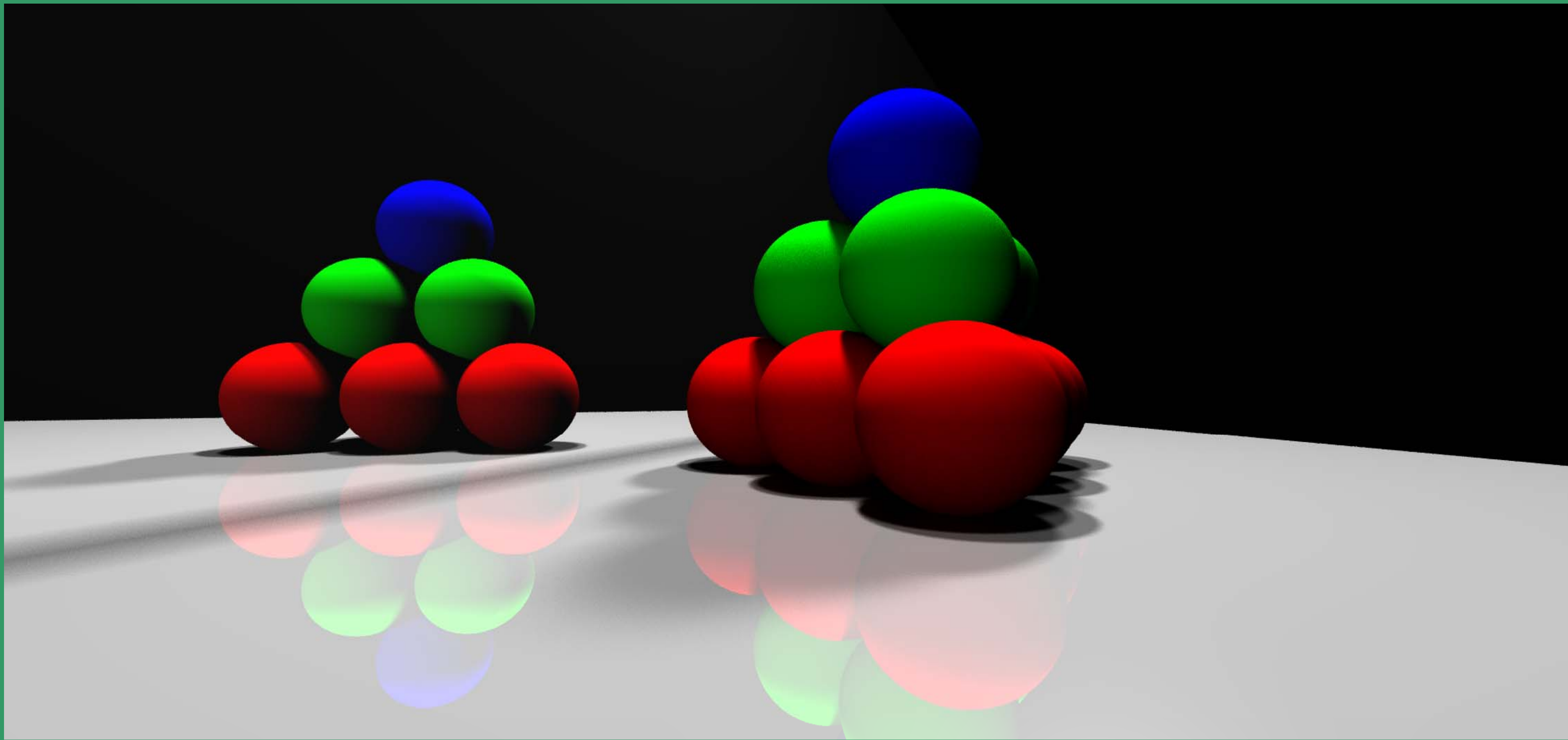


Tae pot with Shading, shadows and Radiosity

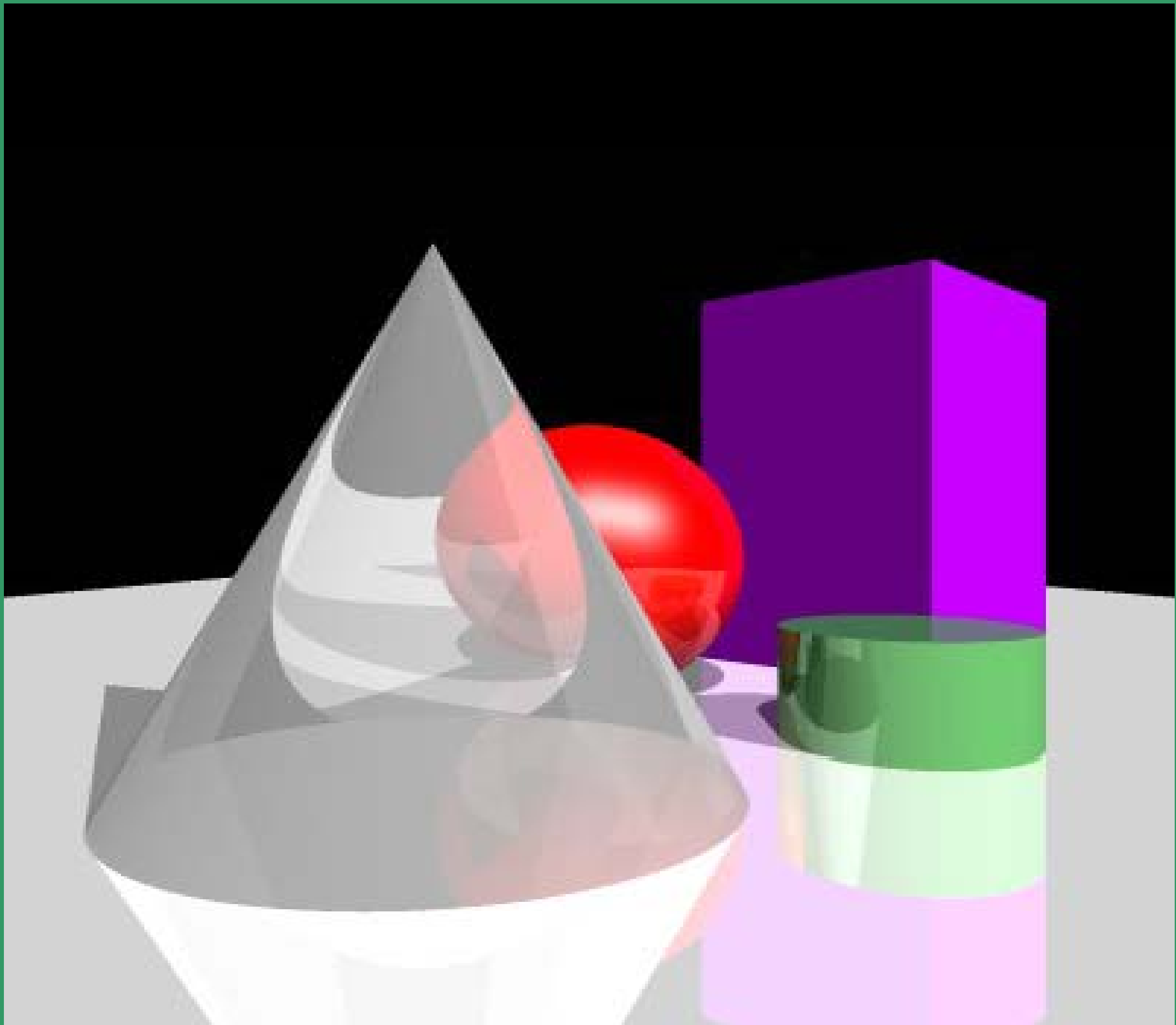
Triangle mesh

Stanford Michaelangelo project

Ray Tracing

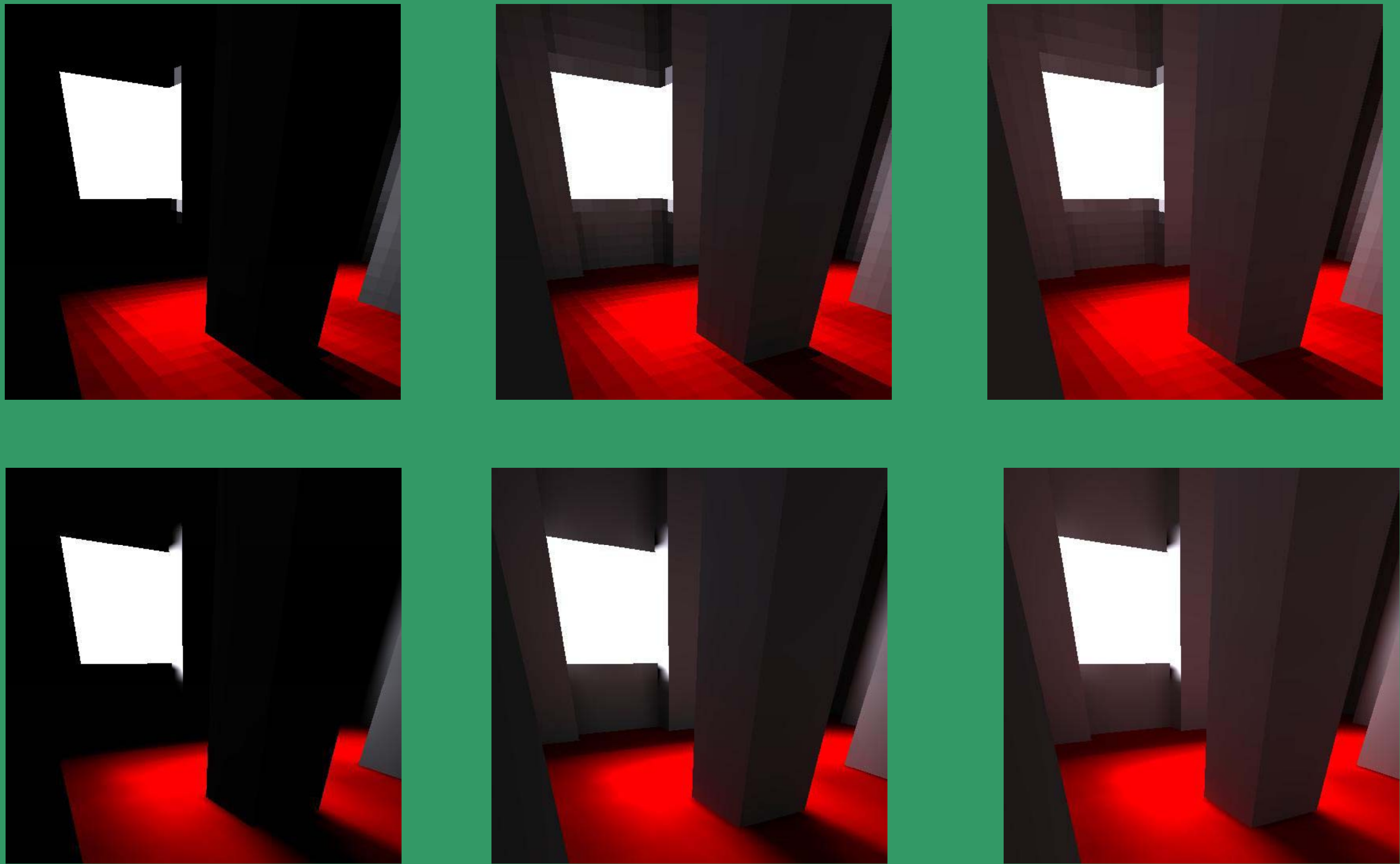


Ray Tracing + Semi-local illumination

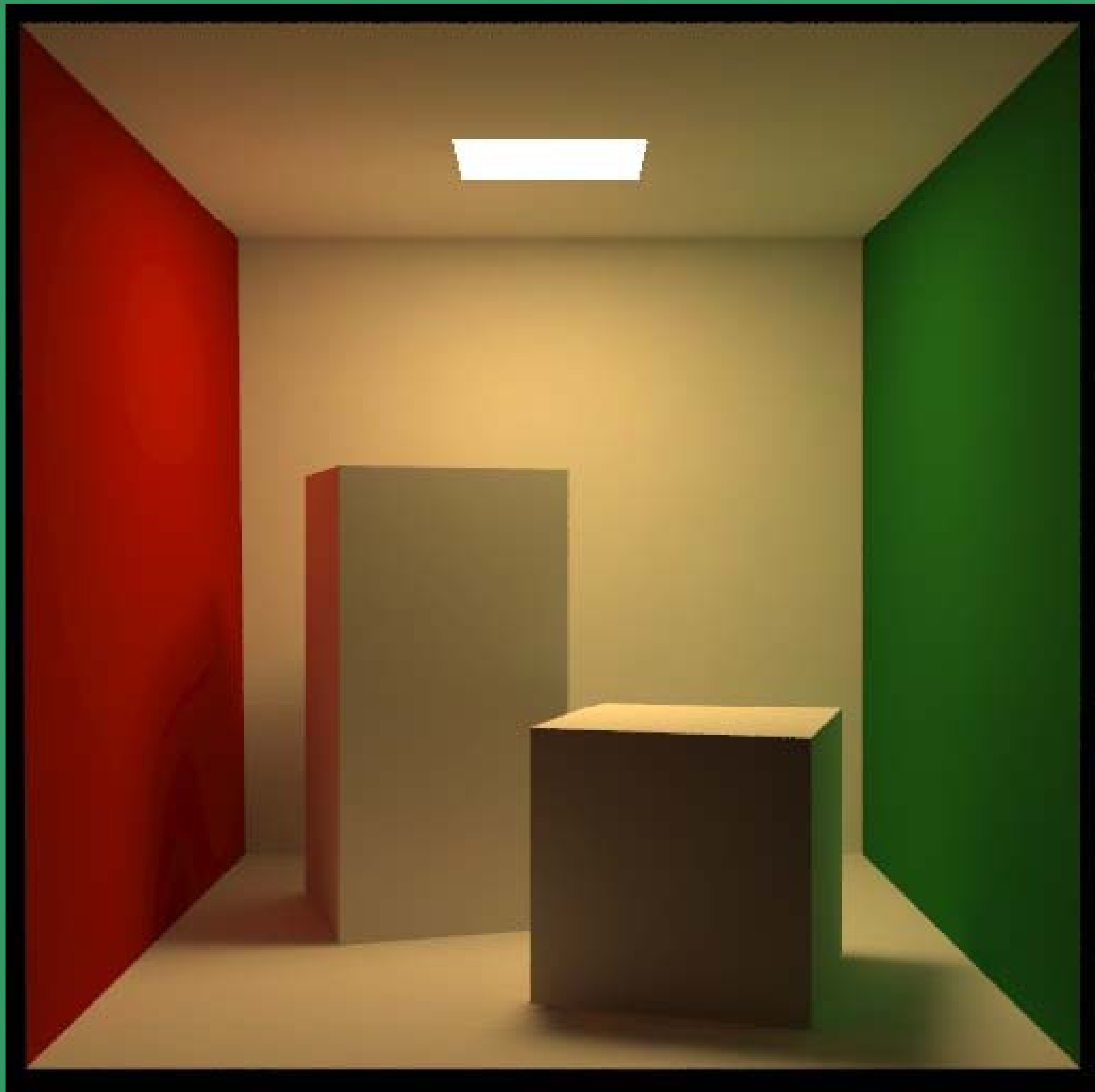


peter henry

Radiosity



Diffuse reflections + Radiosity



The Cornell Box

- Using careful calibration and measurement

Light Measurement Laboratory
Cornell University, Program for Computer Graphics

End of Lectures

on

Advanced Concepts in Computer Graphics