Computer Graphics

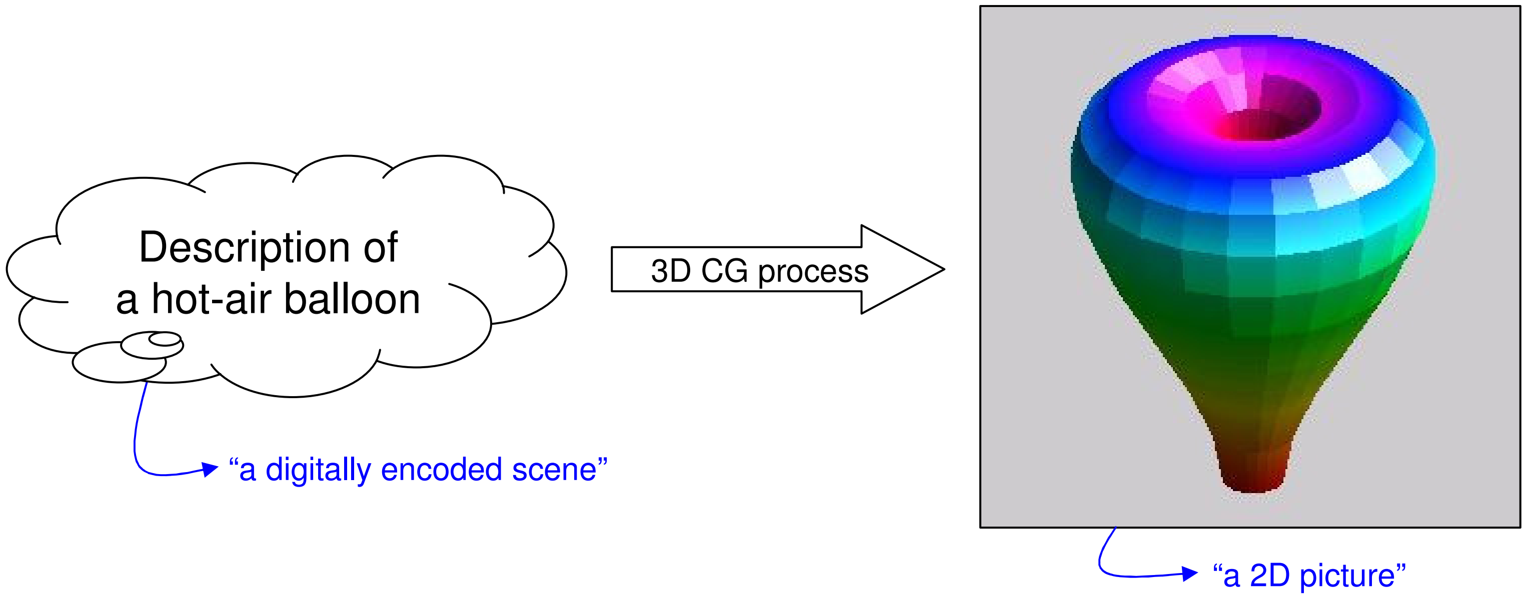
National Chiao Tung University
Chun-Jen Tsai
06/1/2012

Computer Graphics

- Computer graphics (CG) is a research topic about authoring and rendering of any visual data, including:
  - Presentation of text
  - Construction of graphics and charts
  - Design of GUI
  - Editing of photographs
  - Creation of animated motion pictures
  - . . .
- Today, GC is most often used to refer to 3D graphics

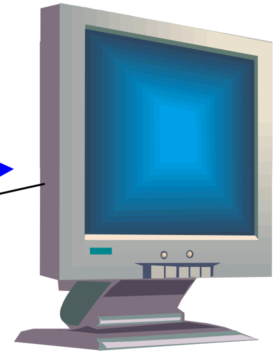
3D Graphics Problem

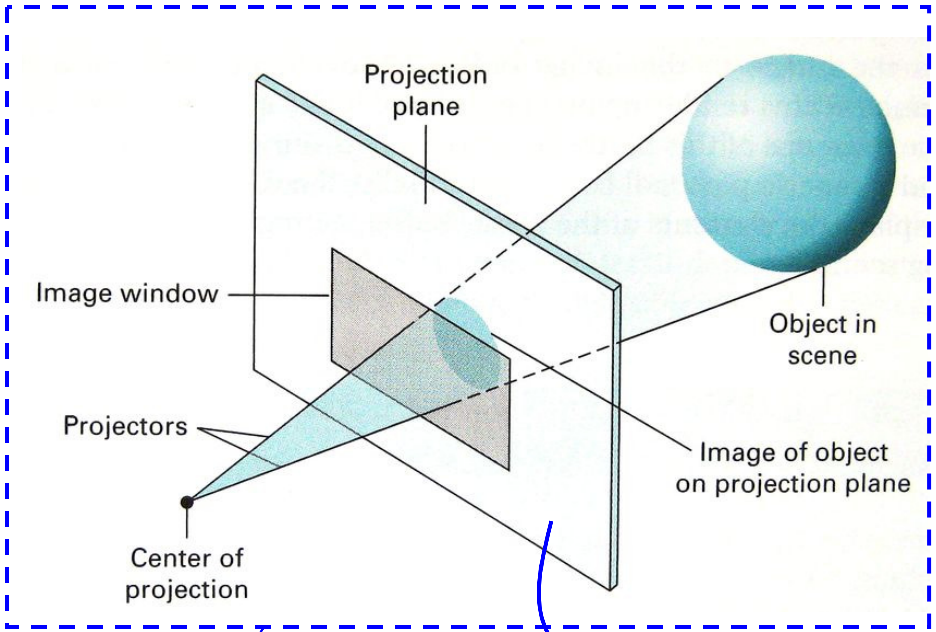
- The field of 3D graphics deals with converting 3D shapes into 2D pictures (images)
  - The process involves simulation of the photographic process to convert a “*digitally encoded scene*” to a “*picture*”



3D Graphics Paradigm

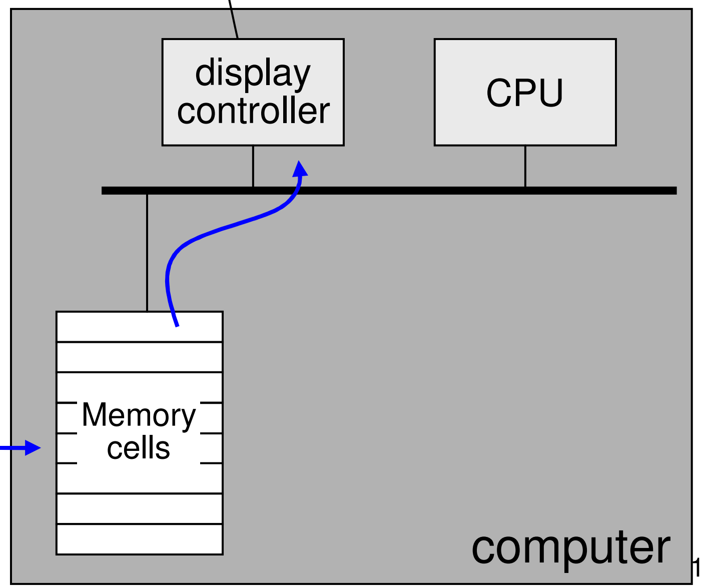
- Three steps in 3D graphics process:
  - modeling, rendering, and displaying





rendering using a perspective projection camera model

copy the 2D image to the memory cells called “frame buffer”



Modeling Problems

- The modeling step in computer graphics tries to solve the following problems
  - Modeling the shape of a 3D object
  - Modeling the surface characteristics
  - Modeling of the entire scenes

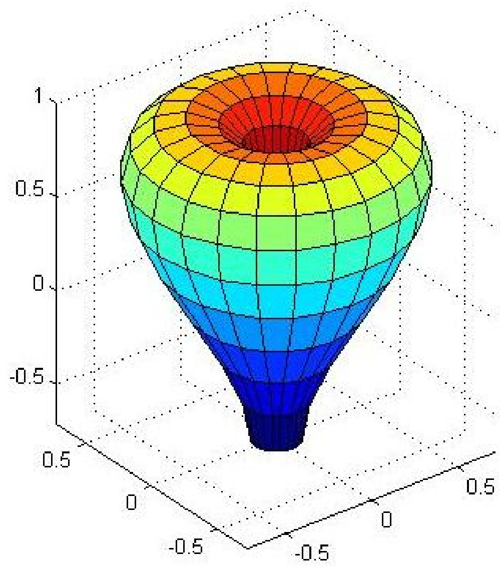
Modeling Shape of an Object (1/2)

- How do we describe a 3D object?
  - 3D shape can be described by a collection of flat surfaces called planar patches, each of which is a solid polygon
  - The collection of these polygons is called a polygonal mesh

```
n = 12;                          % resolution of the drawing grid
a = 0.2;                         % the diameter of the small tube
c = 0.6;                         % the diameter of the bulb
t1 = pi/4 : pi/n : 5*pi/4;       % parameter along the tube
t2 = 5*pi/4 : pi/n : 9*pi/4;     % angle around the tube
u  = pi/2 : pi/n : 5*pi/2;
[X, Z1] = meshgrid(t1,u);
[Y, Z2] = meshgrid(t2,u);

% The bulb
r = sin(Y) .* cos(Y) - (a + 1/2) * ones(size(Y));
x2 = c * sin(Z2) .* r;
y2 = - c * cos(Z2) .* r;
z2 = ones(size(Y)) .* cos(Y);
surf(x2,y2,z2,Y);
```

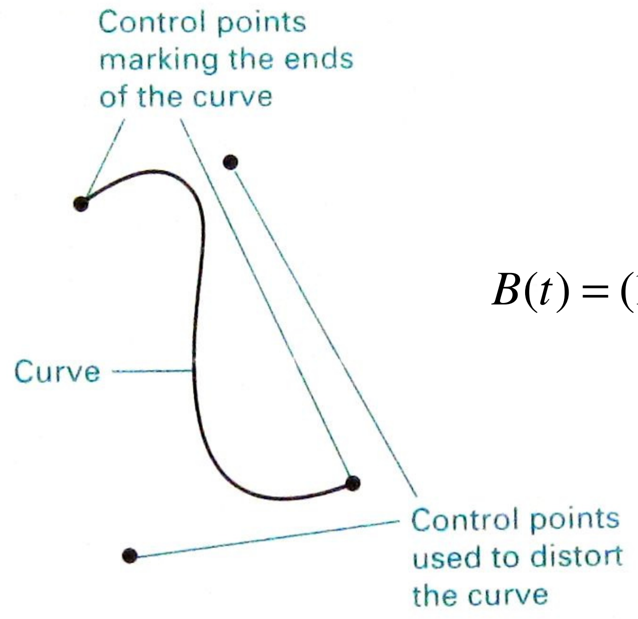
the precise mathematical description (in Matlab language) of a polygonal mesh



a rendered polygonal mesh of quadrangles

Modeling Shape of an Object (2/2)

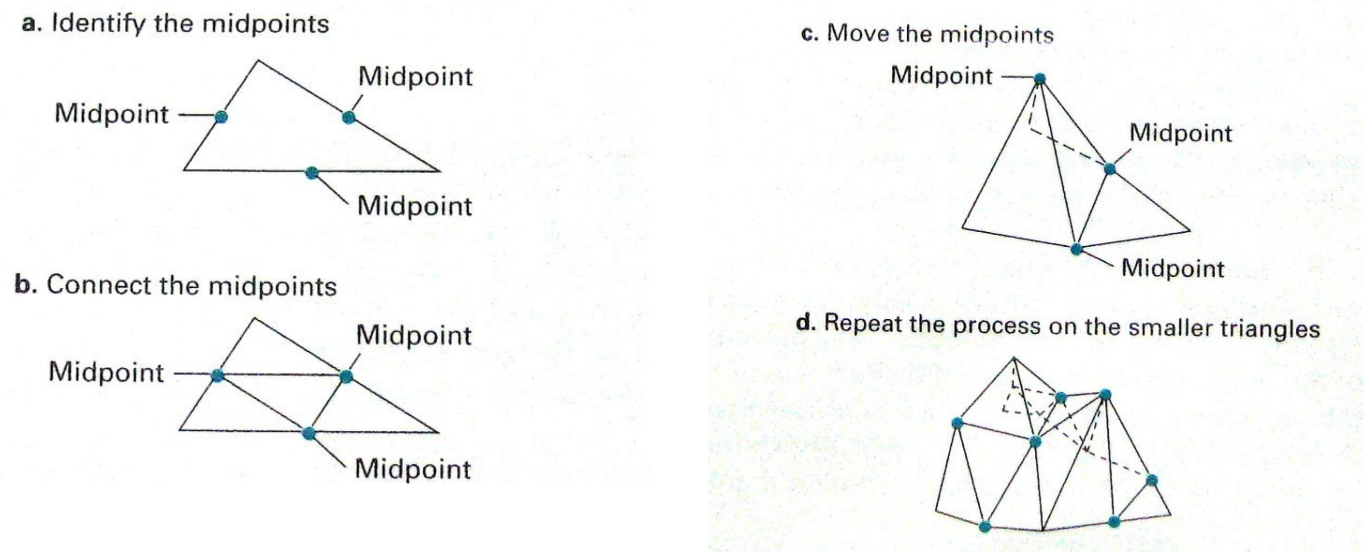
- In general, complex objects cannot be described by a simple 3D mathematical function
- We can use many “piecewise smooth” functions to describe the contour and shape of a complex object
  - Bezier curves and Bezier surfaces



$$B(t) = (1-t)^3 P_0 + 3(1-t)^2 t P_1 + 3(1-t) t^2 P_2 + t^3 P_3,\ \ t \in [0,1]$$

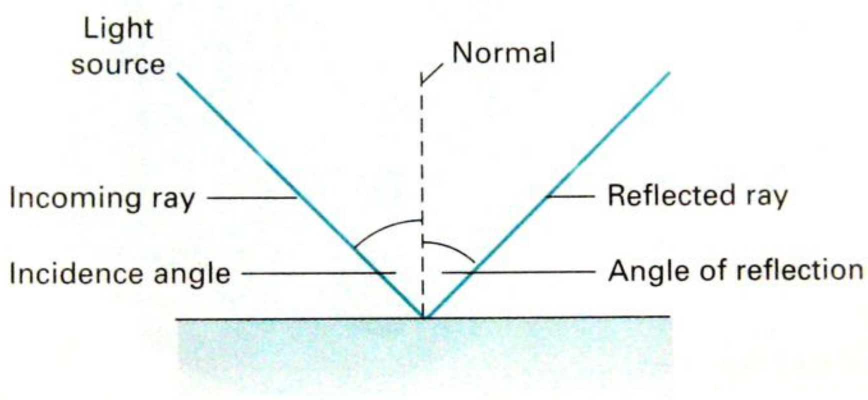
Shape Modeling Techniques

- Geometric modeling
  - e.g., the hot-air balloon model
- Brute force digitizing of a real 3D object
  - e.g., 3D laser scanning of a real object
- Procedural modeling (fractals or particle systems)
  - e.g., growing a mountain using a recursive rule (operations)



Modeling Surface Characteristics

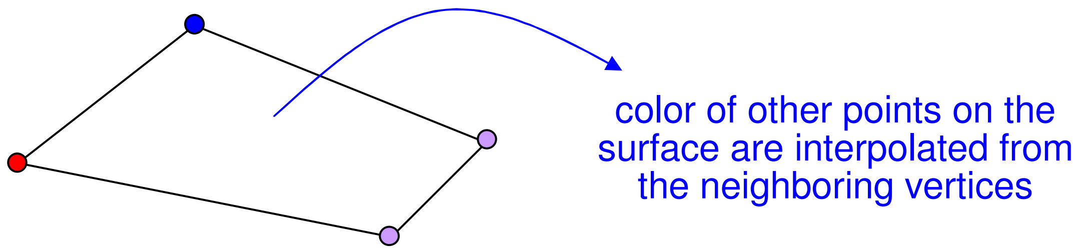
- Surface characteristics of a surface patch is the "reaction" of the patch to incoming light rays
- The model has parameters:
  - The frequencies of the incoming light
  - The incidence angle
  - The position on the surface



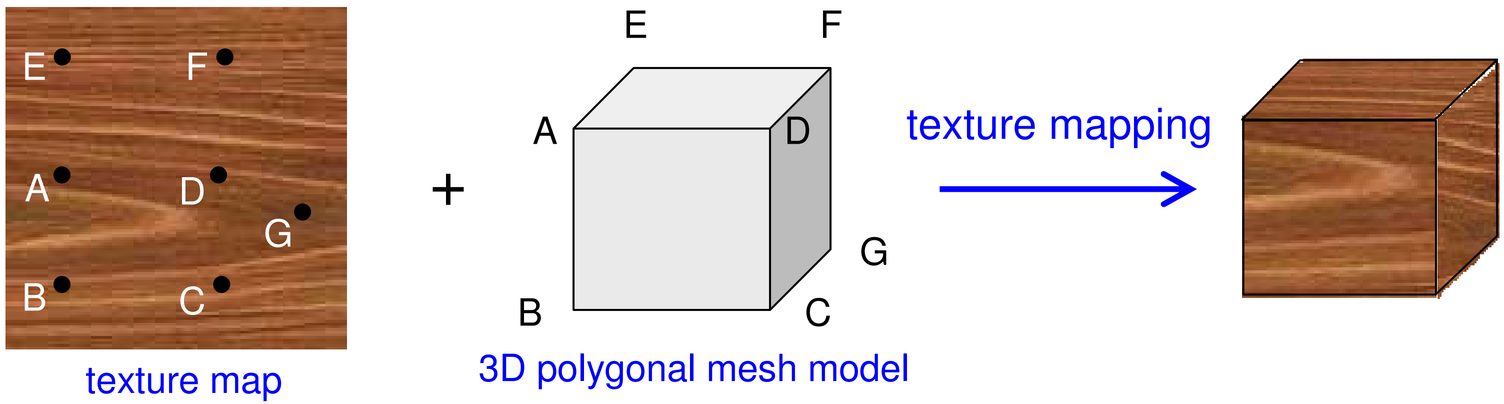
- The output of the model:
  - The frequencies and angles of the out-going light at every points on the surface

Texture Maps for Surface Modeling

- We can encode the color of a surface patch at the vertex only

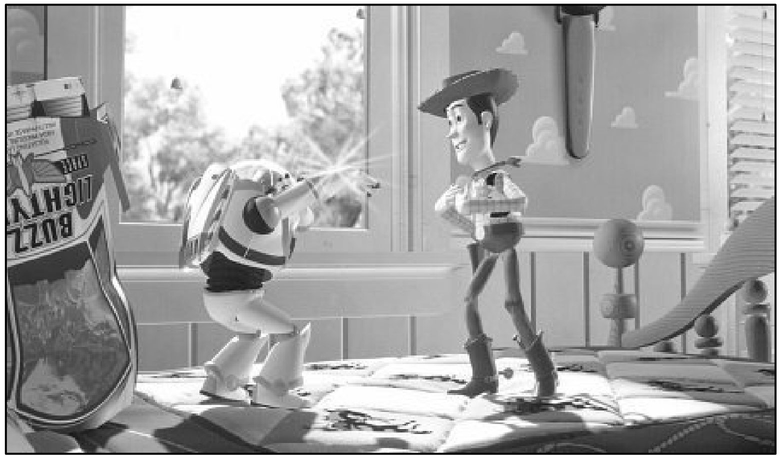


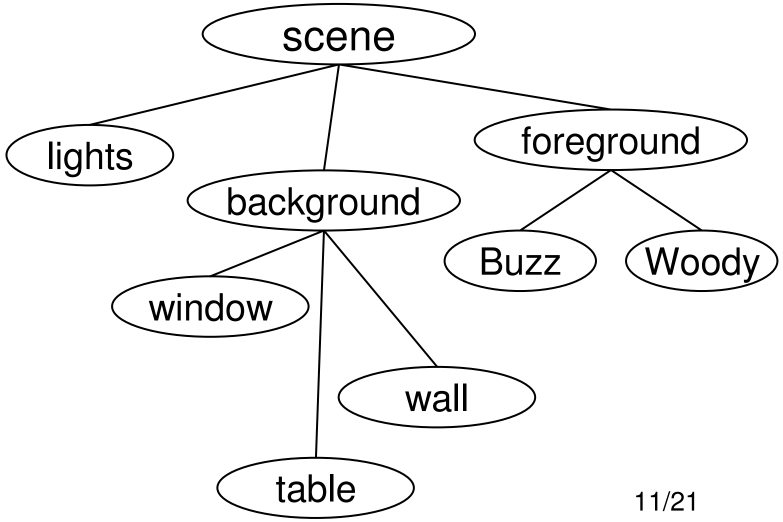
- Another technique is to use a texture map to describe the colors at every points on the surface



Modeling Entire Scenes

- A scene can be described by a scene graph that contains the following information
  - Light sources
  - Background descriptions
  - Foreground object descriptions (including their motions)
- In short, a scene graph describes a virtual world

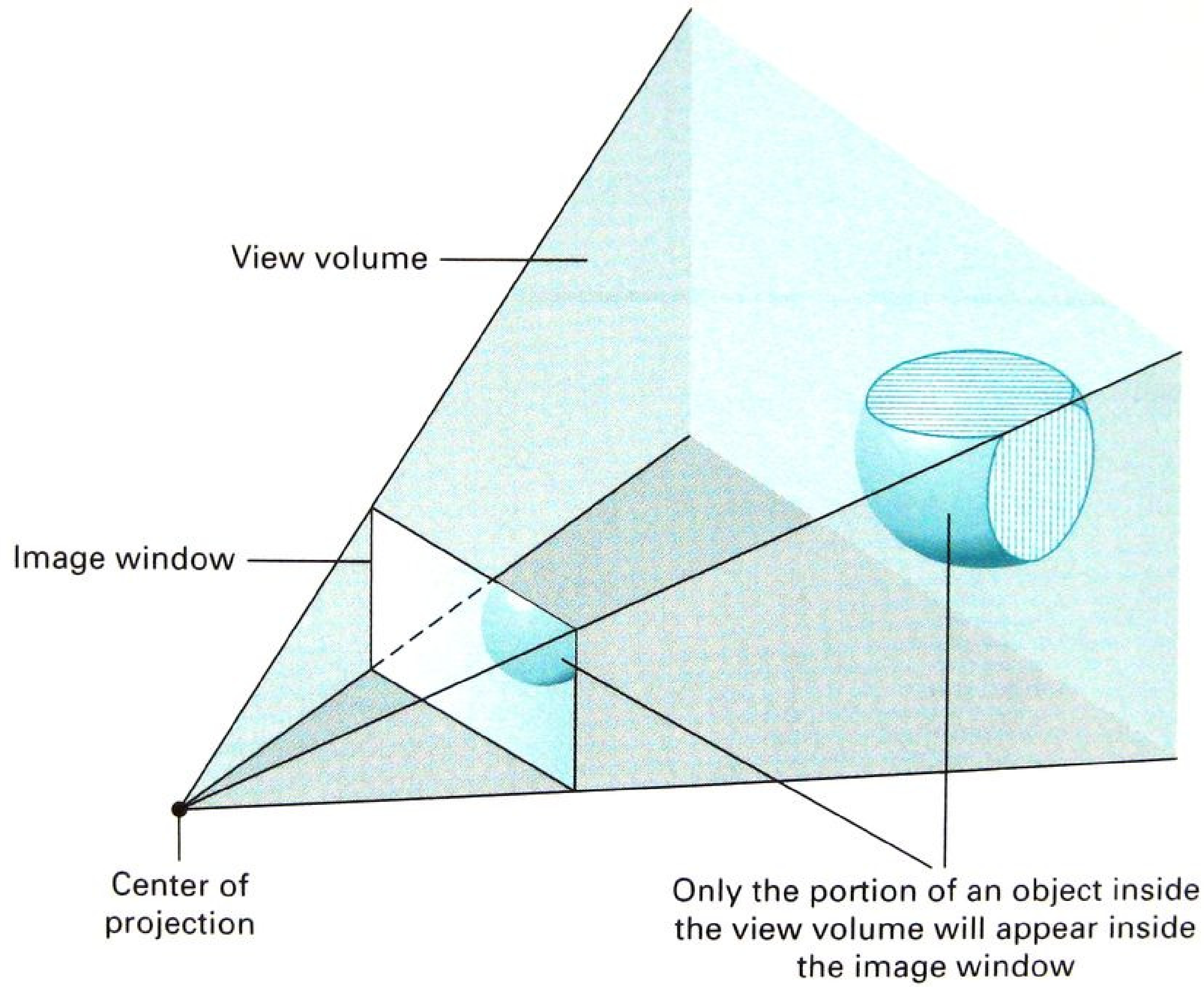




Rendering

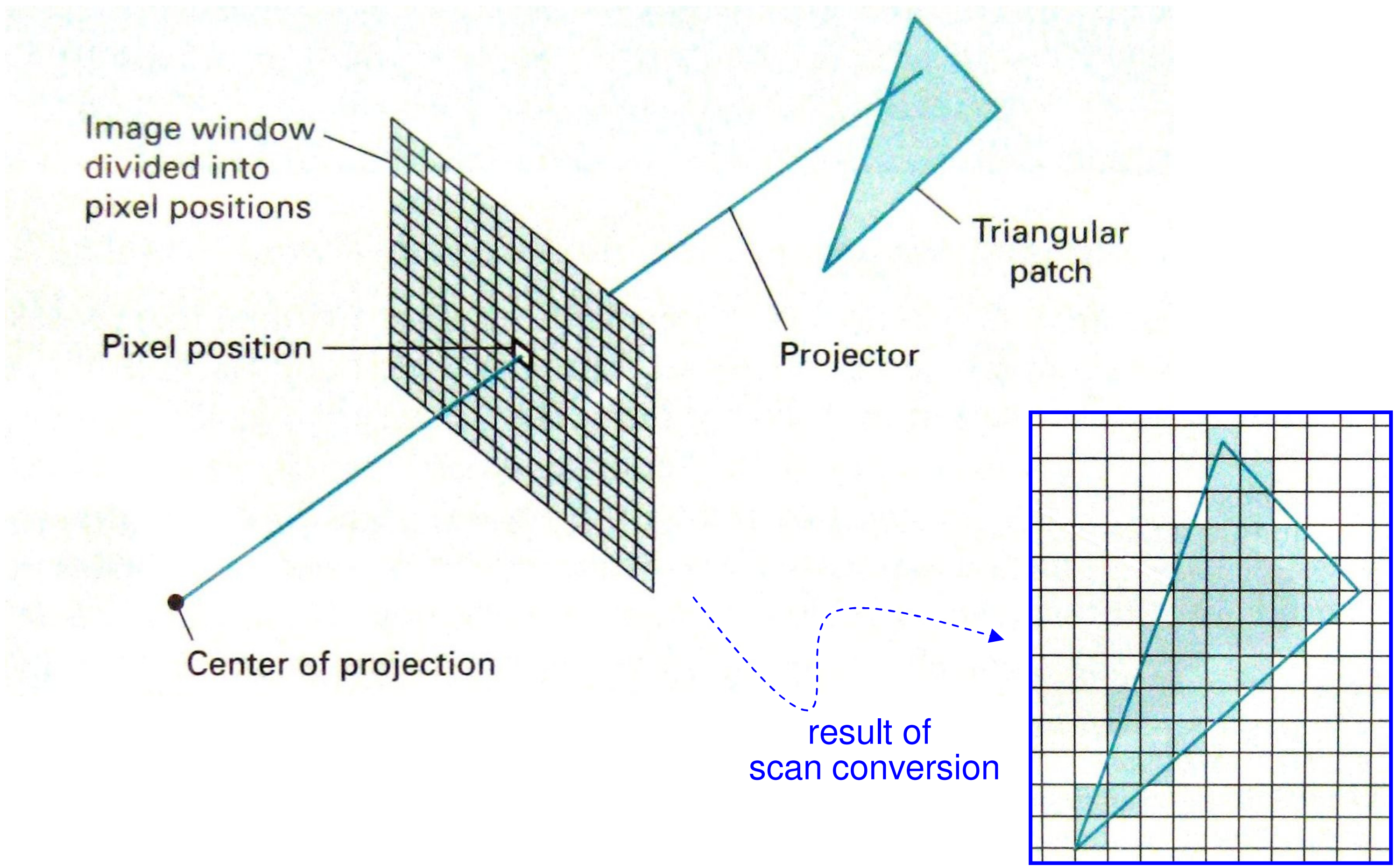
- Given a virtual camera, rendering is the process of projecting the objects in a scene onto the projection plane of the camera
- In computer graphics, the process is achieved using a “rendering pipeline,” which can be implemented in hardware or software
- The rendering process is composed of many steps
  - View volume determination
  - Clipping
  - Scan conversion (rasterization)
  - Hidden surface removals
  - Shading

View Volume and Clipping



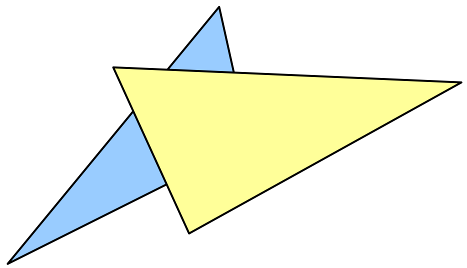
Scan Conversion

- ❑ A 3D patch is projected onto a digital image



Hidden Surface Removal

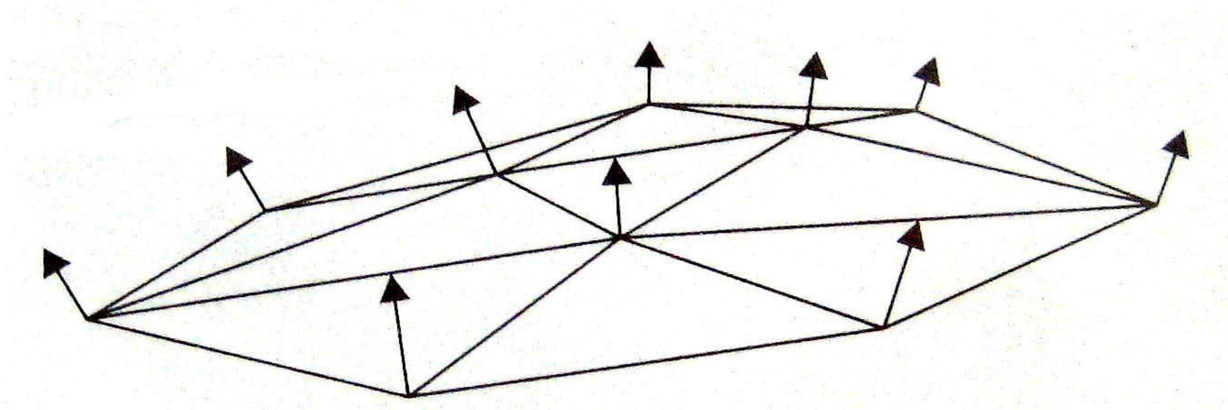
- If part of a 3D object is covered by other objects, the non-visible part should not be displayed



- Common techniques for hidden surface removal
  - The painter’s algorithm (patch-based technique)
  - The z-buffer method (pixel-based technique)

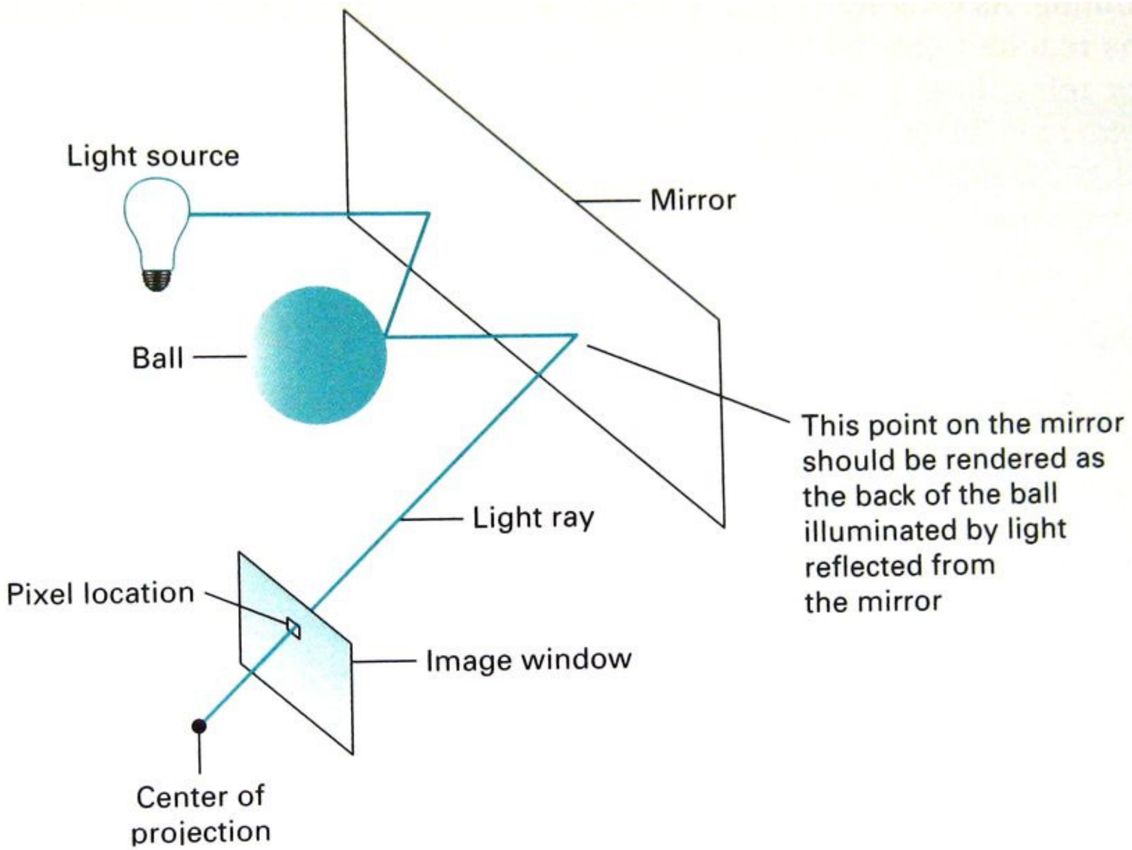
Shading

- For each surface patch which is visible in the 2D image, we have to determine the *appearance* of each pixels as well, this process is called shading
- Common shading techniques
  - Flat shading
  - Gouraud shading
  - Phong shading



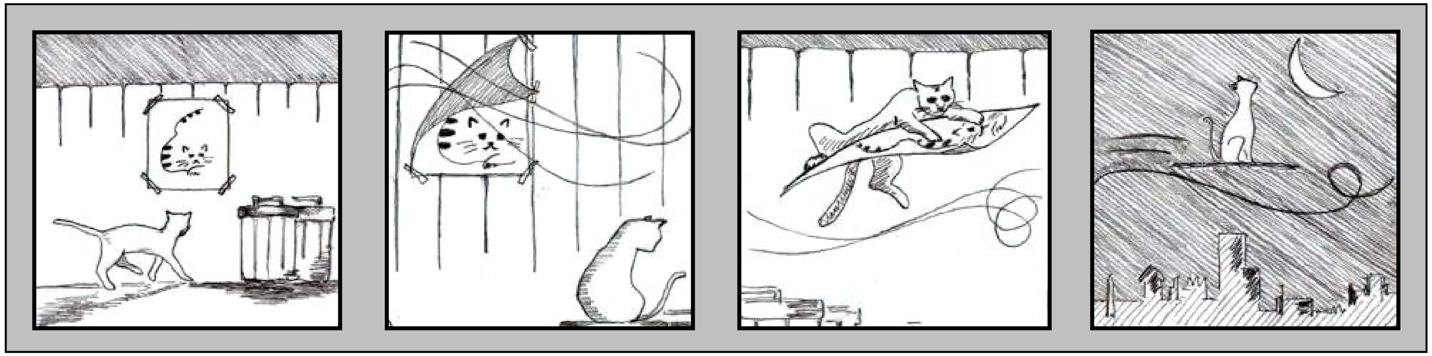
Ray Tracing

- To render a complete scene with complex objects, a interesting technique is called ray-tracing



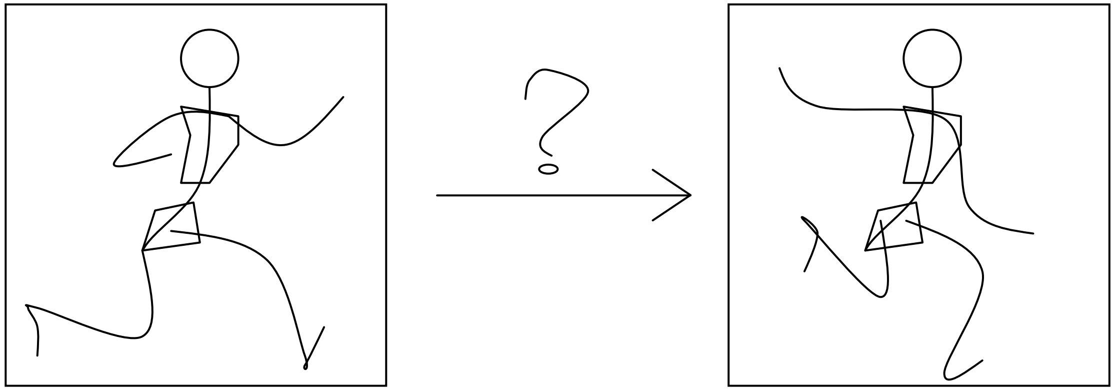
Animation (1/2)

- Computer animation is the technology to use a computer to display successive pictures of a dynamic scene at more than 24 picture per second
  - Each picture is called a frame
  - Today, the standard for smooth animation is to display at least 60 frames per second
- An animation begins with a story board, which is a sequence of hand-drawing pictures that tells a story:



Animation (2/2)

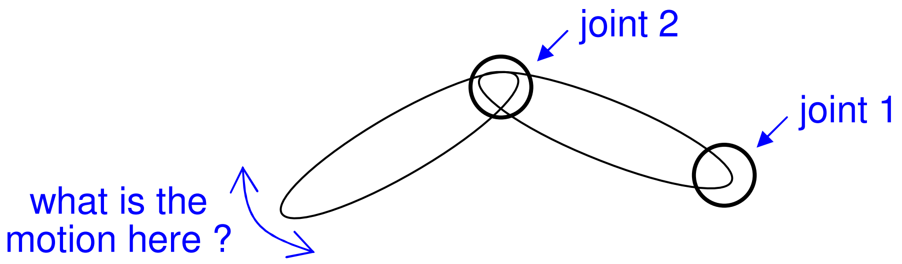
- ❑ Given a storyboard, artists will refine the pictures in a storyboard into detail frames, called key frames
  - Key frames have much less than 30 frames per second, for animation, we must fill in the gaps between key frames



  - Can we use computers to do this “in-betweening” for us?

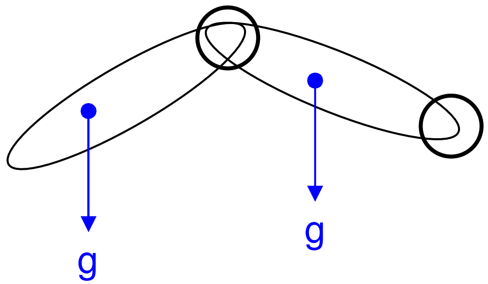
Kinematics and Dynamics

- Kinematics – based on geometry



If joint 1 rotate 10°, and joint 2 rotate 3°, what is the motion at the end point?

- Dynamics – based on physics



Given the mass and center of mass of each object, if we apply some force (torque) on joint 1 & 2, how would the objects move?

Animation Techniques Today

- Although kinematics and dynamics problems can be solved mathematically using physic theories, today's animation studios don't really do it this way
- Techniques used in animation studio:
  - By animation artist using drawing software – artists draw key frames, computers interpolate the remaining frames
  - By manipulation of skeletal structure models and motion captures of real subject (e.g. human beings) – need computational vision technologies