

2. Introduction to Modelling and Animation

2.1 Overview

2.2 Curves and Surfaces

2.3 3D Shapes

2.4 Lighting & Materials

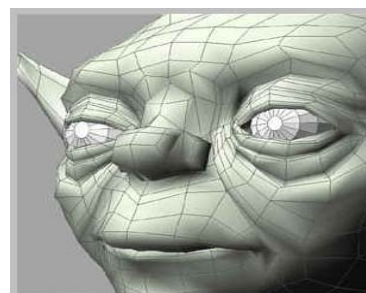
2.5 Texturing

2.6 Animation

2.7 “Blender”

2.1 Overview

- 3D Modelling and Animation packages contain three main functions:
 - An *object modelling environment* where 3D models or meshes are created.



© by Ken Brilliant

- An *animation environment* where models are arranged and animated.
- A variety of *rendering tools* to create fast previews and photorealistic images (movies) of a scene.

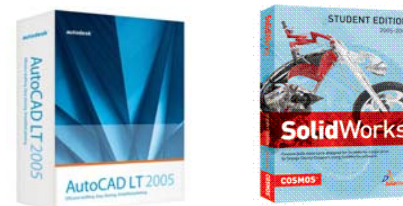
Overview (cont'd)

The most popular (professional) software packages are

- **Maya** (Alias)
- **3D Studio Max** (Discreet)
- **Houdini** (Side Effects Software)
- **LightWave 3D** (NewTek)
- **Softimage | XSI** (Softimage)

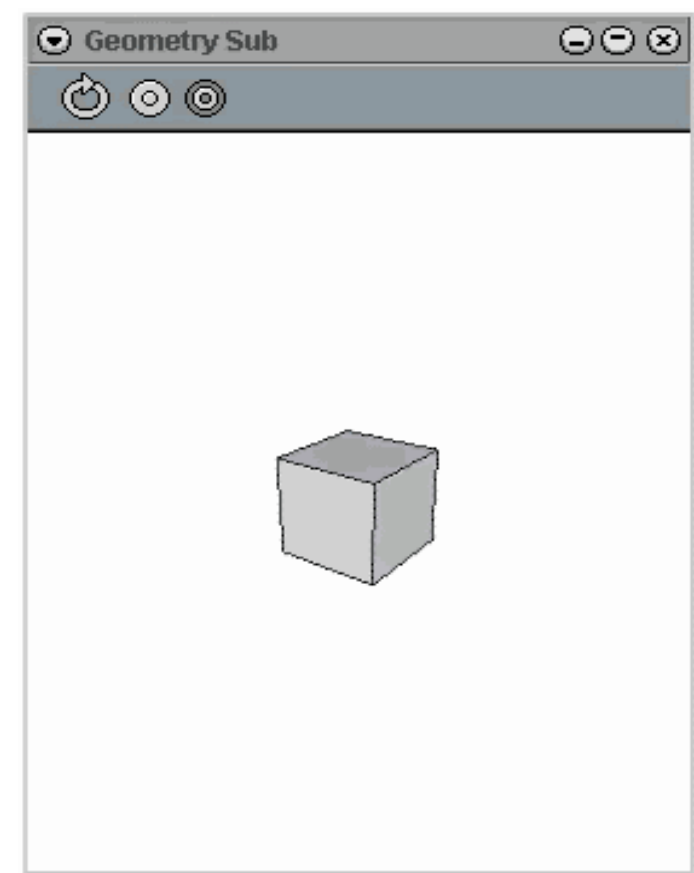
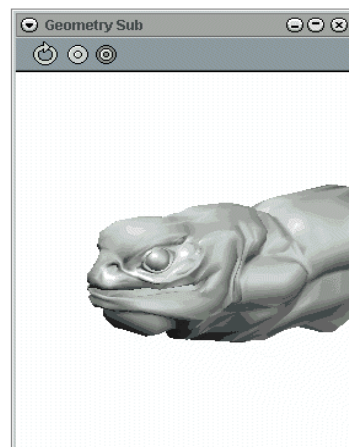


Applications in engineering and architecture use specialised tools (e.g. AutoCAD, SolidWorks)



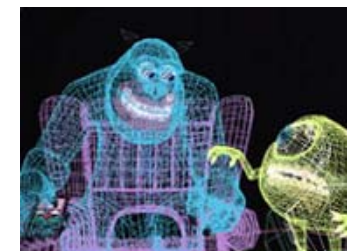
Example – 3D Studio Max

- Models are created by starting with spline surfaces or by transforming simple geometric objects (e.g. cubes). The resulting meshes can be edited, refined, smoothed and combined.



Animation Production

- Storyboard
- **Modelling** [Topics done in this lecture]
 - Curves and surfaces
 - 3D Shapes
- **Animation**
 - Keyframing (motion capture and/or human animator)
 - Physically-based animations
- **Lighting and Texturing**
- **Rendering**
 - Preview (polygon rendering)
 - Production quality rendering (e.g. ray tracing)
- **Post-Production**
 - Special effects, sound, ...



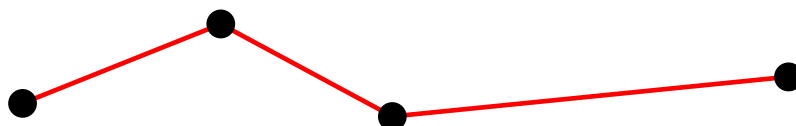
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2.2 Curves and Surfaces

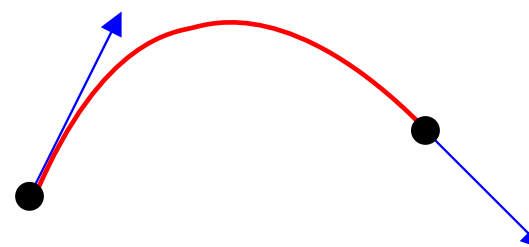
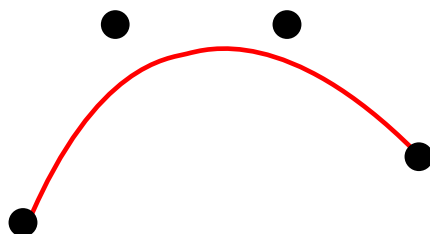
■ Polylines

- Defined by a series of points connected by straight line segments



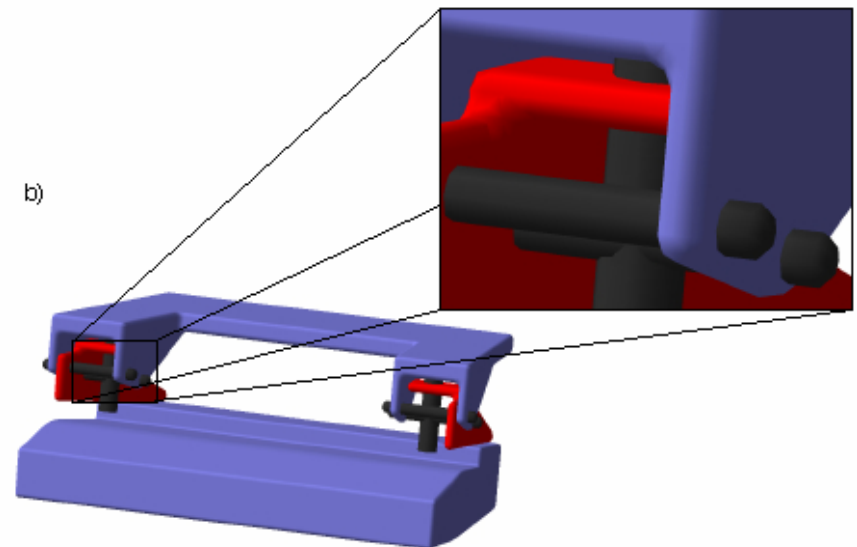
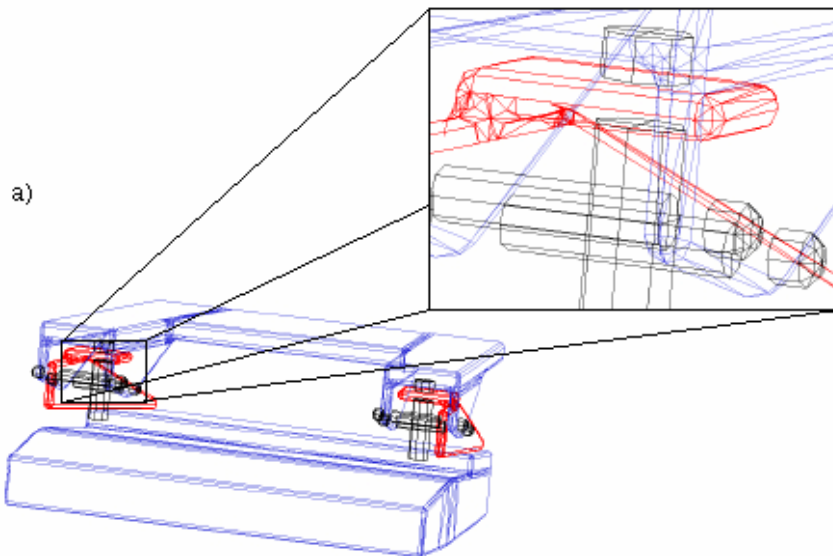
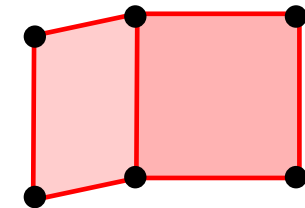
■ Bezier Curves

- A Bezier curve segment is defined by four points (which can be replaced by two points and two tangents)



Polygon Meshes

- Defined by a set of vertices and a set of faces
- Faces are (usually) quadrilaterals or triangles
- The illusion of a solid 3D object is achieved by representing the object's boundary surface with a polygon mesh



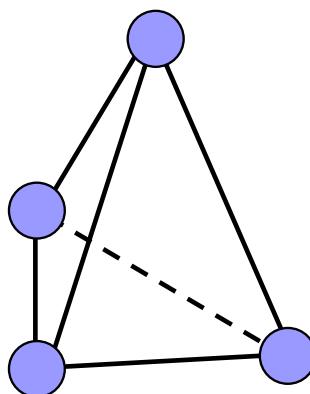
The Euler Formula

The Euler Formula

- Let V be the number of vertices of a polygonal closed manifold mesh, E the number of its edges and F the number of its faces (regions).

- Then $F - E + V = 2$

- Example:



$$V=4$$

$$E=6$$

$$F=4$$

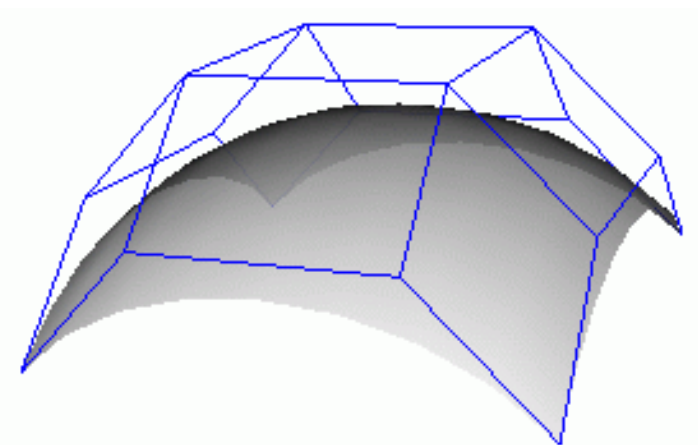
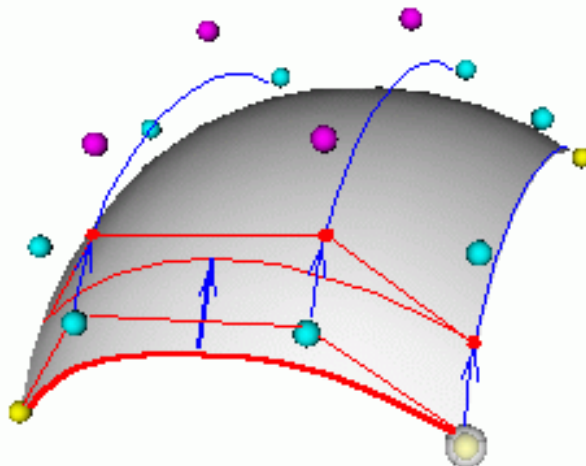
$$F - E + V = 2 \quad \checkmark$$

Note: A closed manifold mesh is a mesh with a clearly defined inside and outside, e.g. every edge belongs to two faces and every face lies on the boundary of the resulting object.

Bezier Surfaces

- Defined by sweeping a Bezier curve along the trajectory of another Bezier curve
- Note that there are many other curve representations (B-Splines, NURBS) which can also be generalised to surfaces (e.g. NURBS surfaces)

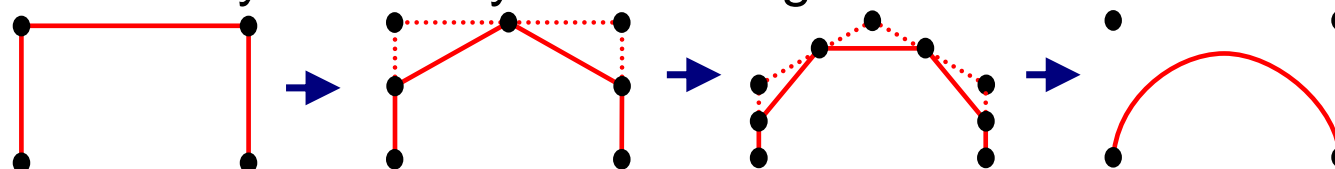
(**NURBS** = **N**on-**U**niform **R**ational **B**-**S**pline)



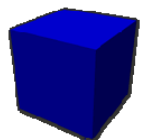
© <http://www.ibiblio.org/e-notes/Splines/Inter.htm>

Subdivision Surfaces

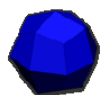
- **Subdivision Surfaces** generate smooth surfaces from coarse control meshes by iteratively subdividing them



Catmull-Clark



1 iteration



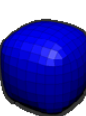
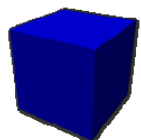
2 iterations



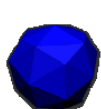
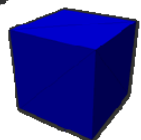
3 iterations



Doo-Sabin



Loop

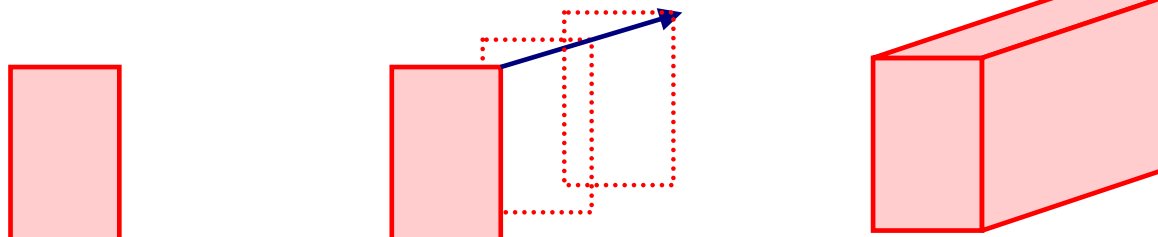


- New vertices are computed as weighted averages of existing vertices
- Different weighting factors result in different surfaces

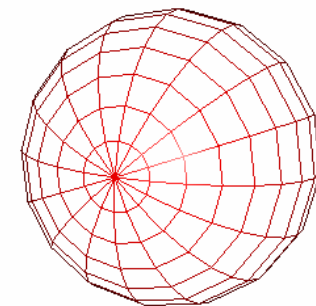
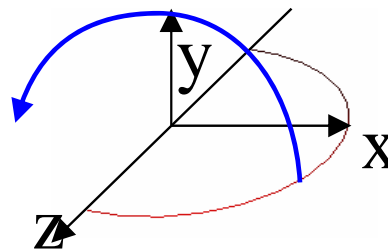
© <http://www.uvmapper.com/sds.gif>

2.3 3D Shapes

- The easiest way to create a 3D shape is to use a closed polygon mesh
 - *Bezier surfaces, subdivision surfaces etc.*
 - *Extruded surfaces*: Extrude a 2D surface along a third dimension

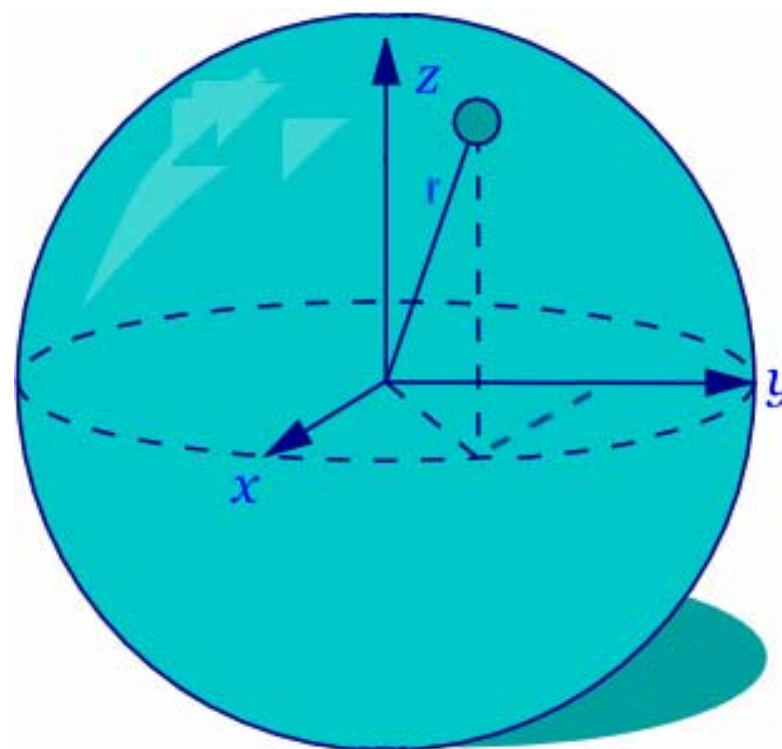


- *Surfaces of Revolution*: Rotate a curve around an axis



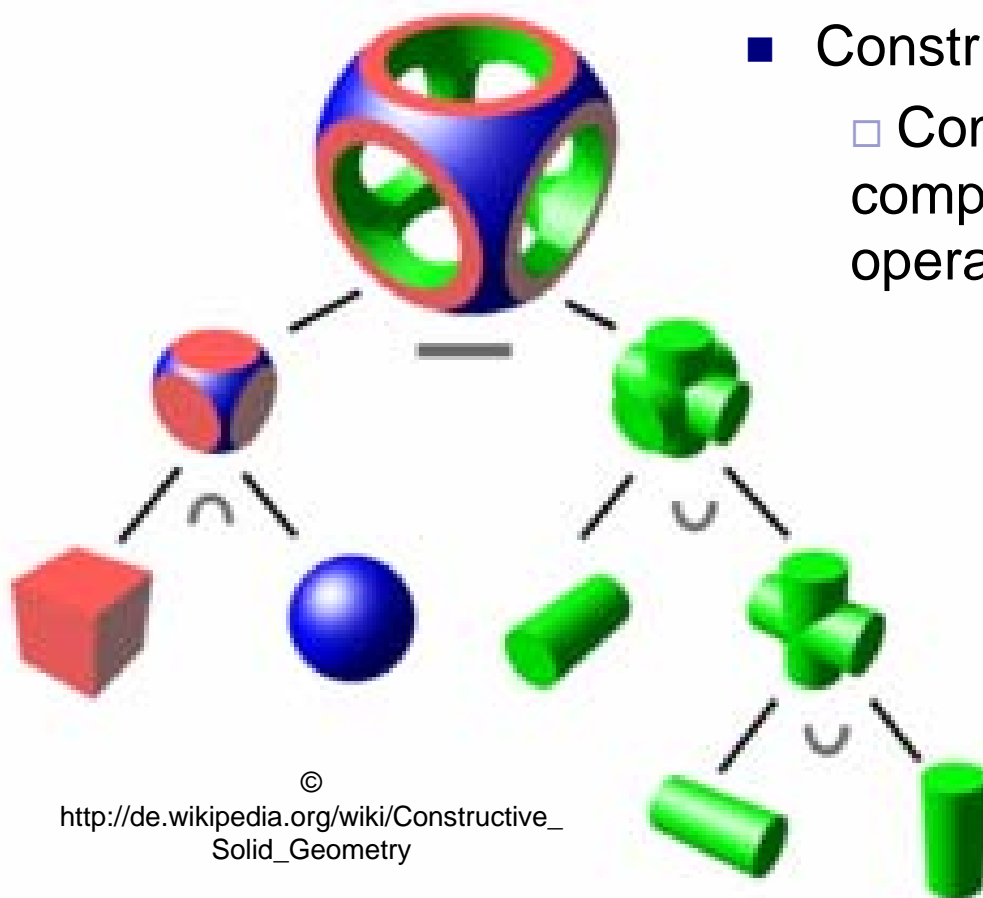
3D Shapes – Implicit Surfaces

- Implicit surfaces are defined as all points (x,y,z) where $f(x,y,z)=0$
 - The inside of the object is given by all points where $f(x,y,z)<0$
- Example:
$$f(x,y,z)=x^2+y^2+z^2-r^2$$



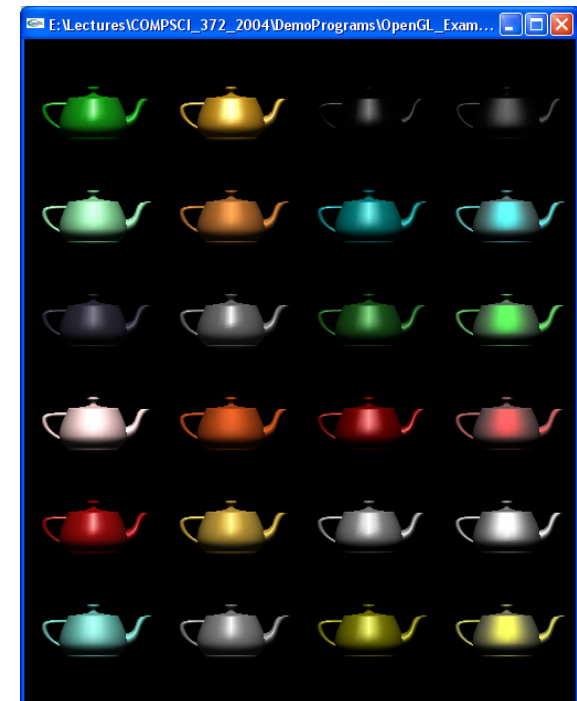
3D Shapes – CSG objects

- Constructive Solid Geometry (CSG)
 - Combine simple objects to more complex objects by using set operations (union, intersection, ...).



2.4 Lighting and Materials

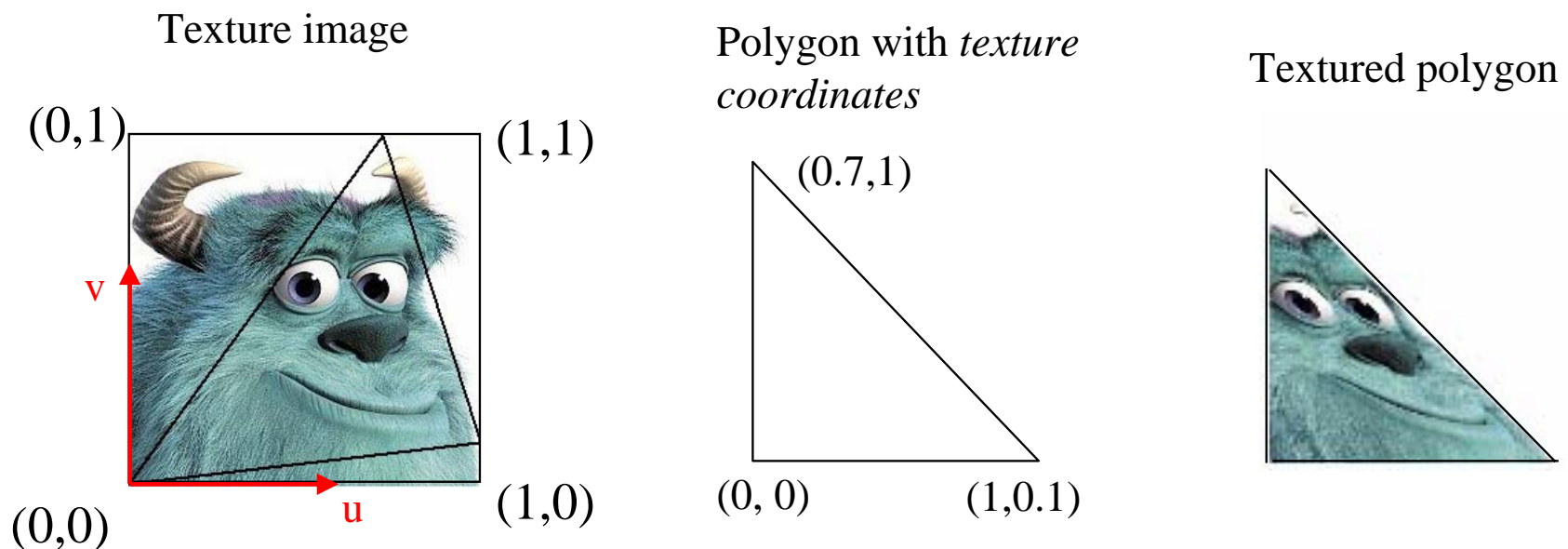
- Real material has colour (pigments) and surface properties
 - Perceived colour depends on effects caused by the microstructure and molecular structure of the material and its interaction with light of different wavelengths
- Modelling packages use simplified descriptions
 - ambient, diffuse and specular colour
 - transparencies
 - reflection and refraction
 - surface roughness (bump mapping), ...



2.5 Texturing

2D Texturing

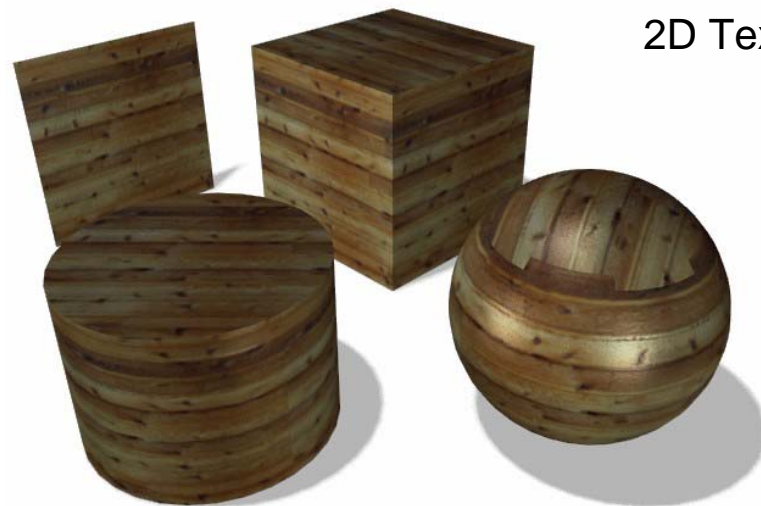
- Map an image onto surface of an object by specifying points of correspondence (\rightarrow texture coordinates)



Texturing (cont'd)

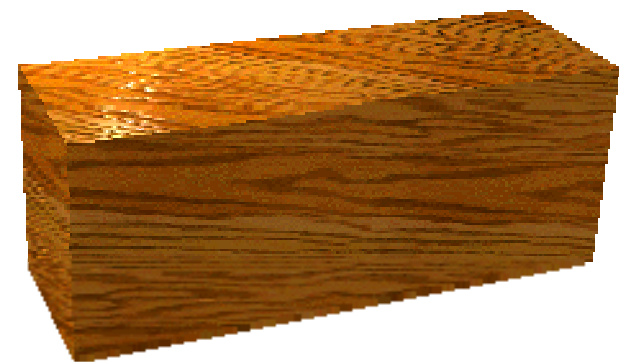
3D Texturing (solid texture)

- Same idea as in 2D but use a 3D texture image (or texture function)
- Objects appear to have been carved out of a solid material



2D Textures

© <http://download.blender.org/documentation/html/ch11.html>



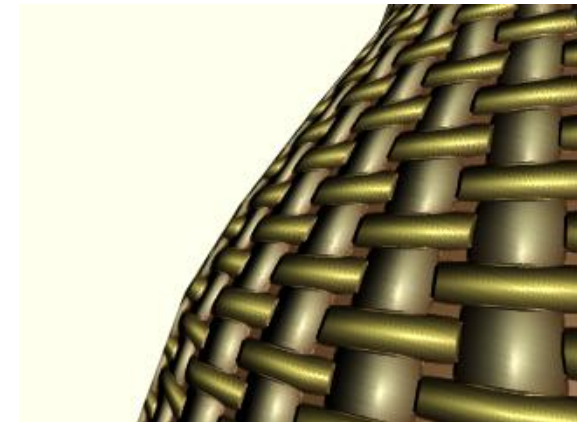
3D Textures

© <http://www.cosc.brocku.ca/Offerings/3P98/course/lectures/texture/>

Texturing (cont'd)

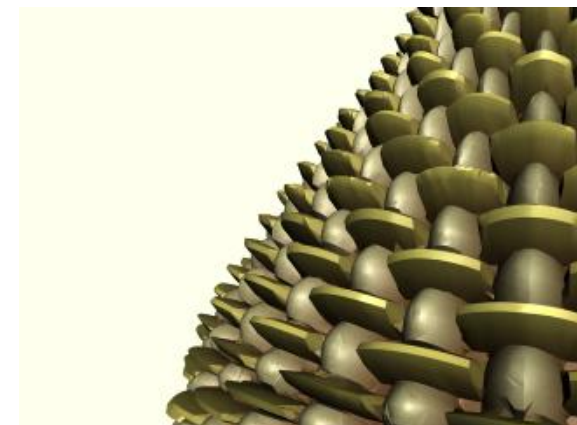
Bump mapping

- Modify the normal at each point of a smooth surface to give the illusion of surface roughness.



Displacement mapping

- Modify the position and normal of each surface point during rendering.



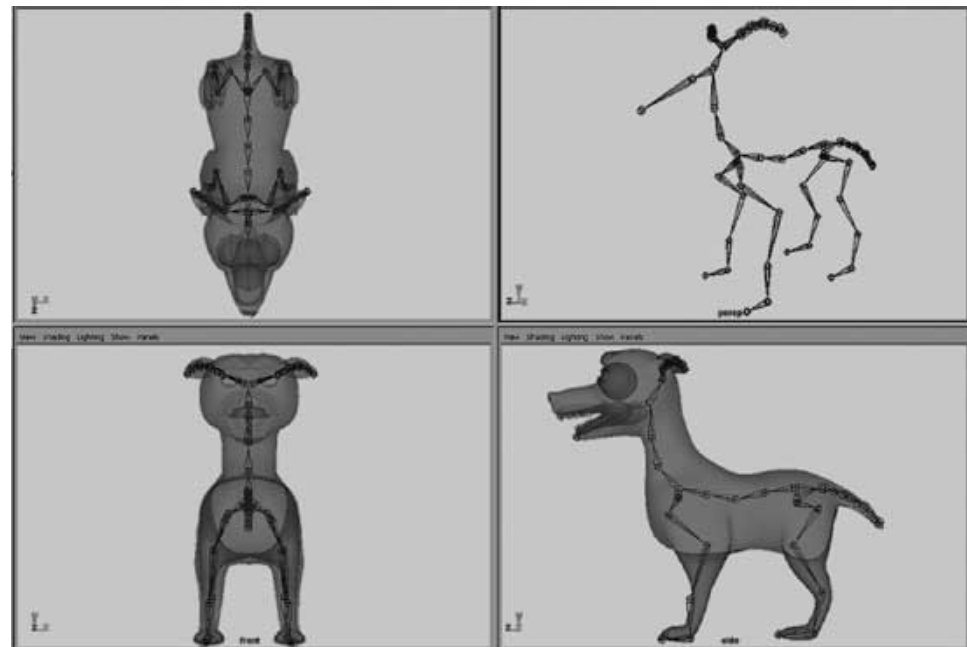
© http://atec.utdallas.edu/midori/Handouts/texture_mapping.htm

2.6 Animation

Skeletal Animation

- Build “computerized puppet” using a hierarchical model.
- Character controlled by a skeleton (“joints” and “bones”).
- Character defined as a surface (“skin”) which is effected by the skeleton. Usually use spline or subdivision surface.

© <http://www.webreference.com/3d/insidemaya/1/2.html>



Controlling the Animation

- Controlled by skilled modellers/animators, via large number of control points (parameters)
- For characters usually animate skeleton but often need exact control over the surface for fine details (e.g. facial expressions)
- e.g. Toy Story
 - Number of control points for Woody: 712
 - Control points for Woody's face: 212
 - Control points for Woody's mouth: 58
 - Control points for Sid's backpack: 128



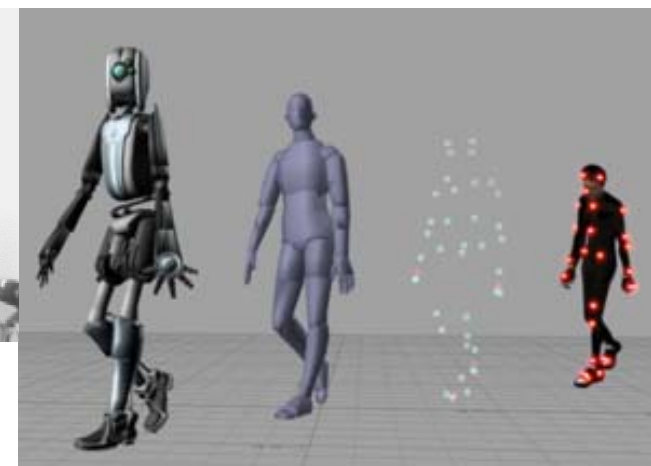
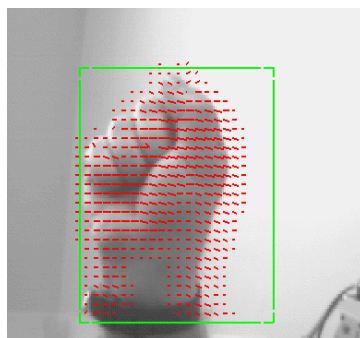
Controlling the Animation (cont'd)

- Need at least 20 frames/second for smooth motions
- Manually create “key frames” and do “In-betweening” by smoothly interpolating parameters
 - Discontinuities a problem (e.g. bouncing ball)
 - May need to add extra key frames and/or velocity information
 - Such methods are called *kinematic* methods
 - *Kinematics*: study of motion in terms of positions, velocities and accelerations)
 - *Dynamics*: study of motion in terms of forces, torques and their effect
 - May have *Inverse Kinematics* (IK) system
 - Move one part of hierarchy, system moves the rest to match (subject to joint constraints, spring controls etc.)

Motion Capturing

Use motion of a human actor to animate the character

- Video methods
 - Standard: Optical markers
 - Emerging: Markerless motion tracking
- Mechanical gadgetry attached to user
 - e.g. “data glove”



Physically-Based Animation

- Compute motions using the laws of physics
 - Use dynamics (forces, torques) to determine kinematics
 - Advantages
 - reduces/eliminates need for human animators
 - models can be reused in different applications
 - Disadvantages
 - mathematically & computationally more complex
- Involves solving differential equations
 - Collisions must be detected



2.7 “Blender”

Blender is an open source software for 3D modeling, animation, and rendering

□ Tutorial:

<http://www.cs.auckland.ac.nz/~jli02/tutorial.htm>

Experimenting with “Blender” will improve your 3D perception and your understanding of modelling and rendering techniques and 3D visualization.

We will use “Blender” for assignment 3D visualization.

□ In this lecture we will learn many of the techniques implemented in “Blender” (e.g. polygon rendering, ray tracing, Bezier curves, lighting and materials, 3D transformations, ...)

