# 2. Introduction to Modelling and Animation





## 2.1 Overview

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


  - 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

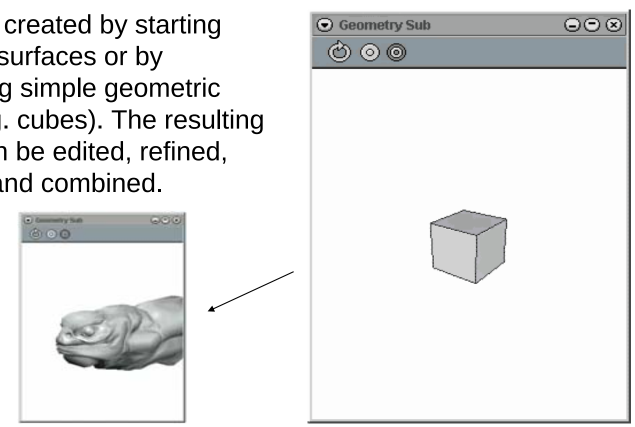
- **Maya** (Alias)
- **3D Studio Max** (Discreet)
- **Houdini** (Side Effects Software)
- **LightWave 3D** (NewTek)
- **Softimage | XSI** (Softimage)

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



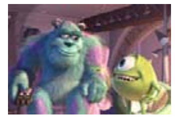

## Example – 3D Studio Max

- 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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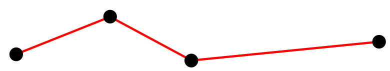
http://www.pixar.com/howwedoit/index.html#



# 2.2 Curves and Surfaces

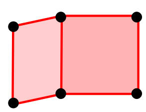
- Polylines
  - Defined by a series of points connected by straight line segments



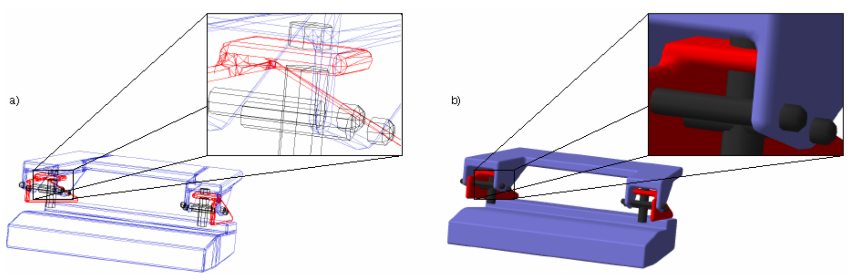
- Bezier Curves
  - A Bezier curve segment is defined by four points (which can be replaced by two points and two tangents)



# 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

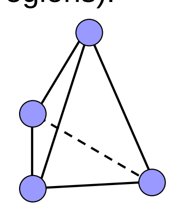





# The Euler Formula

**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:



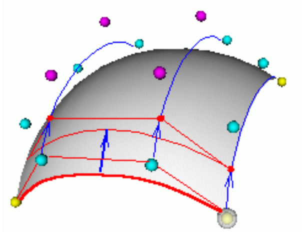
**V=4**
**E=6**
**F=4**
**F-E+V=2 ✓**

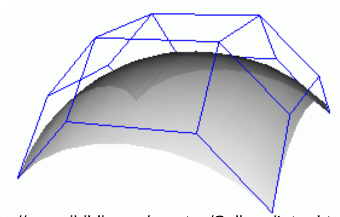
Note: A closed manifold mesh is a mesh with a clearly defined inside and outside, e.g. every edge belongs to two faces and every face lies on the boundary of the resulting object.

# 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)





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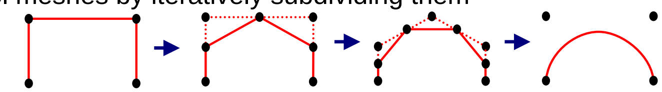
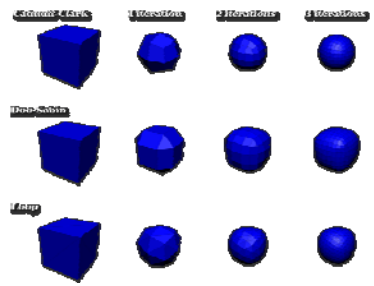
# Subdivison Surfaces

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





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

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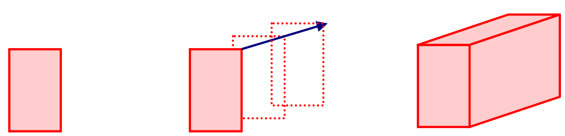
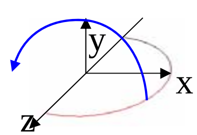
# 2.3 3D Shapes

- 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



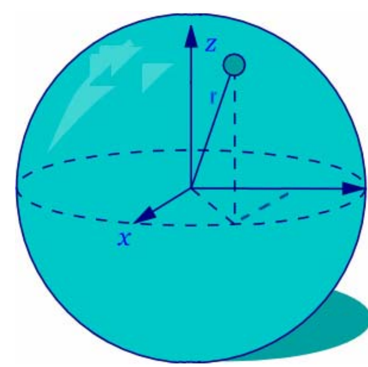
  - *Surfaces of Revolution*: Rotate a curve around an axis



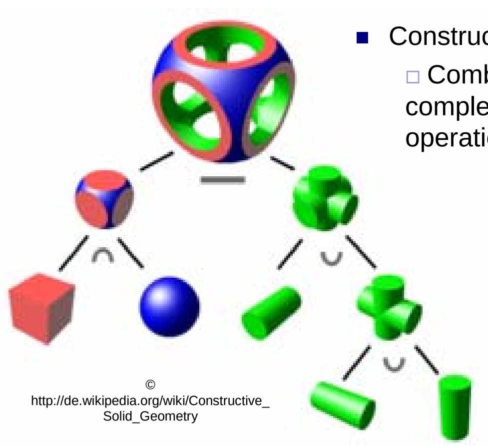



# 3D Shapes – Implicit Surfaces

- 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




© http://de.wikipedia.org/wiki/Constructive_ Solid_Geometry

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



# 2.4 Lighting and Materials

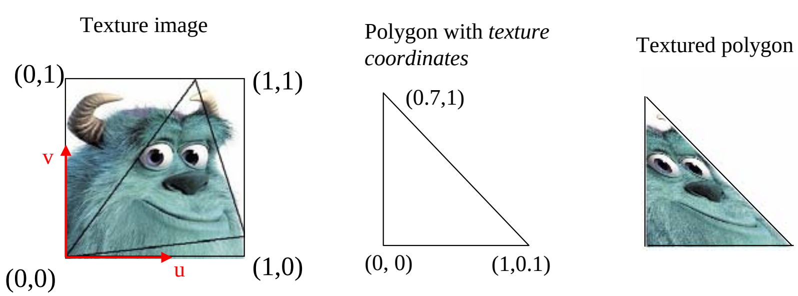
- Real material has colour (pigments) and surface properties
  - Perceived colour depends on effects caused by the microstructure and molecular structure of the material and its interaction with light of different wavelengths
- Modelling packages use simplified descriptions
  - ambient, diffuse and specular 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 (→ 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/htmlI/ch11.html

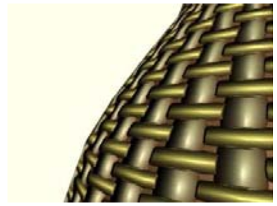
3D Textures

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

## Texturing (cont'd)

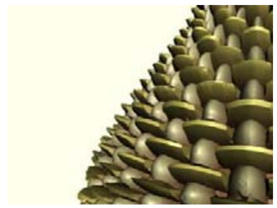
### Bump mapping

- 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.



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## 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.

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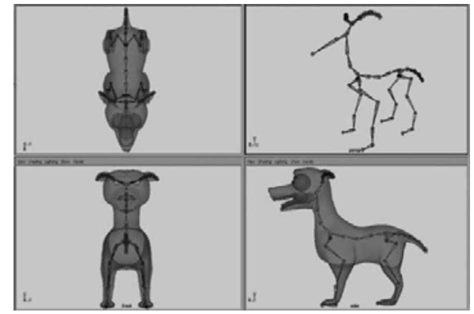
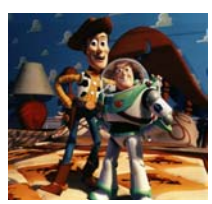




## Controlling the Animation

- 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





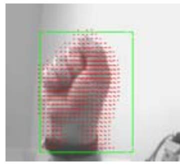
## Controlling the Animation (cont'd)

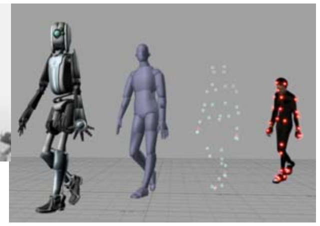
- Need at least 20 frames/second for smooth motions
- Manually create "key frames" and do "In-betweening" by smoothly interpolating parameters
  - Discontinuities a problem (e.g. bouncing ball)
  - May need to add extra key frames and/or velocity information
  - Such methods are called *kinematic* methods
    - *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.)

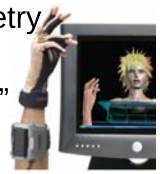
# Motion Capturing

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"



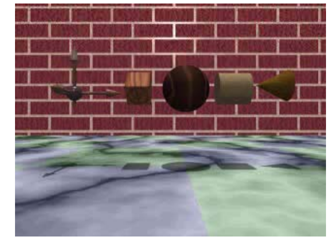






# Physically-Based Animation

- 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



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# 2.7 "Blender"

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

- Tutorial: http://www.cs.auckland.ac.nz/~jli02 utorial.htm

Experimenting with "Blender" will improve your 3D perception and your understanding of modelling and rendering techniques and 3D transformations.

- We will use "Blender" for assignm
- 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, … )