Computer Graphics

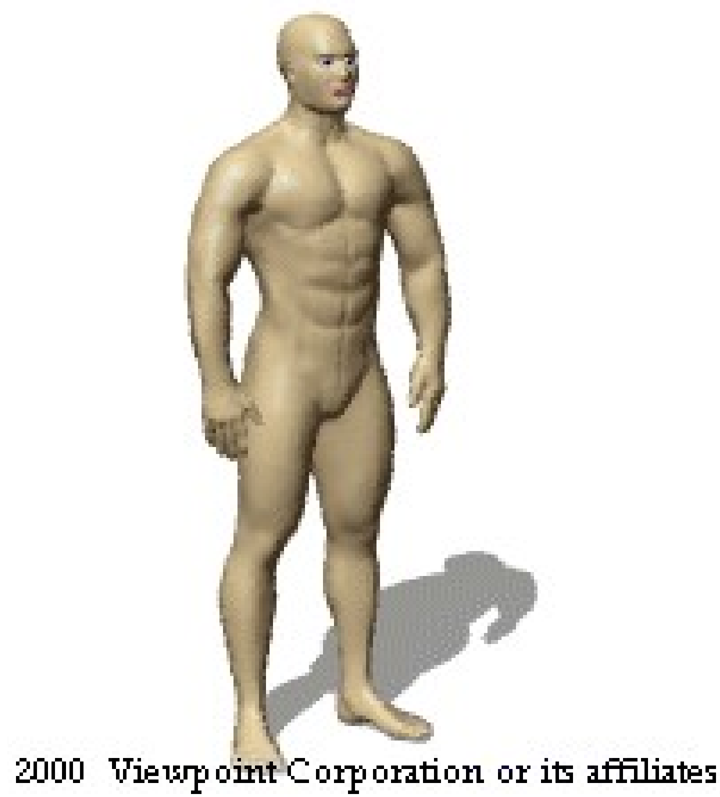
Lecture 4

Geometry of 3D objects

Object polygonal shape:

- ✓ Can be programmed from scratch using OpenGL or other toolkit editor; it is tedious and requires skill;
- ✓ Can be obtained from 3D modelling software
- ✓ Can be created using a 3-D digitizer (stylus), or a 3-D scanner (tracker, cameras and laser);
- ✓ Can be purchased from existing online databases (Viewpoint database). Files have vertex location and connectivity information, but are ***static***.

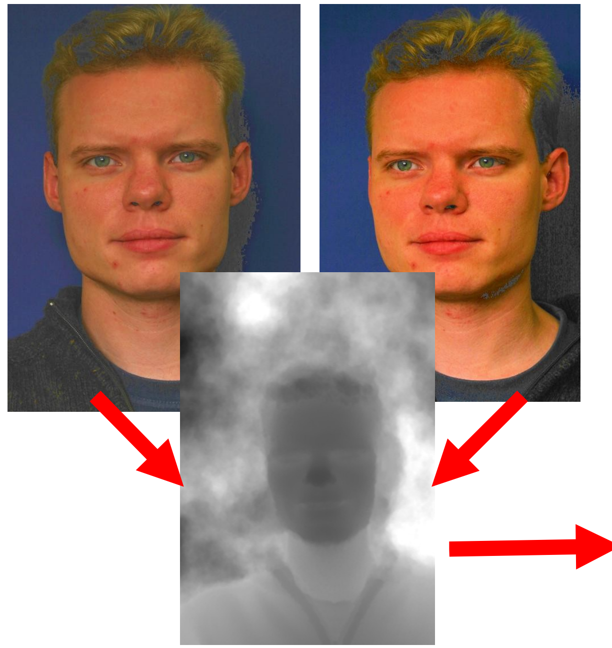
Geometric Modeling – using online databases



Low res. Model – 600 polygons

Higher resolution model > 20,000 polygons.

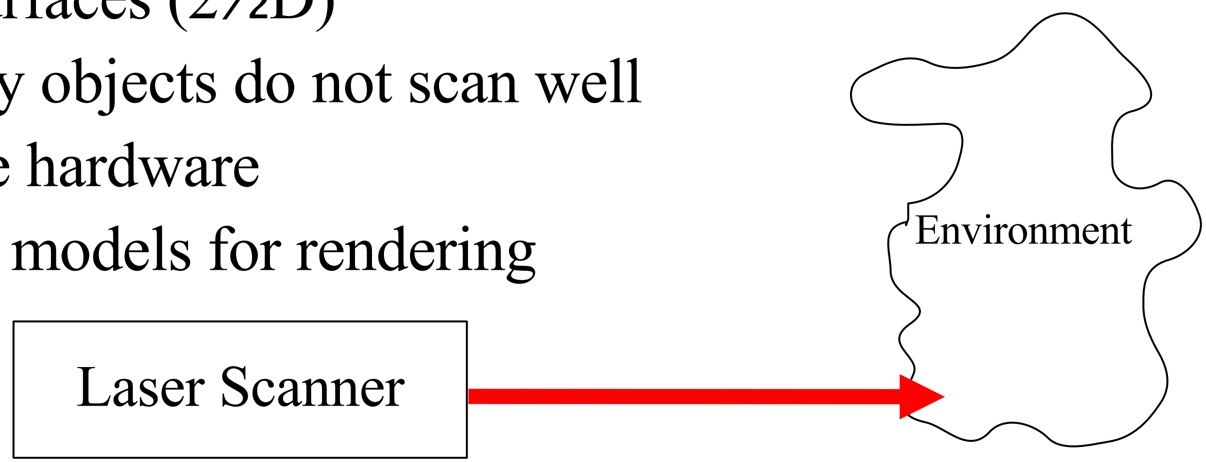
Commercial System : 3D face capture



- 2 x 6 mega-pixel digital SLR cameras
- Commercial 3D stereo software (http://www.di3d.com/)
  - *Results : 6 mega-pixel depth map / VRML 3D surface mesh model*

3D capture : laser range scanning

- **Active depth sensing** using laser beam signal
  - **direct, accurate 3D** scene information
  - unambiguous measurement (unlike stereo)
  - **Limitations**
    - hidden surfaces (2½D)
    - dark/shiny objects do not scan well
    - expensive hardware
    - dense 3D models for rendering



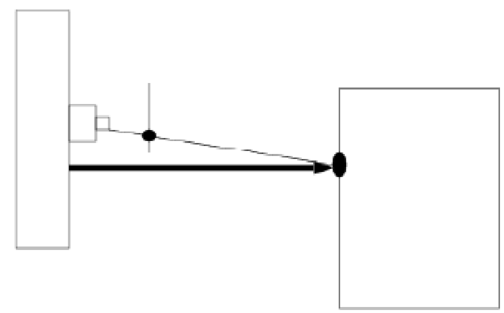
Great Buddha Project in Japan

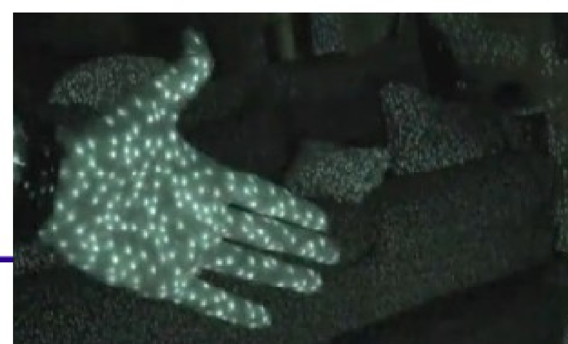
- Capturing took 3 weeks x 2 trips x 10 students/staff

http://www.youtube.com/watch?v=OoNr7DV0b-M&feature=channel_page

Microsoft KINECT

- Estimating the depth from projected structured infra-red light
- Practical ranging limit of 1.2–3.5 m (3.9–11 ft)



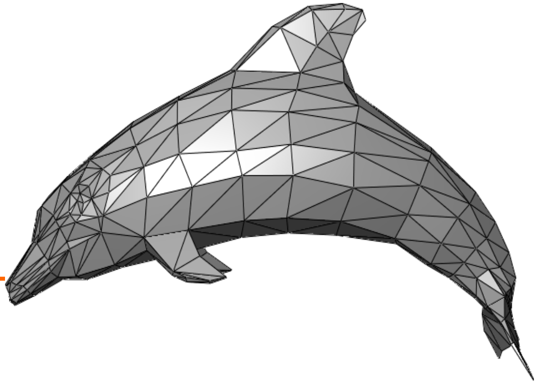


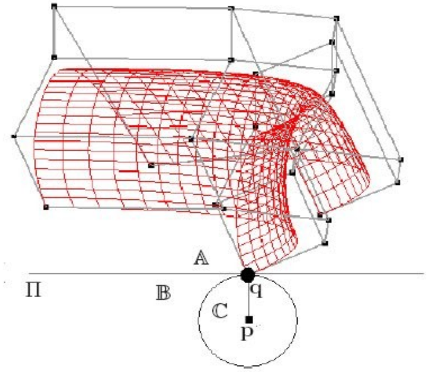
3D objects

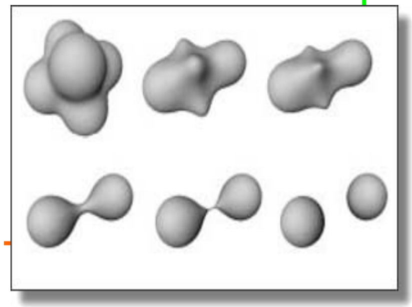
Required to compose the virtual environment

Modelled by

- **Parametric surfaces**
- Implicit surfaces
- Polygon surfaces (triangle mesh)



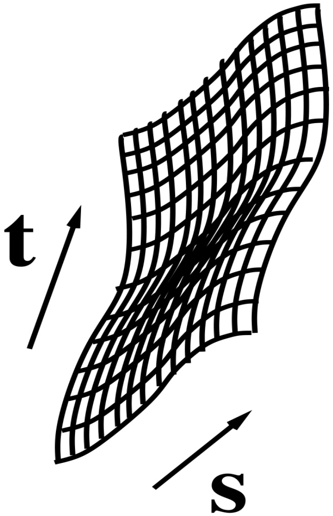




Parametric surfaces

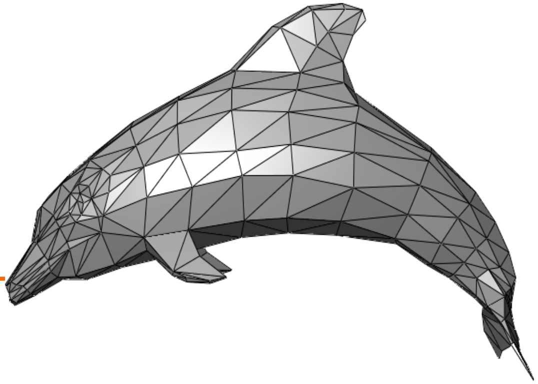
- A way of representing virtual objects;
- Functions are of higher degree than linear functions describing a polygon – use less storage and provide increased surface smoothness.
- Parametric splines are represented by points x(t), y(t), z(t), t=[0,1] and a, b, c are constant coefficients
- Covered more later

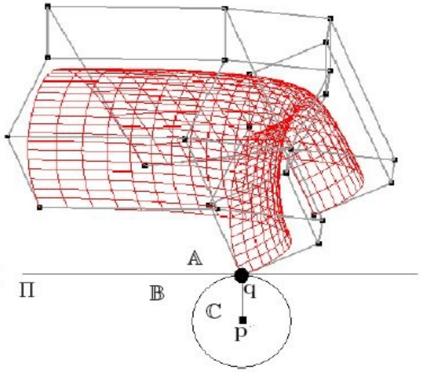
$$x(t) = a_x \cdot t^3 + b_x \cdot t^2 + c_x \cdot t + d_x,$$
$$y(t) = a_y \cdot t^3 + b_y \cdot t^2 + c_y \cdot t + d_y,$$
$$z(t) = a_z \cdot t^3 + b_z \cdot t^2 + c_z \cdot t + d_z,$$

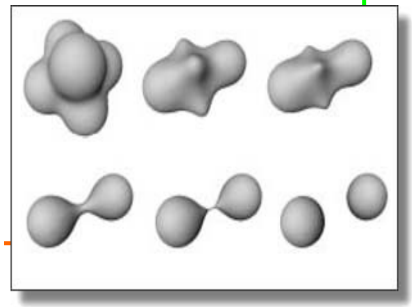


3D objects

- Required to compose the virtual environment
- Modelled by
  - Parametric surfaces
  - **Implicit surfaces**
  - Polygon surfaces (triangle mesh)







Implicit Surfaces

Output given **explicitly** in terms of the *input* value x:

$$y = f(x).$$

implicit if the value of y is obtained from x by *solving* an equation of the form:

$$R(x,y) = 0.$$

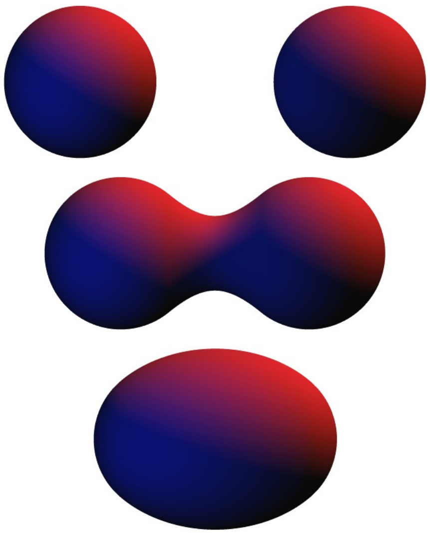
Implicit surfaces

- Sphere
- $x^2 + y^2 + z^2 - 1 = 0$

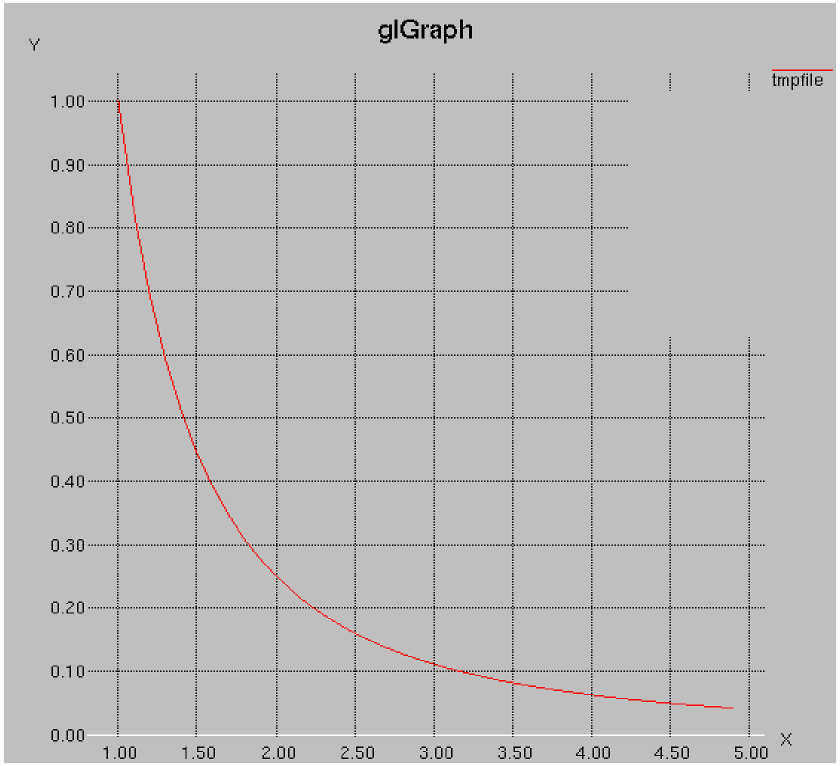
Implicit Function : Metaballs

- A particle surrounded by a density field
- The density decreases with distance from the particle location.
- The density of multiple particles is summed
- A surface is implied by sampling the area where the density is a predefined threshold

$$\sum_{i=0}^{n} \mathrm{metaball}_i(x, y, z) \leq \mathrm{threshold}$$



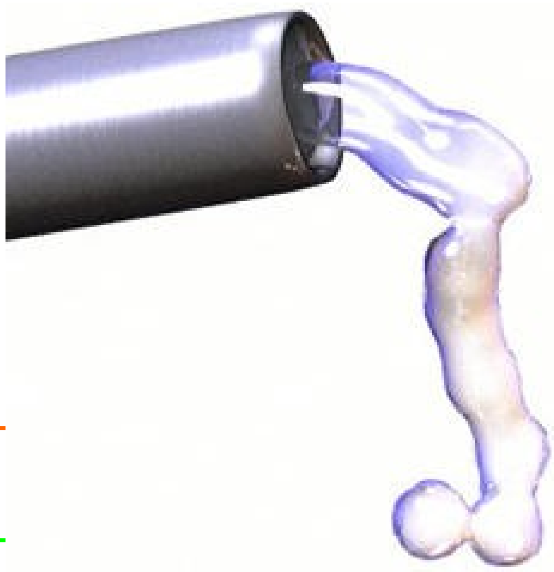
Examples of the density function

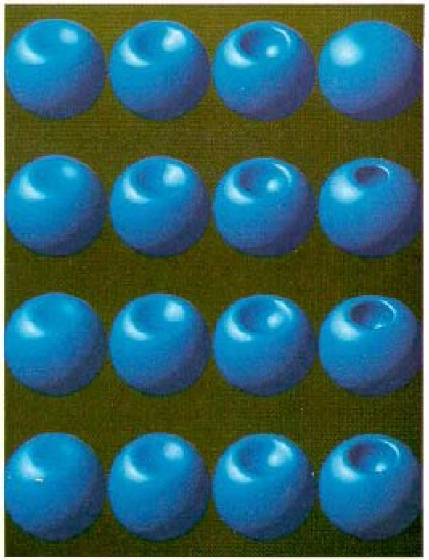


Meta balls (2)

- Also known as blobby objects
- Negative volume to produce hollows
- Can be used to model smooth surfaces, liquid

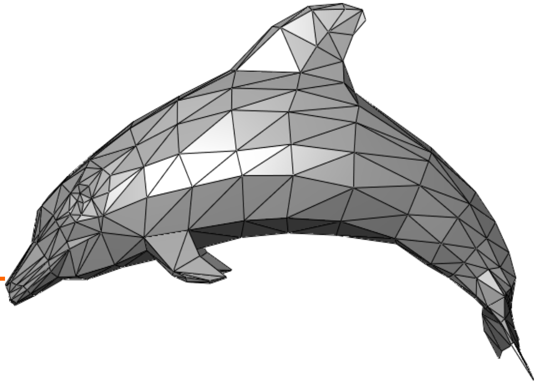
http://www.youtube.com/watch?v=vGapGt25U3U

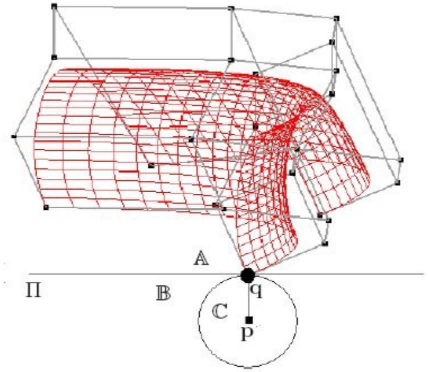


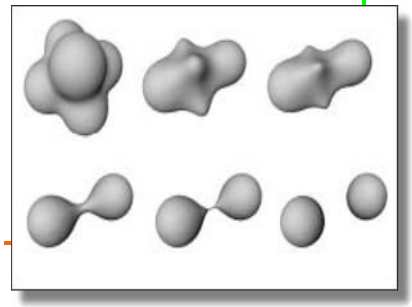


3D objects

- Required to compose the virtual environment
- Modelled by
  - Parametric surfaces
  - Implicit surfaces
  - **Polygon surfaces**



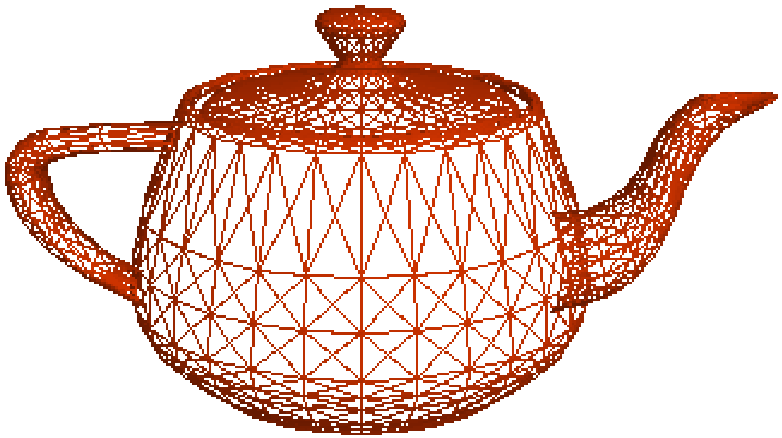


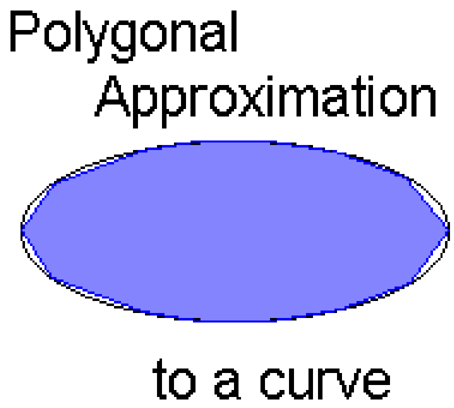


Polygon Surfaces

- Basic form of representation in most applications – all real-time displays.
- Easy to process, fast to process.
- Some applications may allow other descriptions, eg. Splines, but reduce all objects to polygons for processing.

Arbitrary shapes with triangles



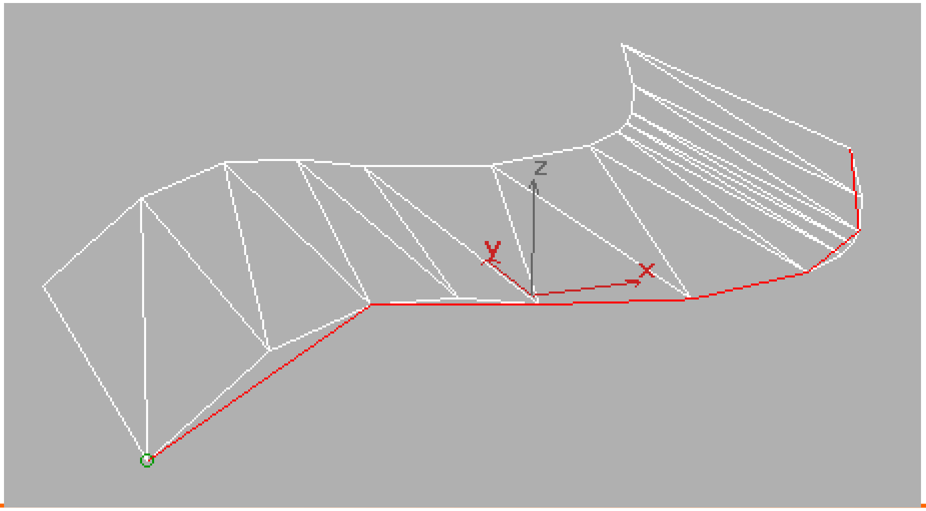


Any 2D shape (or 3D surface) can be approximated with locally linear polygons. To improve, need only increase no. of edges

Quadrilaterals are simple too and often mixed with triangles

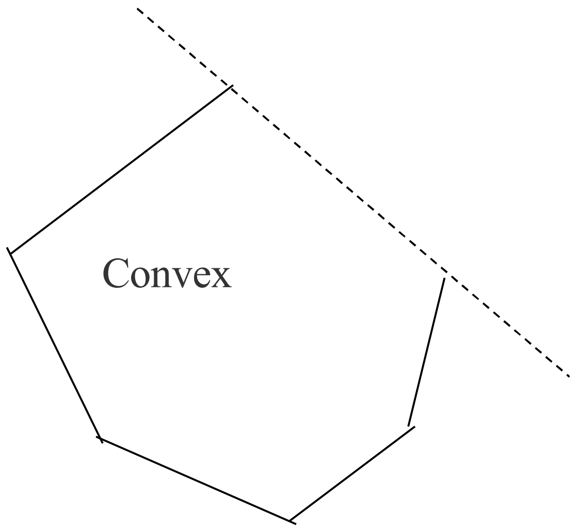
How to visualize parametric surfaces?

- The parametric surfaces need to be decomposed into polygons for rendering purpose
- tessellation



Definitions.

- A polygon is convex if: for all edges, all other vertices lie on the same side of the edge.
- Otherwise it is concave.
- Concave polygons can be difficult to process.

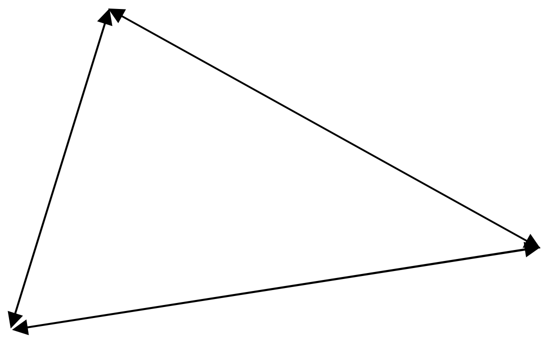


Triangles are Always Convex

- Mathematically very simple – involving simple linear equations.
- Three points guaranteed coplaner.
- Any polygon can be decomposed into triangles.
- Triangles can approximate arbitrary shapes.

How do we draw triangles faster?

Represent triangle as 3 vertices and 3 edges.



If we're performing a transformation on the triangle, we need to transform the position of 3 points.

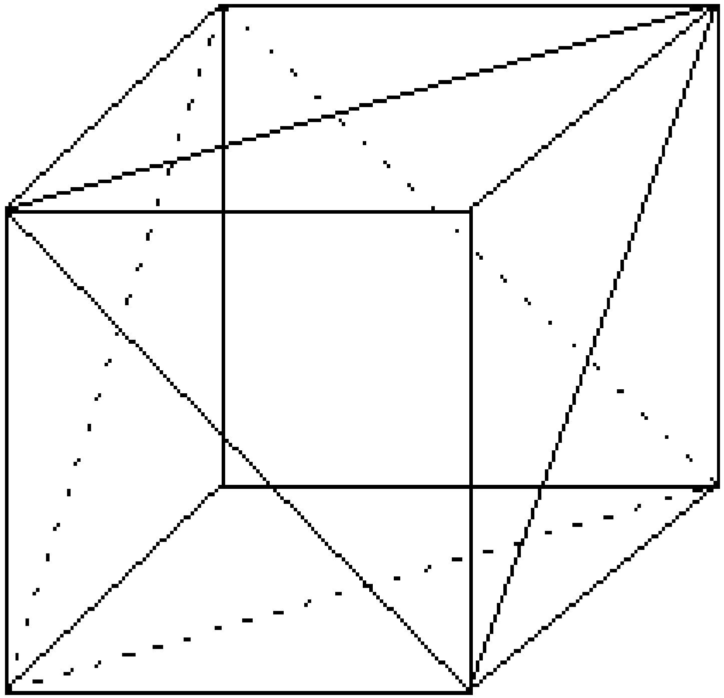
Example (What is this shape?)

- Vertex
- 0 1 0
- 0 0 0
- 1 0 0
- 1 1 0
- 0 1 -1
- 0 0 -1
- 1 0 -1
- 1 1 -1

- Triangles
- 1 2 3
- 1 3 4
- 1 4 8
- 1 8 5
- 4 3 8
- 3 7 8
- 5 7 6
- 5 8 7

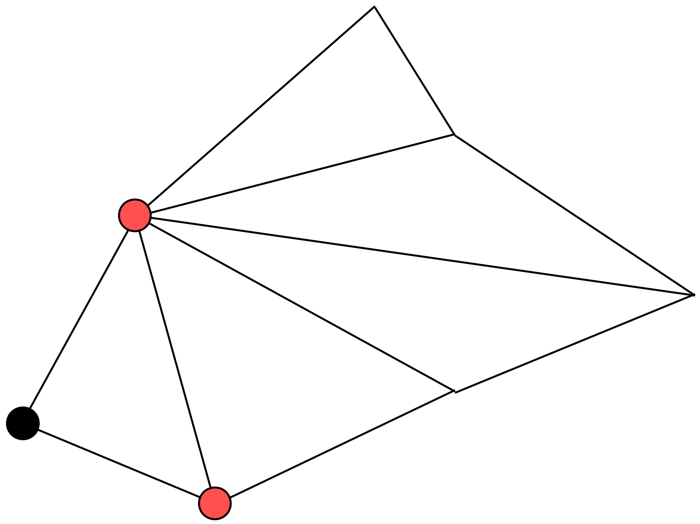
- 1 5 2
- 5 6 2
- 2 6 7
- 2 7 3

Answer



Triangular fans.

Triangles used in complex polygonal geometry.



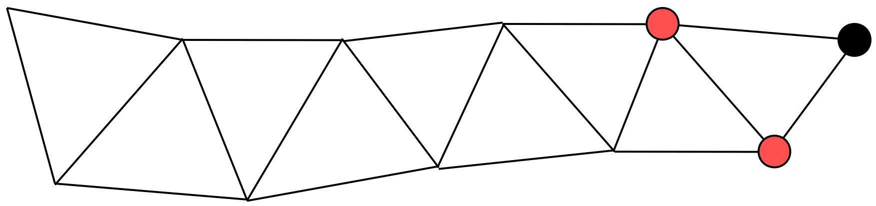
Triangular Fan.

To add new triangle, only 1 vertex needs to be added.
Red - existing vertices.
Black - new vertex

Tri-strip

Use triangles to represent a solid object as a mesh.

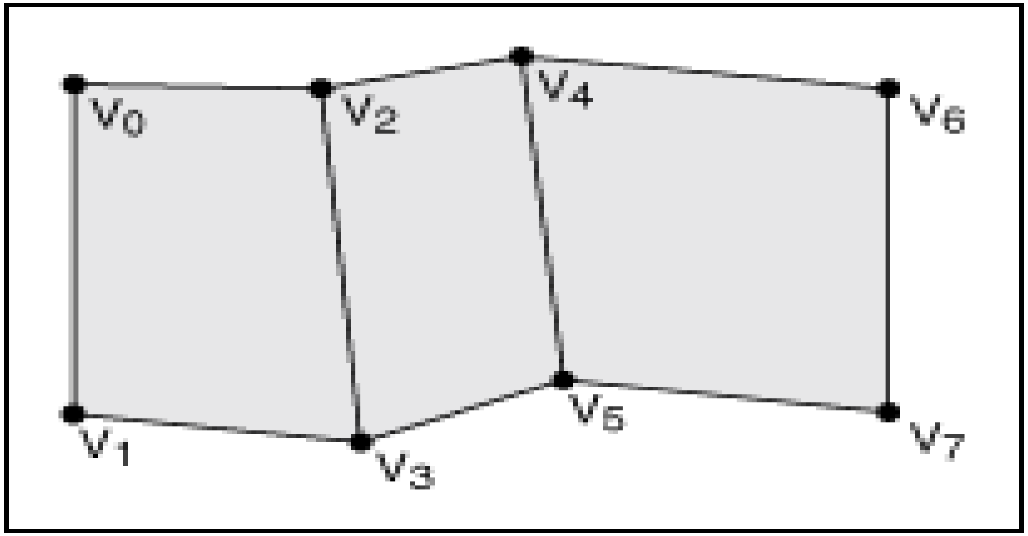
Triangles frequently appear in strips :



A new triangle is defined by 1 new vertex added to the strip.

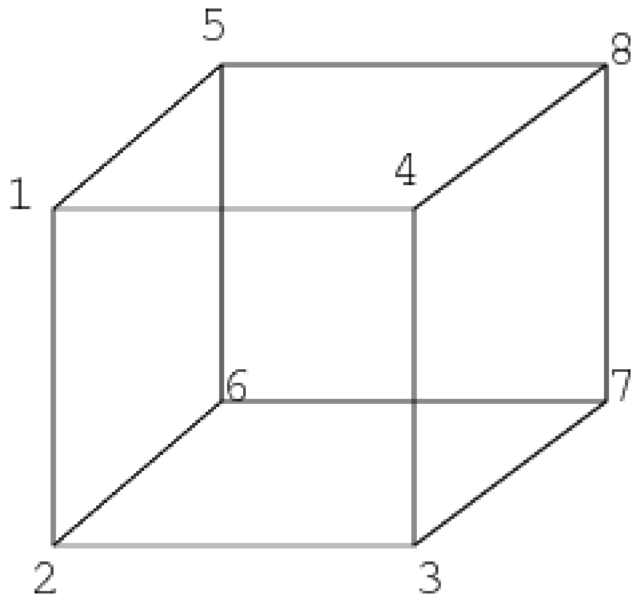
We can do something similar for quads

Also Quad-strip - 2 vertices per quad

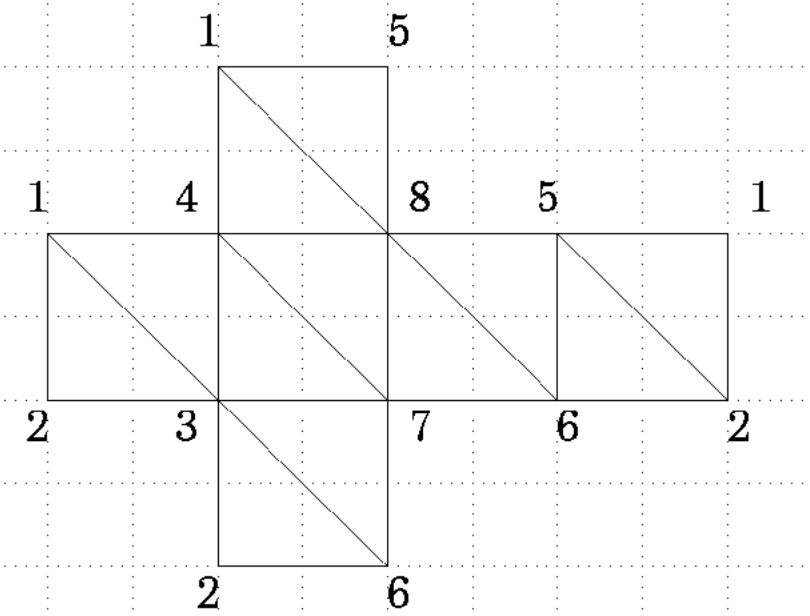


Quiz

- Make a box by a number of triangle strips
- How many bytes per triangle in average?



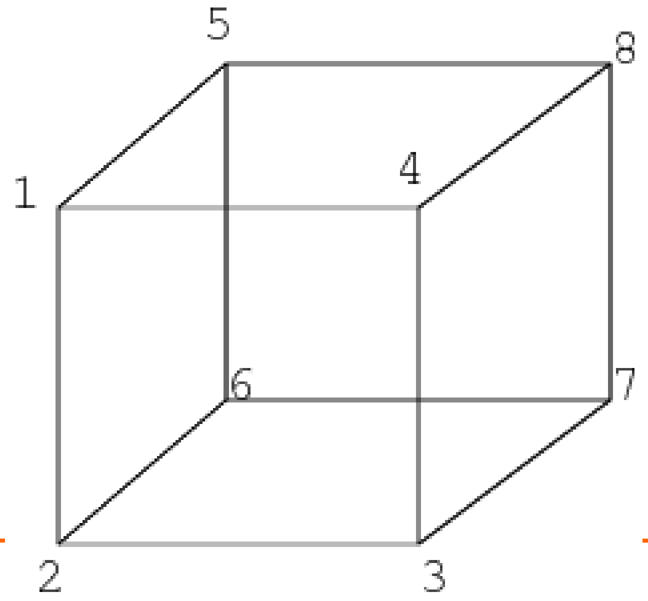
Answer (example)



- Strips
- 2 1 3 4 7 8 6 5 2 1
- 4 1 8 5
- 2 3 6 7
- (18 + a) / 12 = 1.5 + a...

Quiz

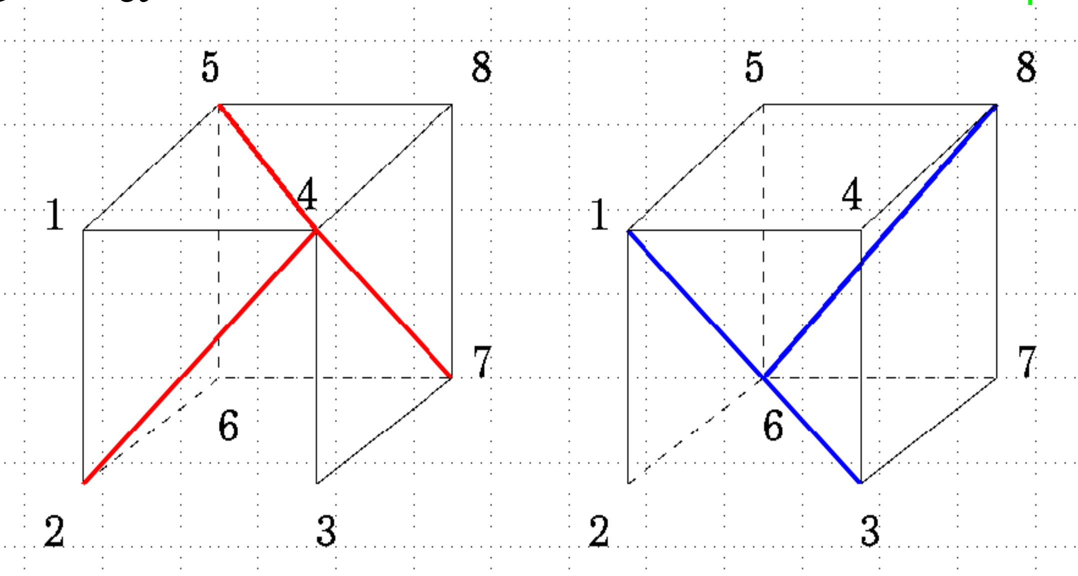
- Make a box by a triangle fan
- How many bytes per triangle in average?



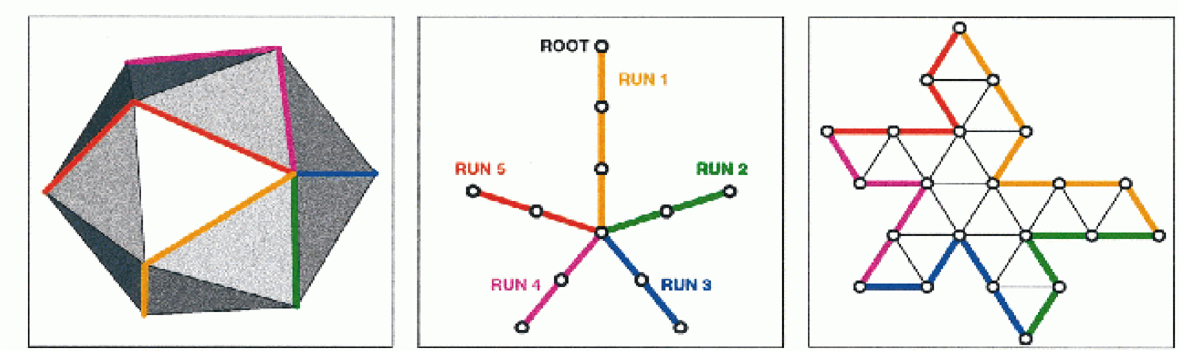
Answer (example)

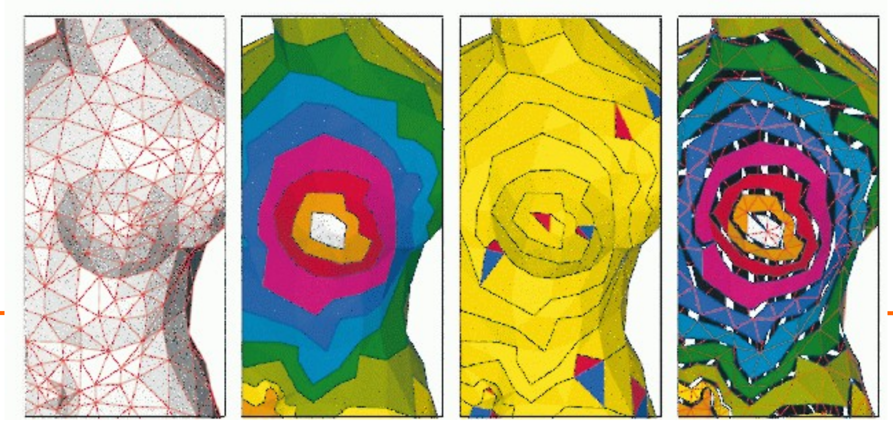
- Fan
- 4 1 2 3 7 8 5 1
- 6 2 1 5 8 7 3 2

- (16 + a) / 12 = 1.33 + a



Complex shapes can be drawn efficiently by combining triangle fans and strips





Summary

Triangles

3 matrix operations per transformation.

Triangle Fan

Connected group sharing 1 common vertex, and 1 from previous triangle.

Tri-strip.

Group of triangles sharing 2 vertices from previous triangle.

About the first practical

- Write a program that loads a 3D teapot and shows its wireframe on the screen
- I will provide the data and a simple program to start from
- You are supposed to load the teapot data, apply a 3D transformation and finally draw the triangle by lines
- Details will be on web on this weekend
- Deadline : 5th November