Computer Graphics

Lecture 3

Modeling
Triangle Meshes: Geometry

Announcements

- Tomorrow's and Friday's classes: watch video(s) ahead, work on Problems in class.
    - Tomorrow: 35 minutes of video
    - Friday: ~27+20 minutes of video (+8 optional but helpful minutes)
    - for Friday, a laptop is not required but one per group might be useful for the in-class problems (so can test your OBJ files)

Goals

- Know how to find out whether a 2D point is inside a given triangle.
- Understand the advantages and disadvantages of modeling objects using triangle meshes.
- Know how contiguous meshes of triangles can be represented using separate triangle sets, indexed triangle sets, triangle strips, and triangle fans.

Point-in-Triangle (2D)

- (whiteboard)

The Cross Product (3D)

- (whiteboard)

Modeling

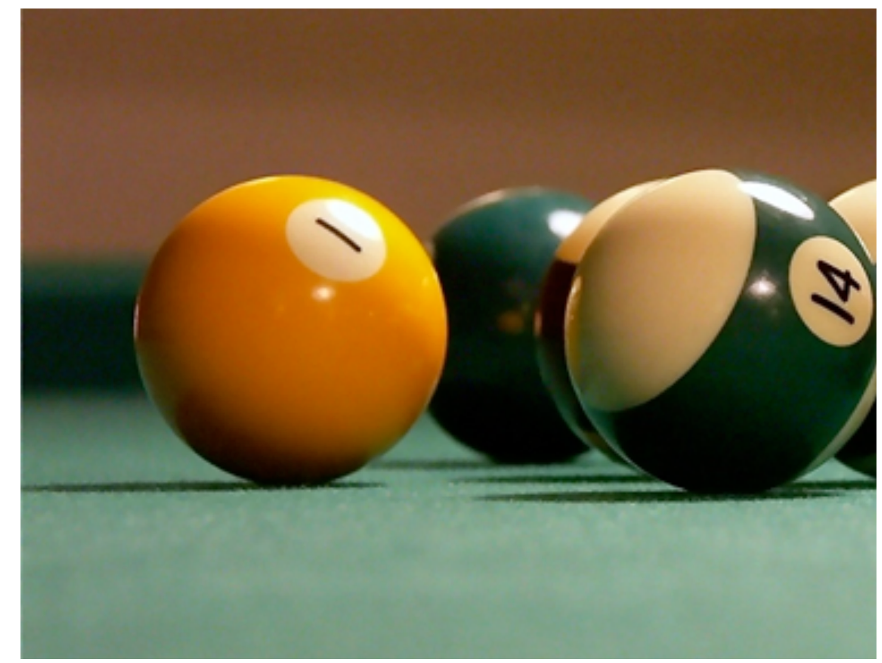
Pseudocode for graphics:

```
Create a model of a scene
Render an image of the model
```

Modeling a Sphere

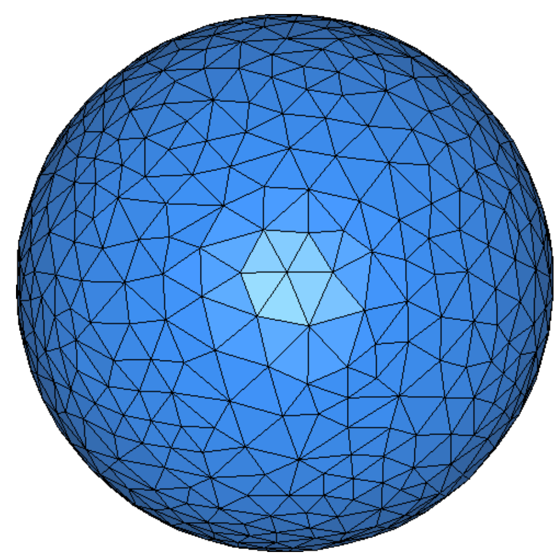
Recall two possibilities:

- Center point and radius
- Triangle mesh



spheres

which is better?



approximate sphere

what does "better" mean?

This is a choice of data structures.

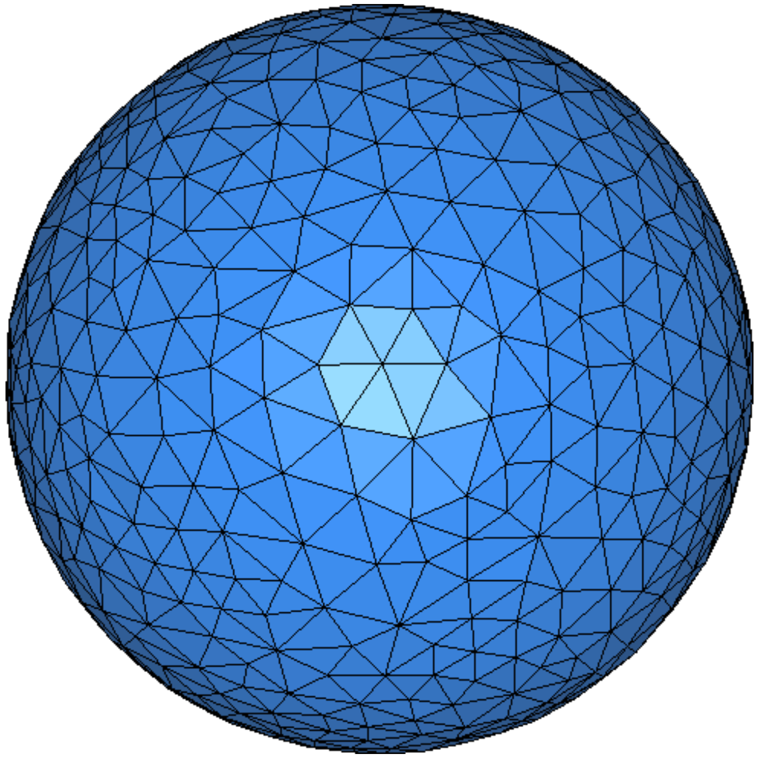
What's important to us? Let's brainstorm.

Modeling

- This is really a choice of data structures. What's important to us?
  - What can the data structure represent?
    Here: **generality** and **manipulability** for modeling.
  - Space complexity: how memory-efficient is the representation?
  - Time complexity
    Here: efficient **operations needed for rendering**
    - Intersect rays with object (image-order)
    - Project all points on object down to 2D (object-order)

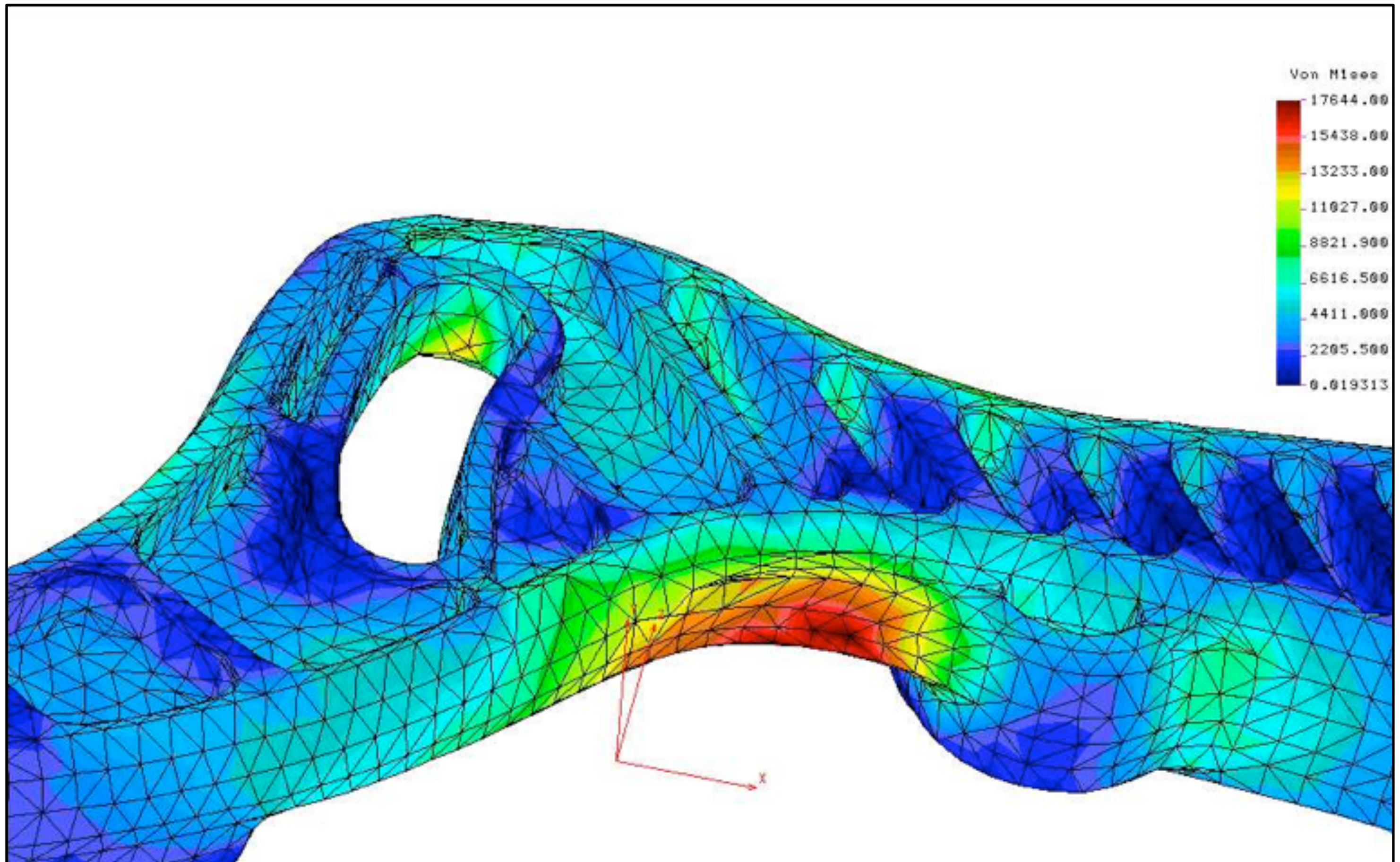
Meshes - Advantages

- Made of very simple *primitives* (usually triangles)



Meshes - Advantages

- Approximate arbitrary geometry
- Enables storage of surface properties beyond geometry



Finite element analysis

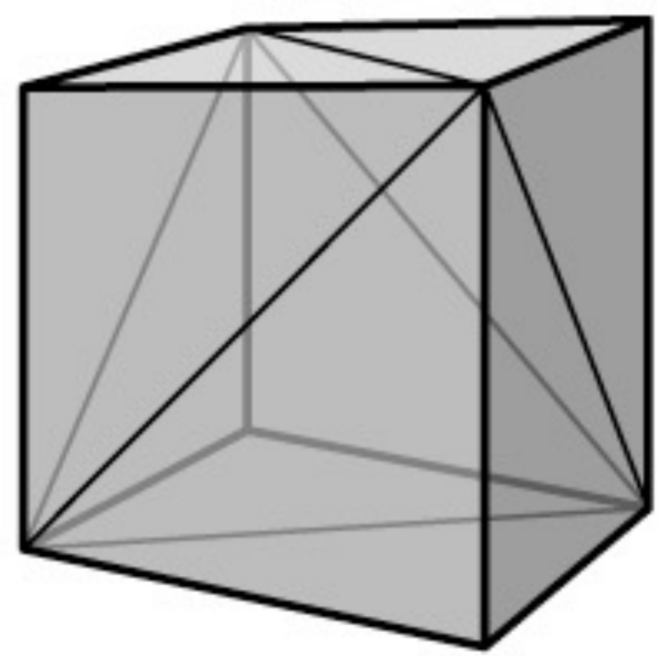
Meshes - Advantages

- Makes for cool architecture

Ottawa Convention Center

Amazon Spheres Complex

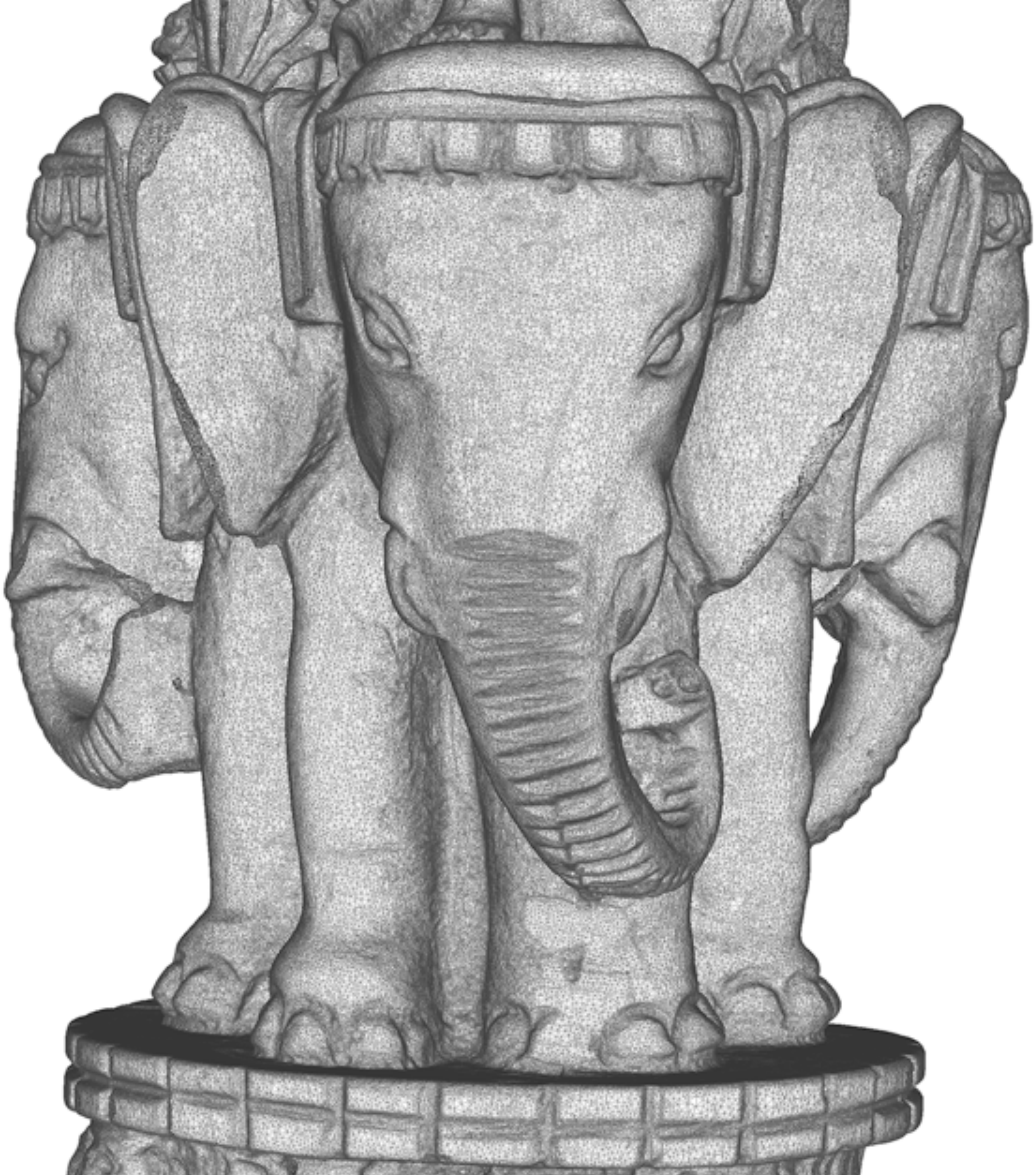
A small mesh

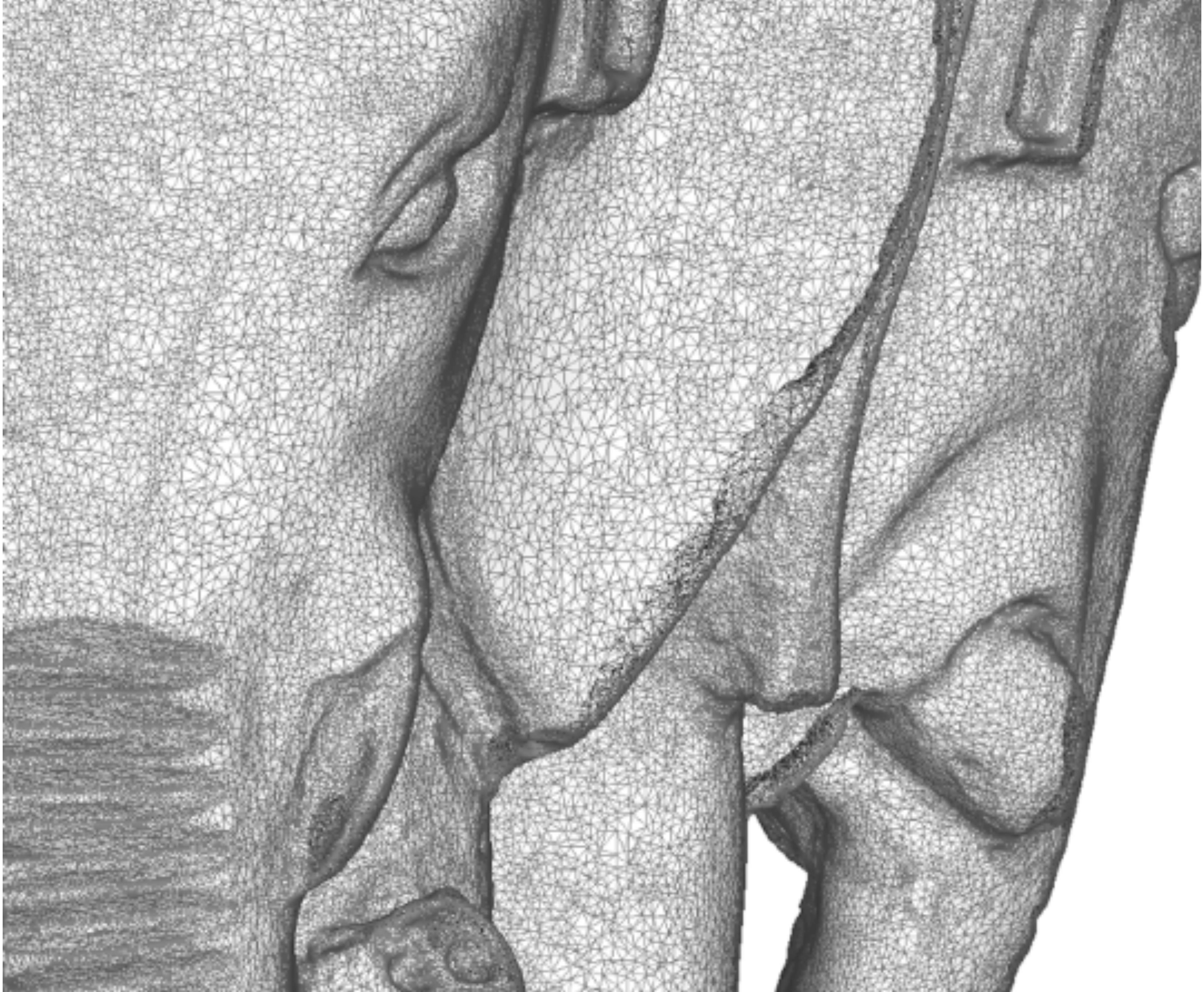


12 triangles, 8 vertices

A large mesh

Traditional Thai sculpture
scan by XYZRGB, inc.
Image by MeshLab project





A large mesh

- 10 million triangles
- Generated from a high-resolution 3D scan

Let's talk about triangles

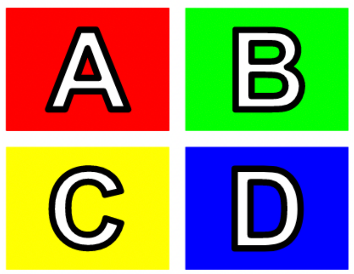
- Defined by three vertices
- Live in the plane containing those vertices
- Vector normal to plane is the triangle’s normal
- Conventions (for this class; not everyone agrees):
  - vertices are counter-clockwise as seen from the “outside” or “front”
  - surface normal points towards the outside (“outward facing normals”)

Take a minute to consider:
why not quadrilaterals? Other polygons?

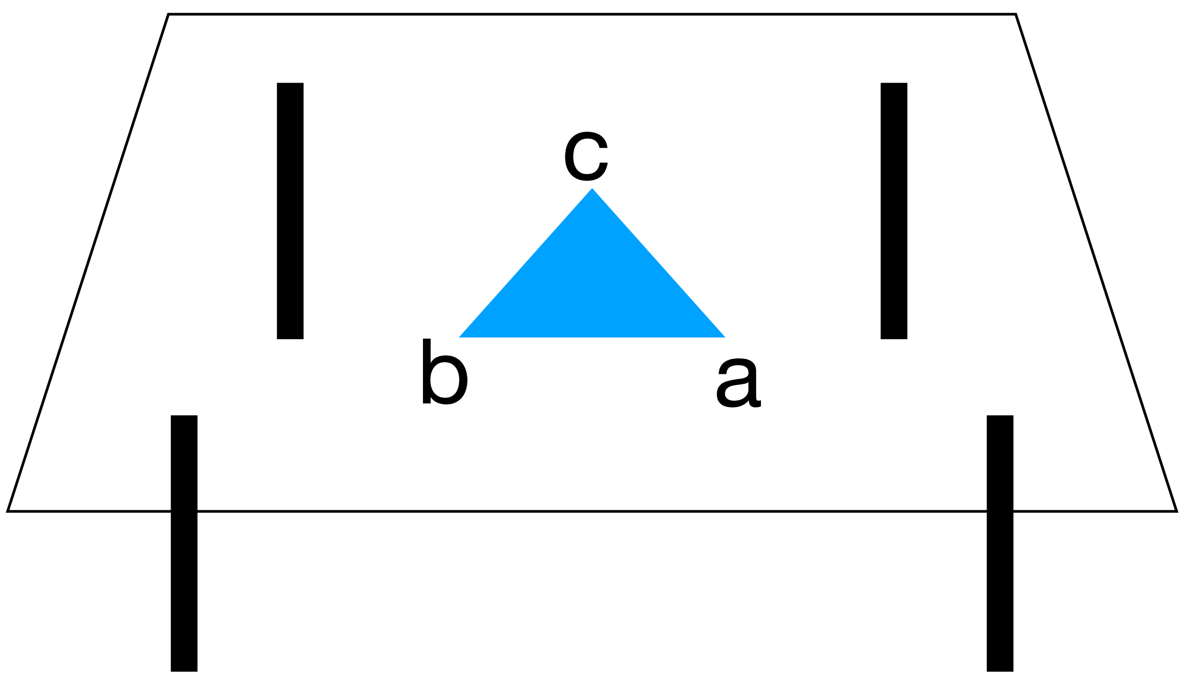
Why not use other polygons?

- Some systems do!
  - More common in modeling than rendering.
- Triangles are nice:
  - simplest possible polygon (makes rendering code easier!)
  - 3 vertices are always coplanar
  - always convex
  - any other polygon can be **triangulated**

Let's talk about triangles



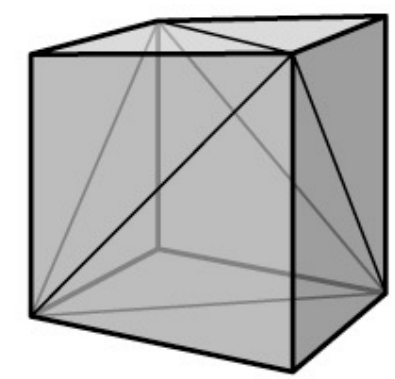
The triangle below sits **face down** on the table - which of the following does **not** describe the triangle?

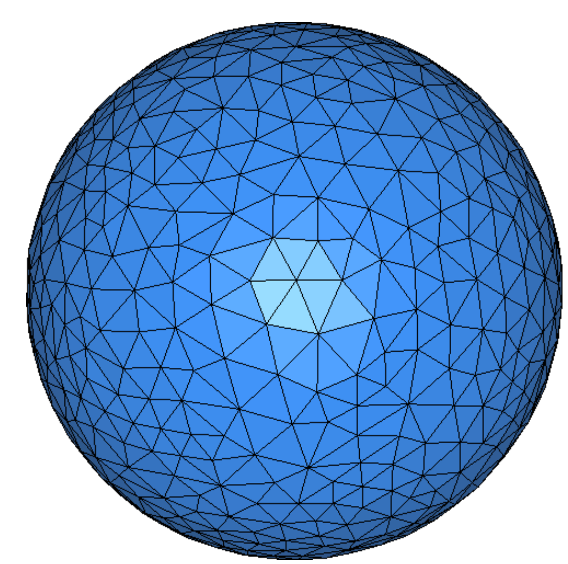


A. abc
B. bca
C. cab
D. acb

Triangle Meshes

- A bunch of triangles in 3D space that are **connected together** to form a surface
- Geometrically, a mesh is a piecewise planar surface
  - almost everywhere, it is planar
  - exceptions are at the edges where triangles join
- Often, it's a piecewise planar **approximation of a smooth surface**
  - in this case the creases between triangles are artifacts—we don't want to see them

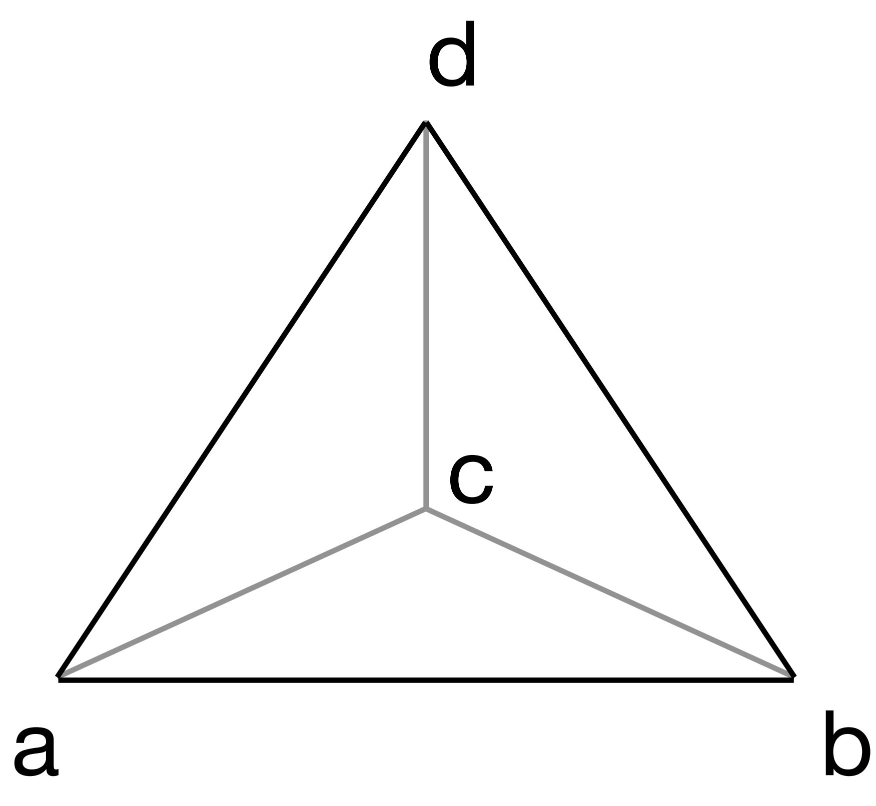




Representing Triangle Meshes

How do we represent these in memory?

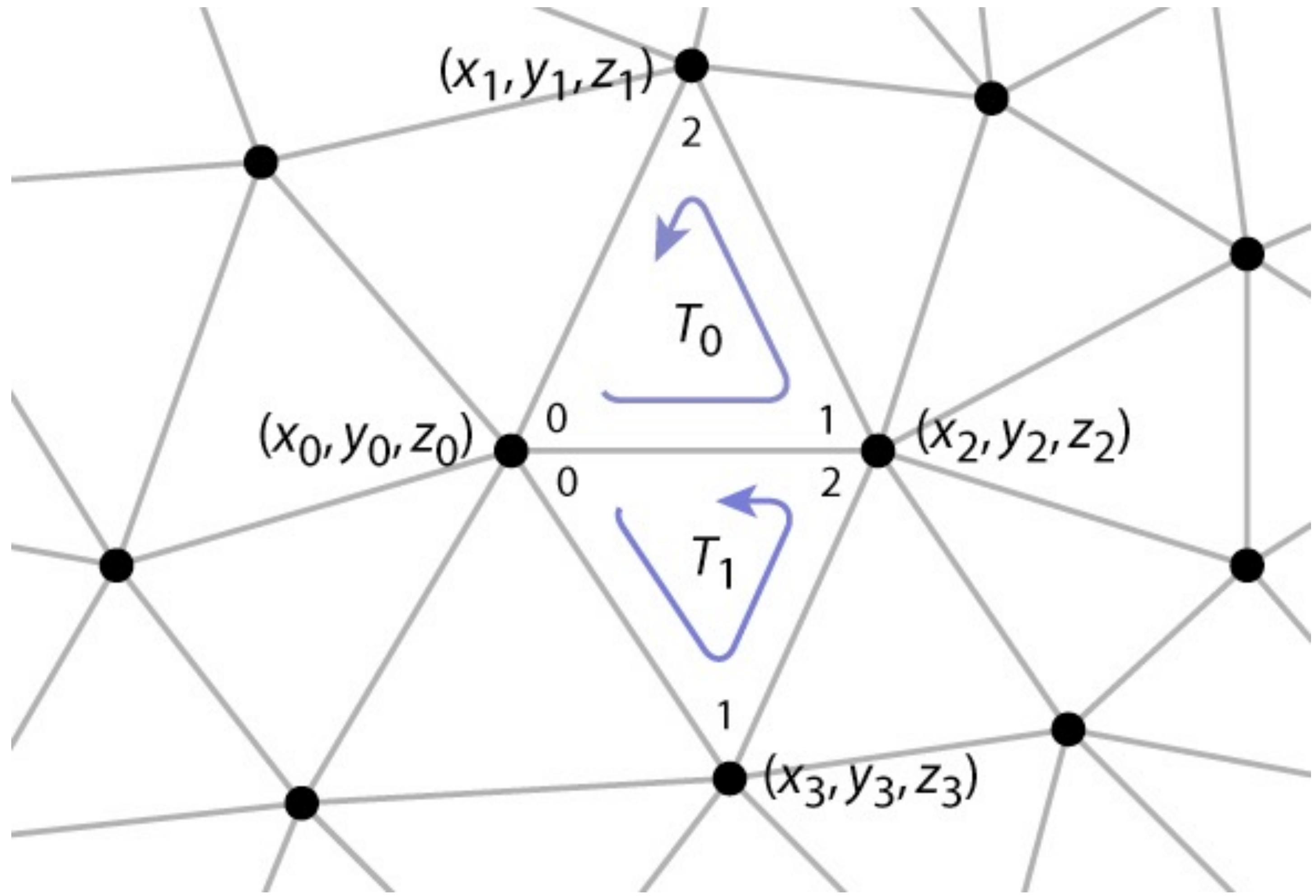
Example: a tetrahedron



illusion disambiguation: c is *behind* the triangle abd

Separate Triangles

	[0]	[1]	[2]
tris[0]	x_0, y_0, z_0	x_2, y_2, z_2	x_1, y_1, z_1
tris[1]	x_0, y_0, z_0	x_3, y_3, z_3	x_2, y_2, z_2
	⋮	⋮	⋮

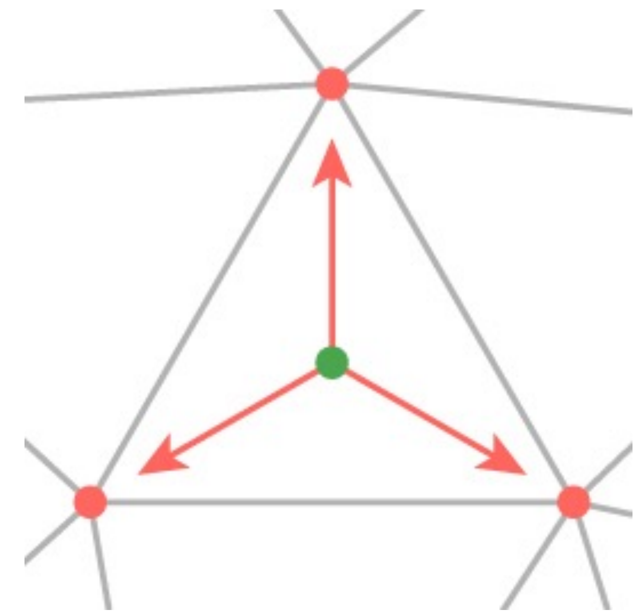


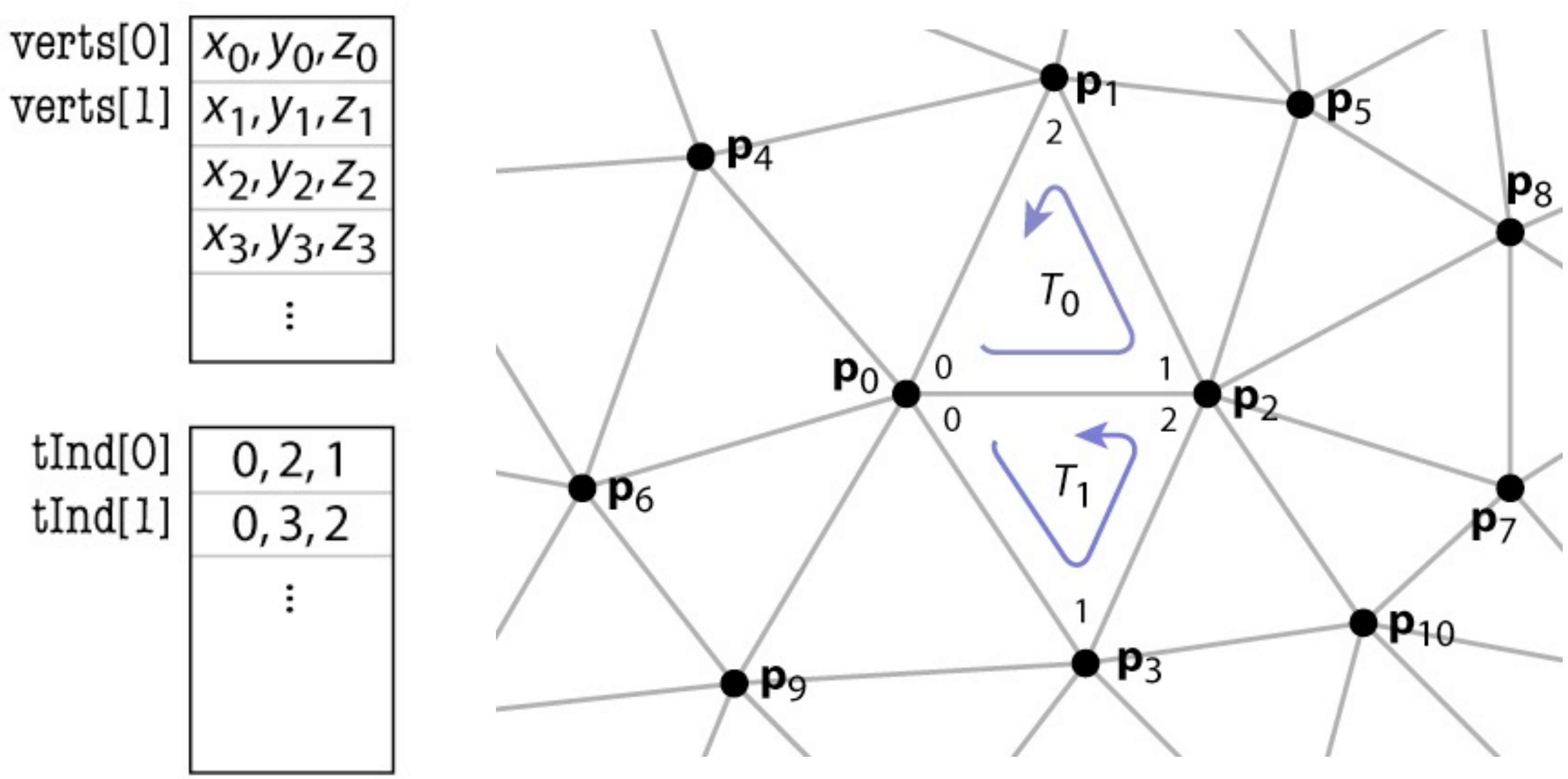
Problems:

- Wastes space
- Repeated floats with different round-off creates problems:
  - Cracks in the mesh
  - Finding neighbors may fail

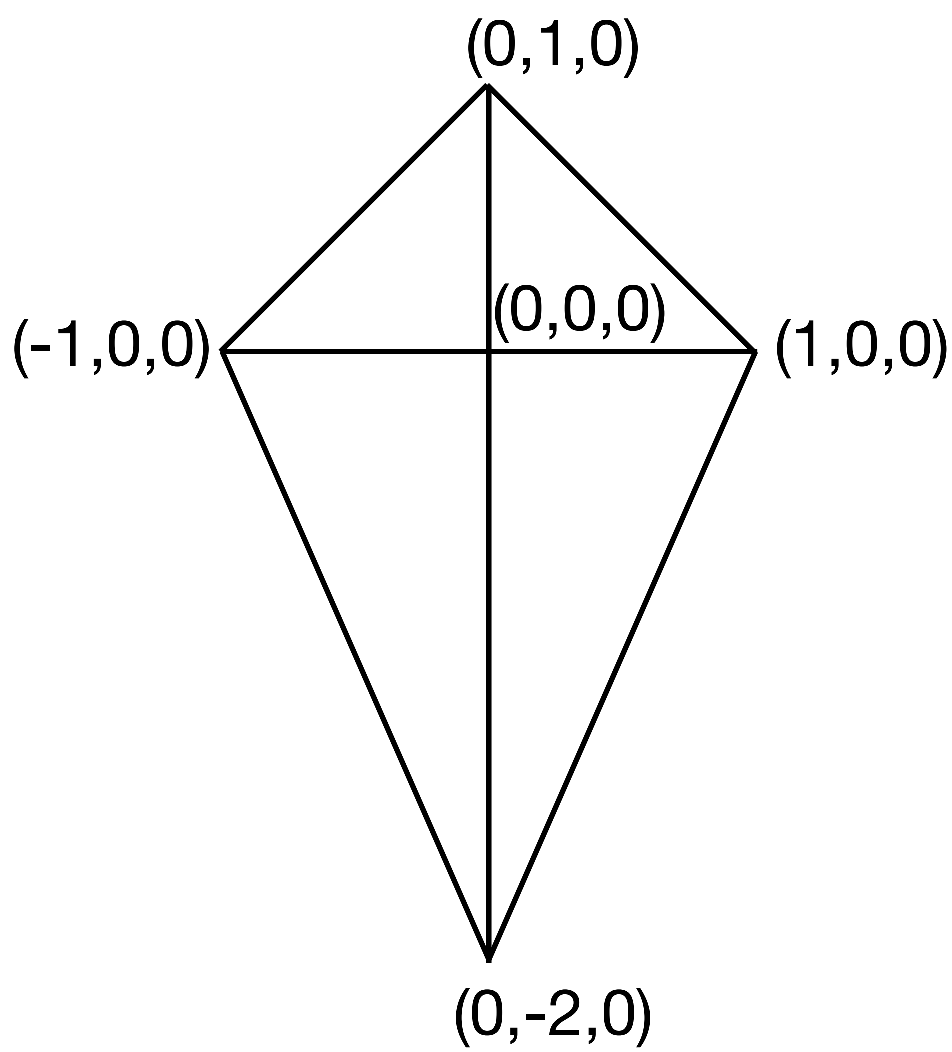
Indexed Triangle Set (A1)

- Vertices are listed once, without duplicates
- Each Triangle stores **indices** of its vertices





Problems: Kite Mesh



Represent this surface using:

1. Separate triangles.

2. Indexed triangle set.

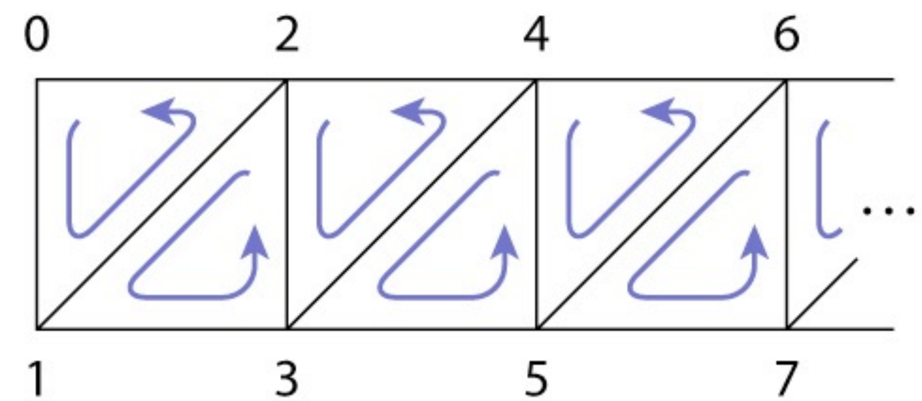
Note: all the triangles are facing towards you in the view shown.

Storage Cost?

- Always depends on the geometry, but for contiguous surface meshes, indexed triangle sets usually give large space savings.
  - Exercise: verify this on the tetrahedron example

Triangle Strips

- Takes advantage of mesh properties:
  - Each triangle is usually adjacent to previous
  - Next triangle reuses previous two vertices
  - Every subsequence of 3 vertices is a triangle



Vertex sequence

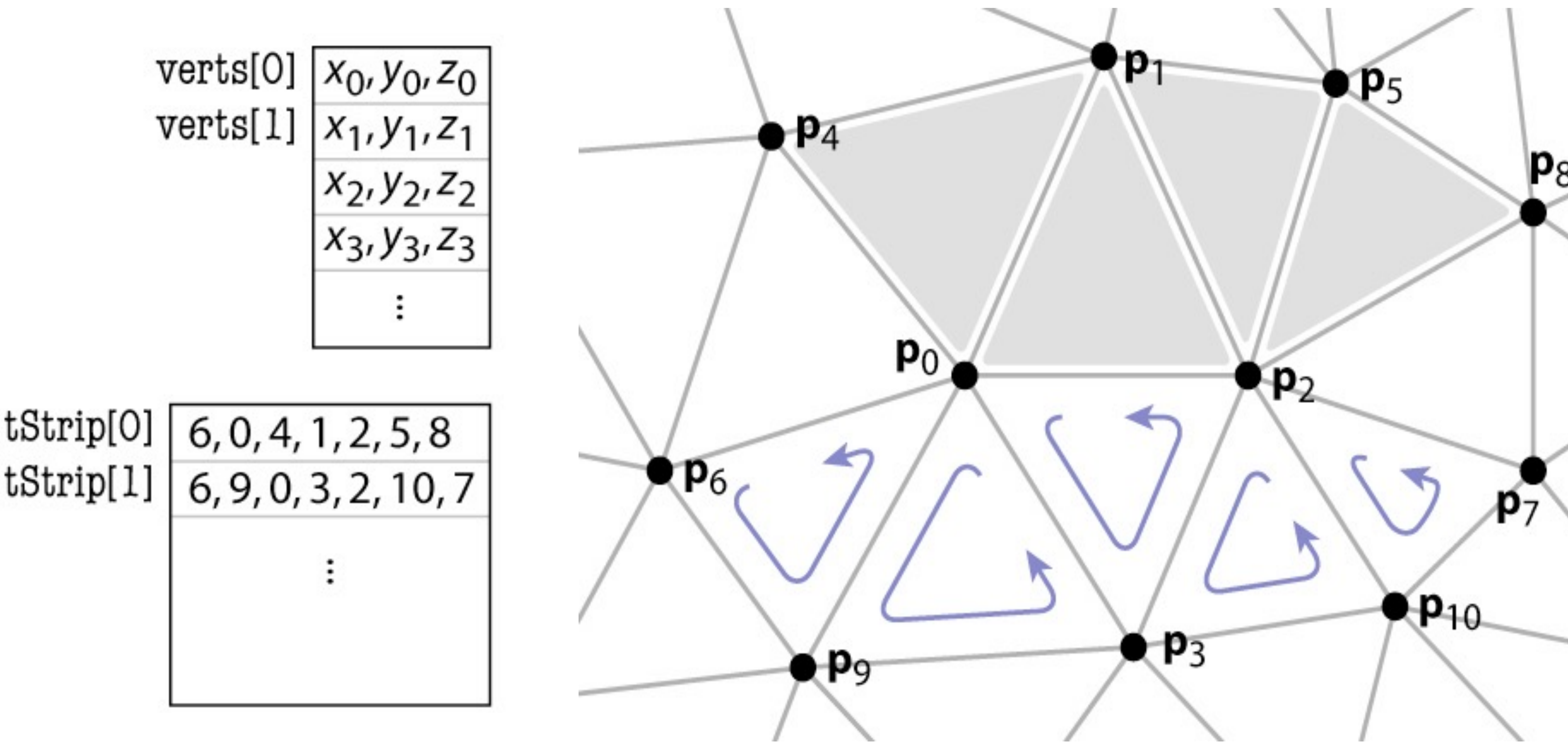
0, 1, 2, 3, 4, 5, 6, 7, …

leads to triangle sequence:

(0 1 2), (2 1 3), (2 3 4), (4 3 5), (4 5 6), (6 5 7), …

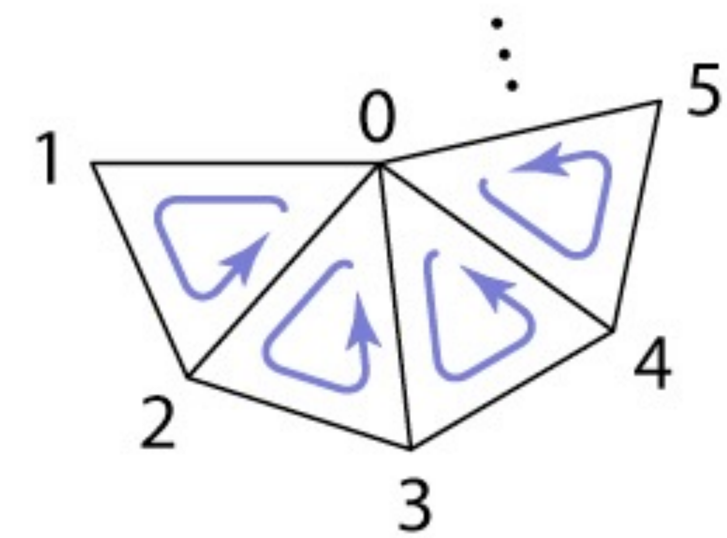
For long strips, about one index per triangle!

Triangle Strips



Triangle Fans

- Same idea as triangle strips, but keep oldest index rather than newest
  - Every sequence of three vertices is a triangle
  - Same benefits as triangle strips

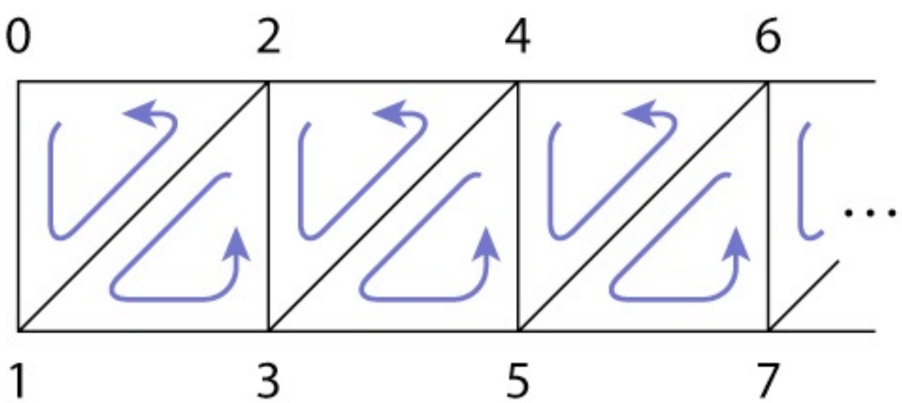


What else?

- Indexed triangle sets are good for rendering, but not great for mesh **processing**.
- What if we want to efficiently find:
  - all triangles containing a vertex?
  - all triangles adjacent to a triangle?
  - the triangle across a particular edge of a triangle?
- You can augment the mesh data structure to store more. See Section 12.1.4.

Problems 3-5

Triangle Strip:



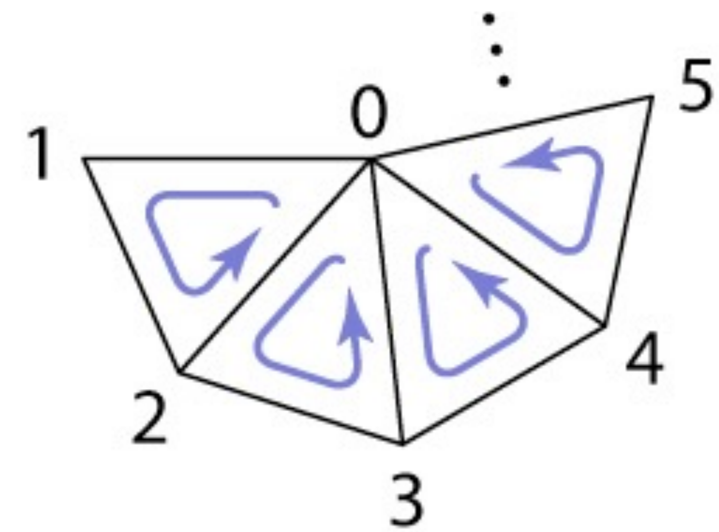
Vertex sequence

0, 1, 2, 3, 4, 5, 6, 7, …

leads to triangle sequence:

(0 1 2), (2 1 3), (2 3 4), (4 3 5), …

Triangle Fan:



Vertex sequence

0, 1, 2, 3, 4, 5, ...

leads to triangle sequence:

(0 1 2), (0 2 3), (0 3 4), (0 4 5), …