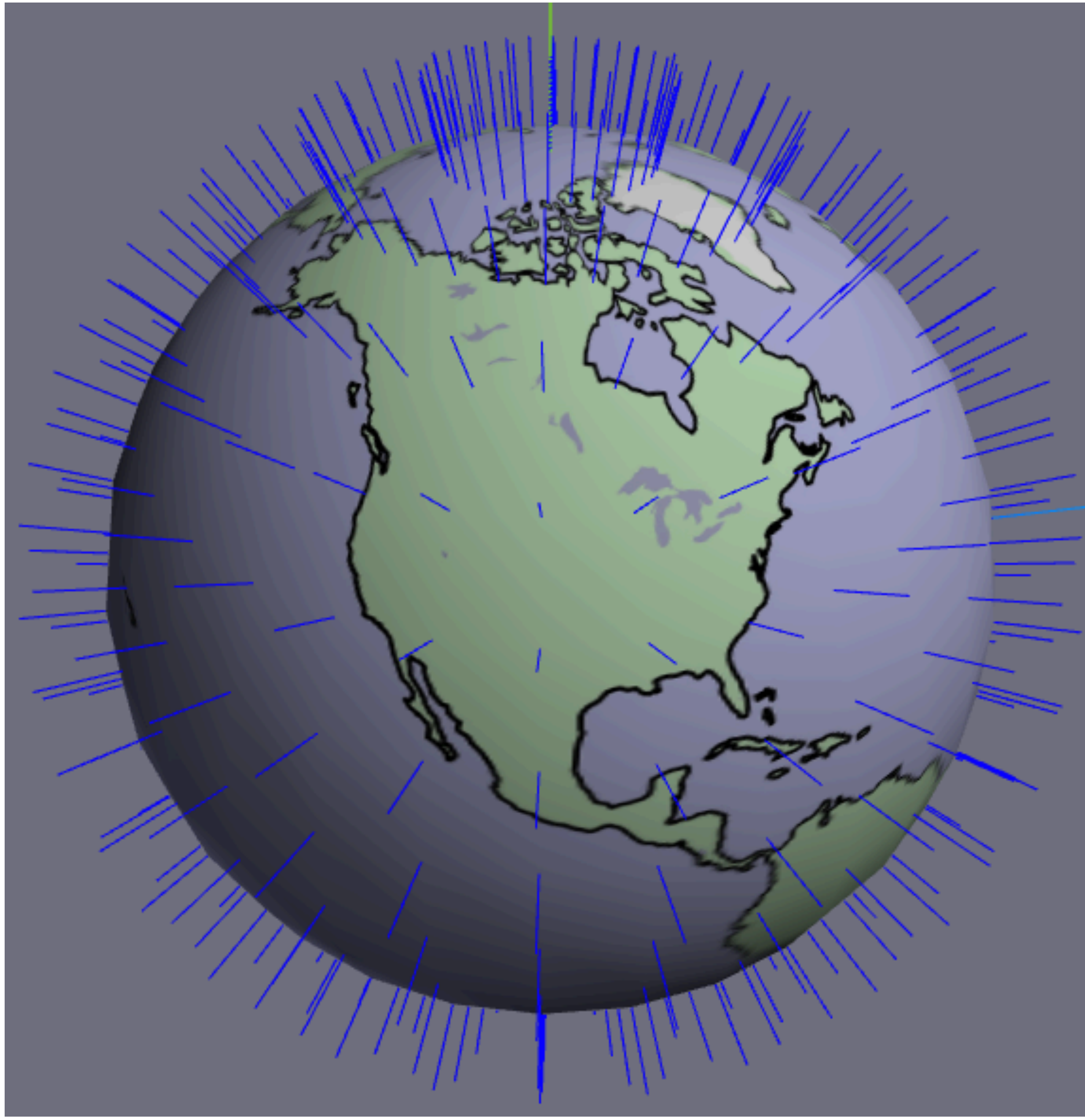
Computer Graphics



Lecture 3

Triangle Meshes:
Surface Normals

Announcements

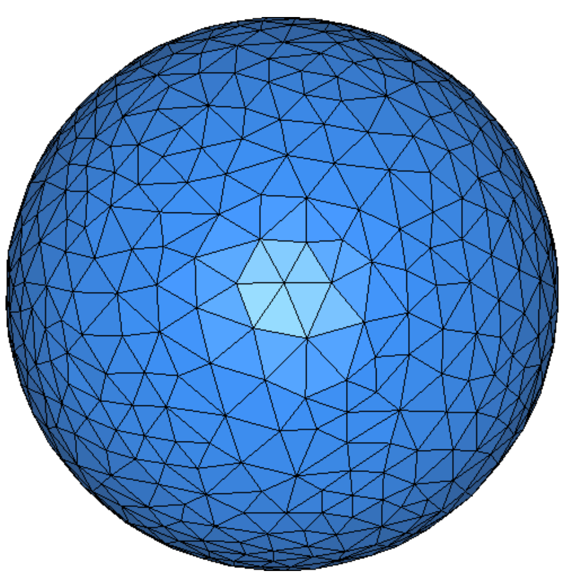
- A1 is out!
- Ask questions on Piazza!
- All necessary material covered by Monday's lecture, but you can get started on the geometry now.
- Today: vertex normals
- Monday: texture coordinates

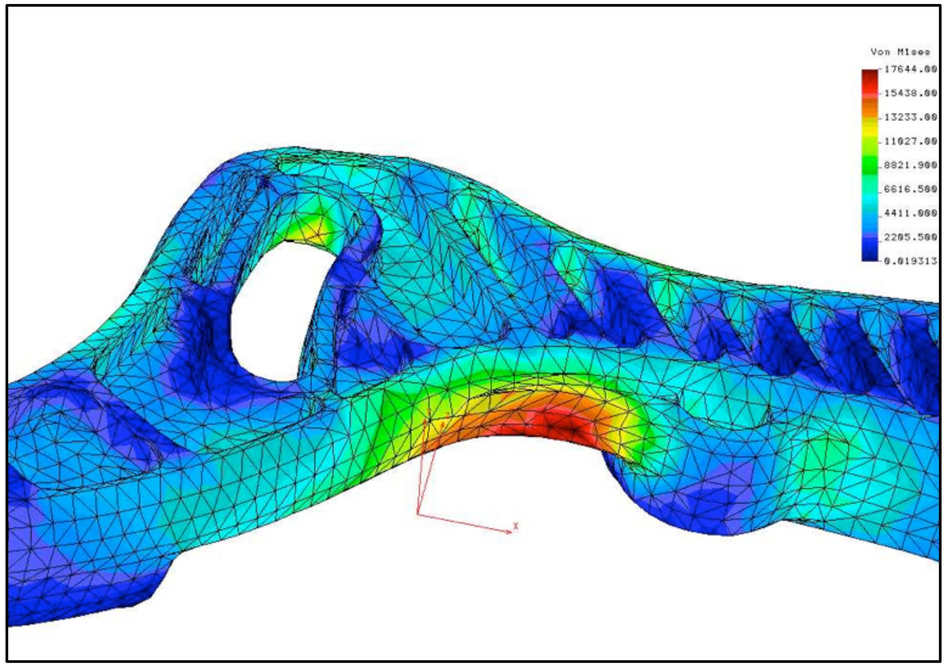
Where are we?

Pseudocode for 3D graphics:

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

Triangle meshes - one way to approximate arbitrary surfaces





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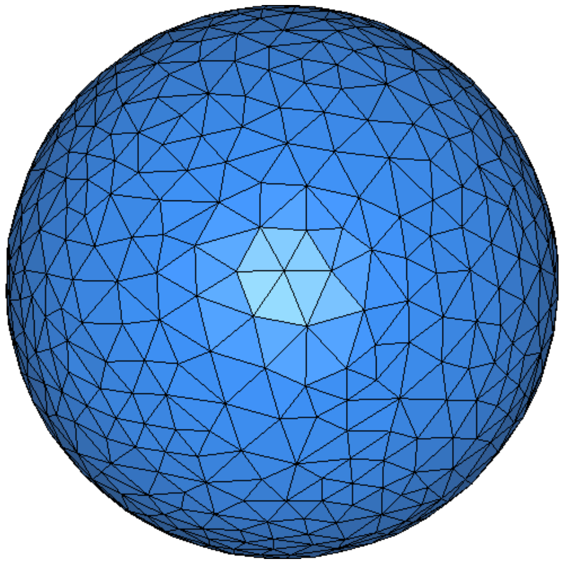
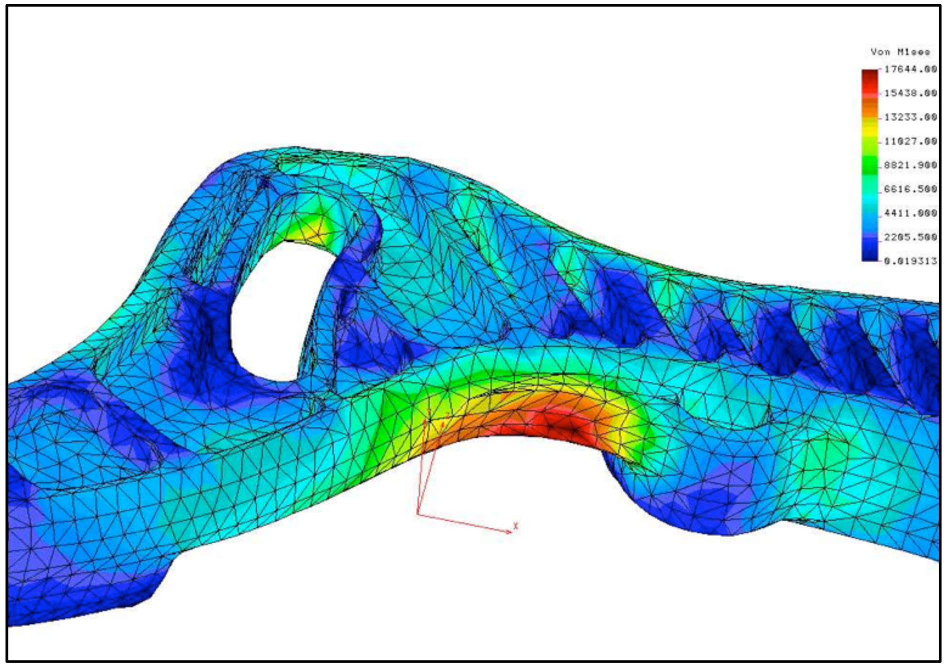
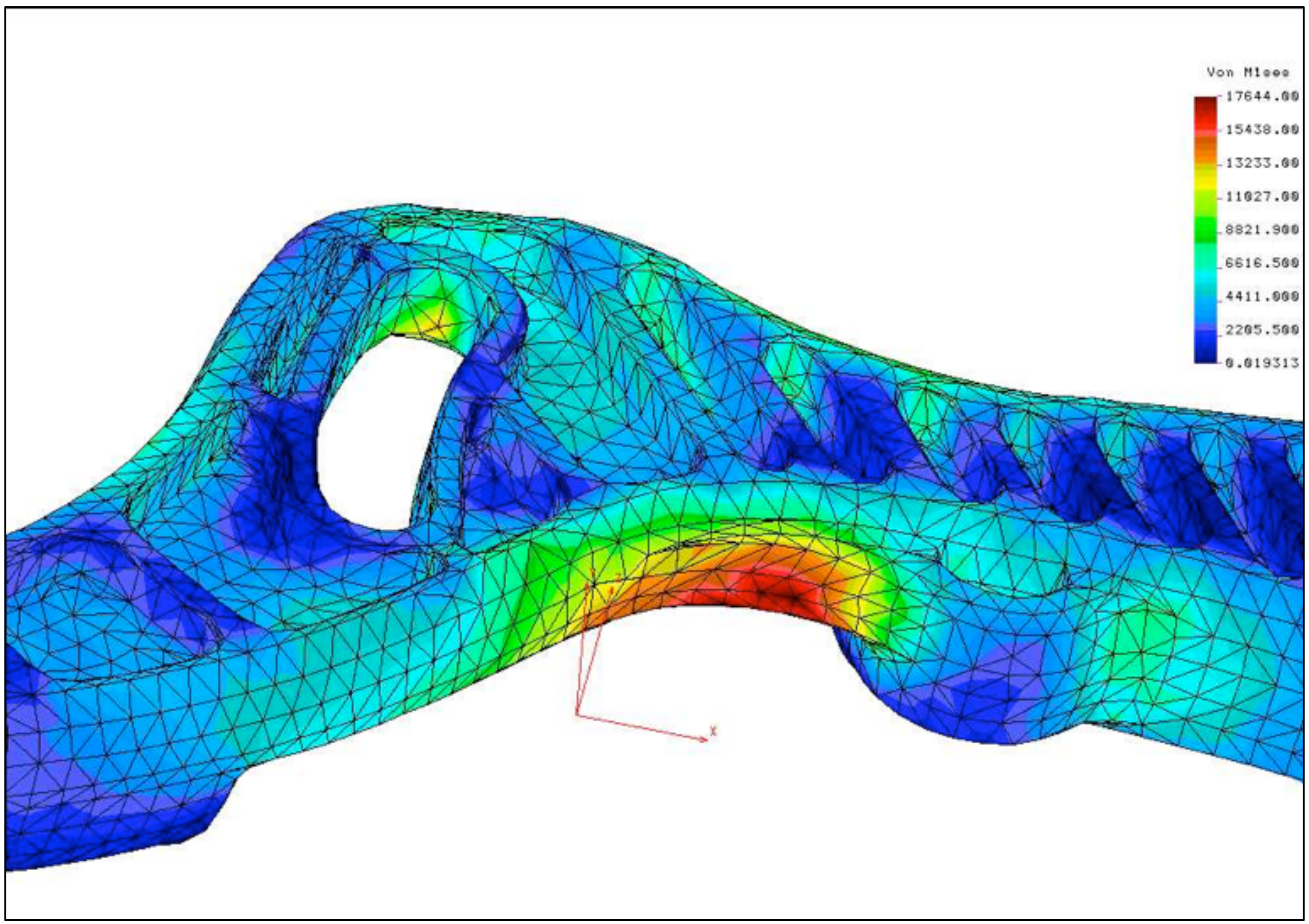




Data on Meshes

- Often we need more than just geometry.



Data on Meshes

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- Where do we store it - **Vertices**? Edges? **Faces**?
- Examples:
  - colors stored on face, for faceted objects
  - information about sharp creases stored at edges
  - anything that varies continuously is stored at vertices

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*when rendering, **interpolate** values in between*

Interpolation - Intuition

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- Fill in missing values between known values

Interpolation - Intuition

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- How? This is a question for rendering.
  We'll talk about the specifics later.

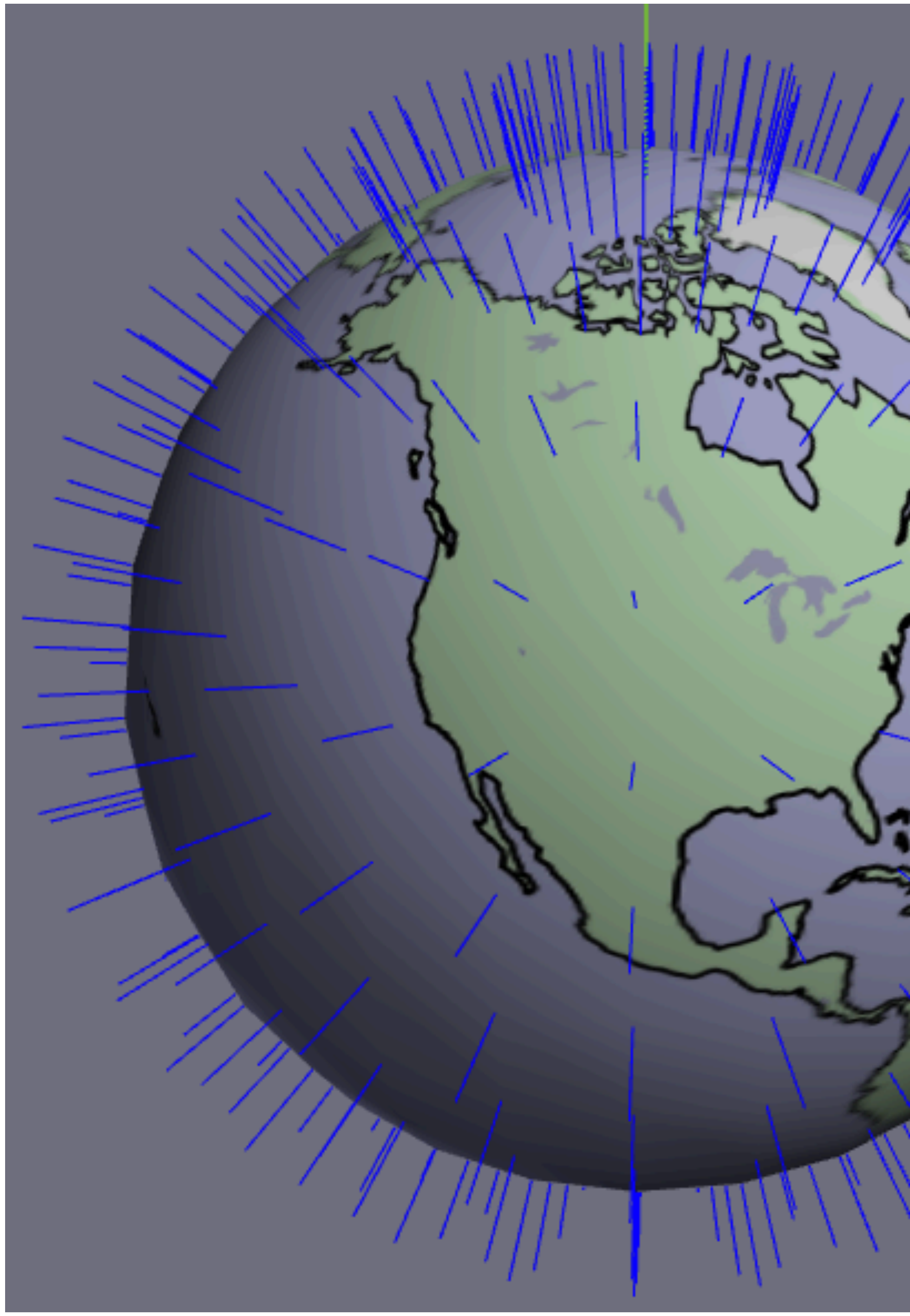
Data on Meshes

- What do we need to store at vertices?

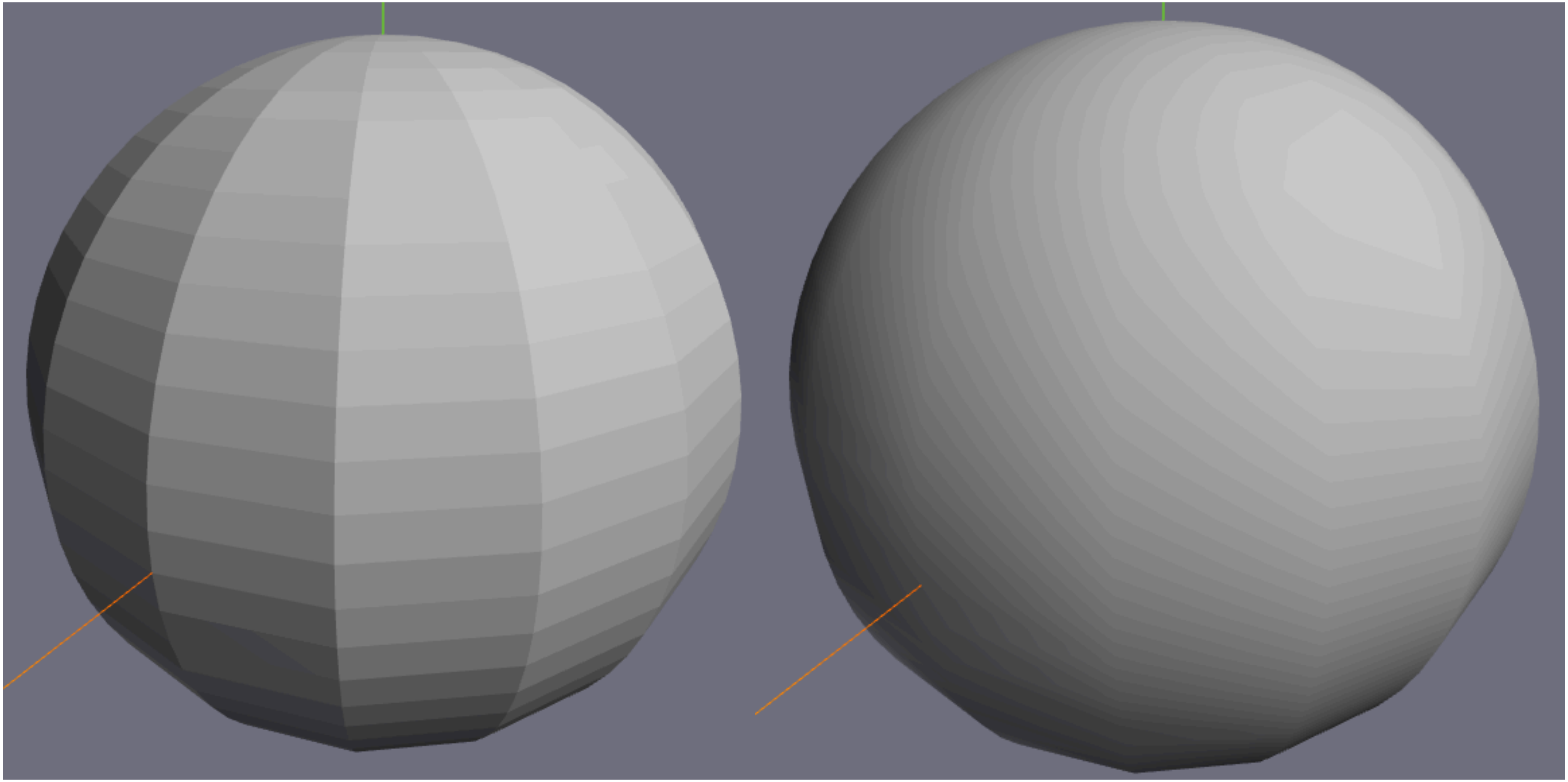
  - **Surface Normals**
    to more accurately portray geometry

  - **Texture Coordinates**
    to paste image data onto surfaces

  - **Positions!?** (last lecture)
    just another piece of per-vertex data!



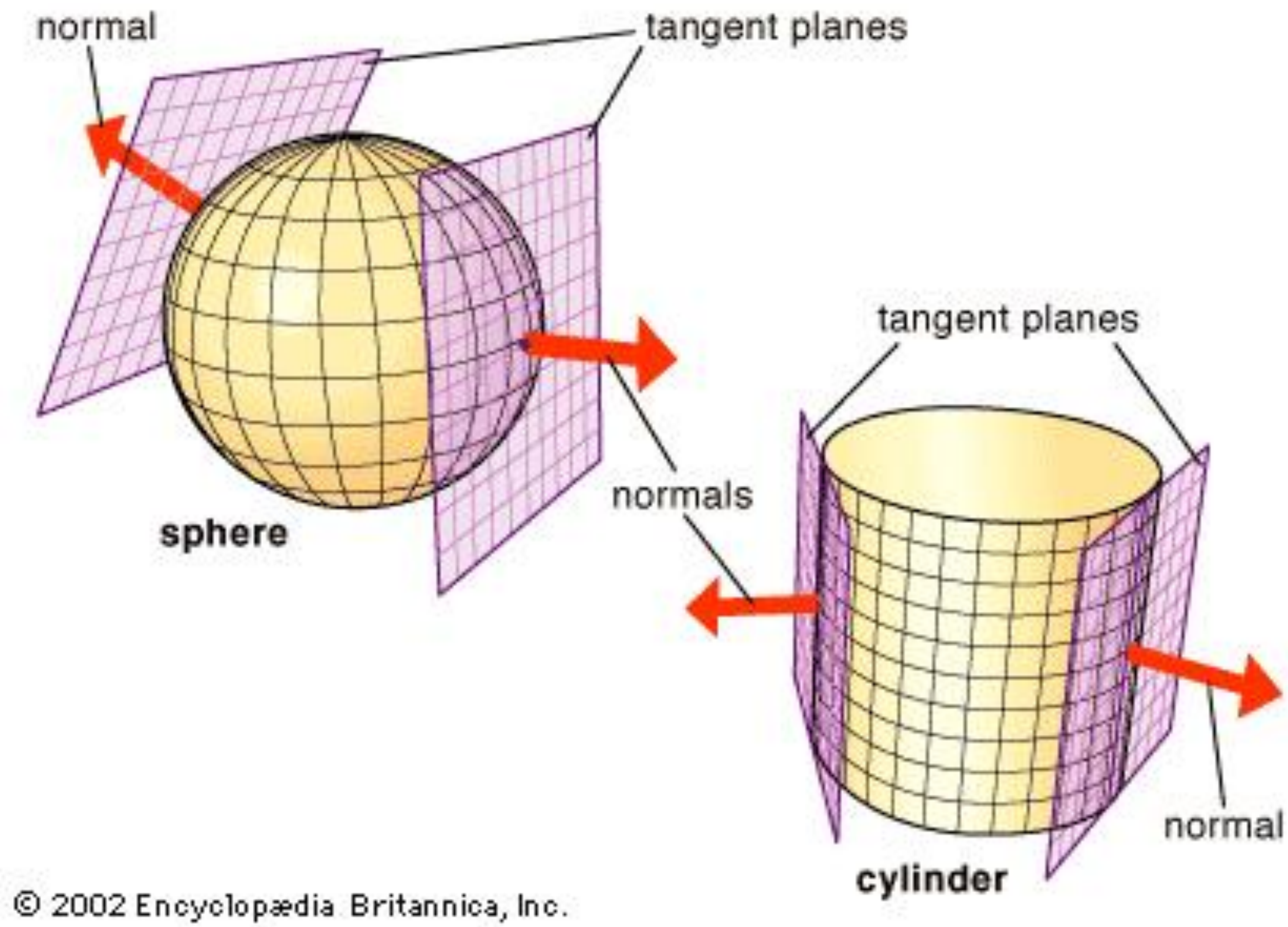
Surface Normals: Visual Intuition



https://facultyweb.cs.wwu.edu/~wehrwes/courses/csci480_20w/meshviewer/viewer.html

Surface Normals - Formally

- A point on a smooth surface has a **tangent plane**
- A **normal vector** is orthogonal to the surface (i.e., its tangent plane).



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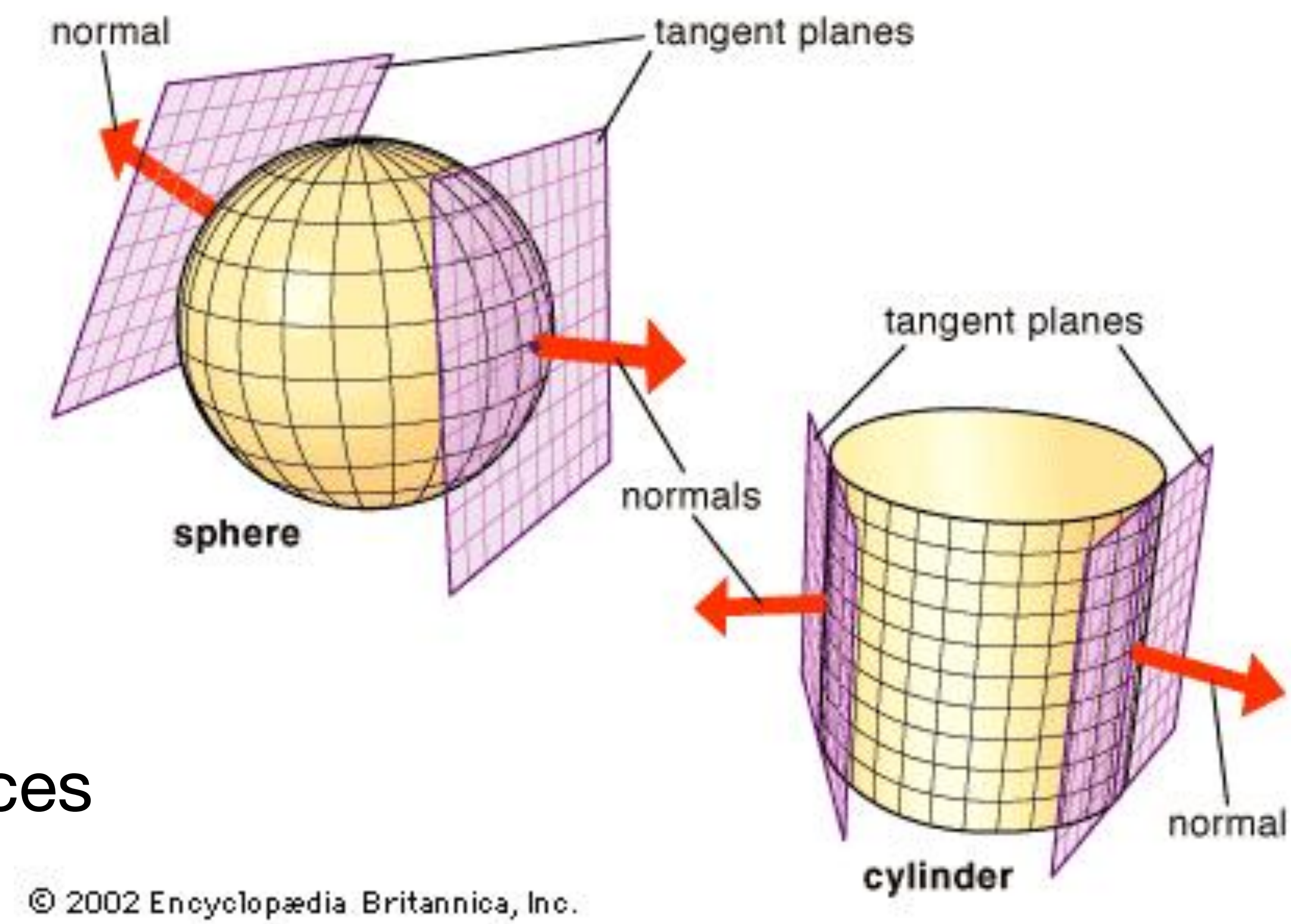

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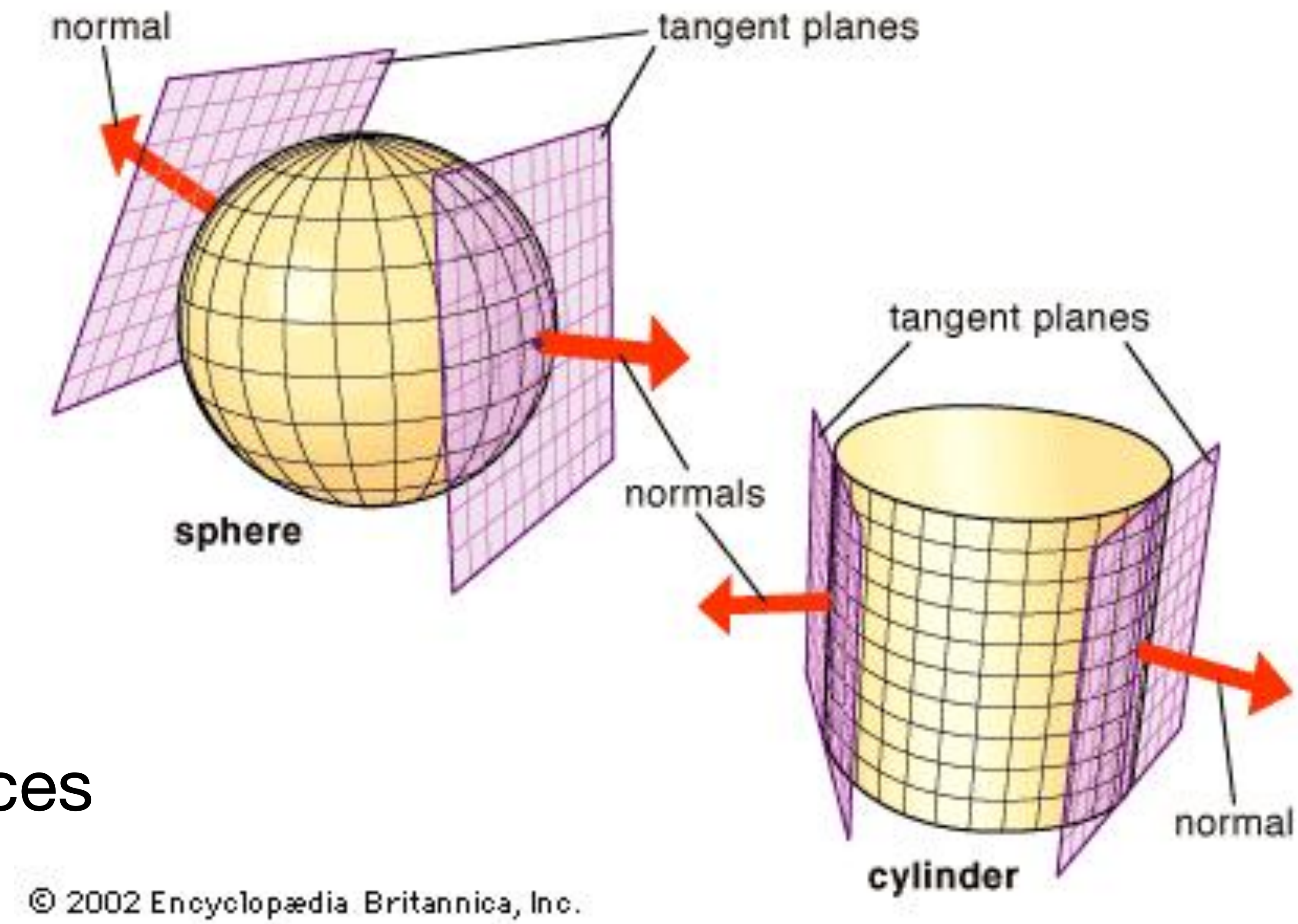

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By convention, normal vectors are (usually) **unit length**.

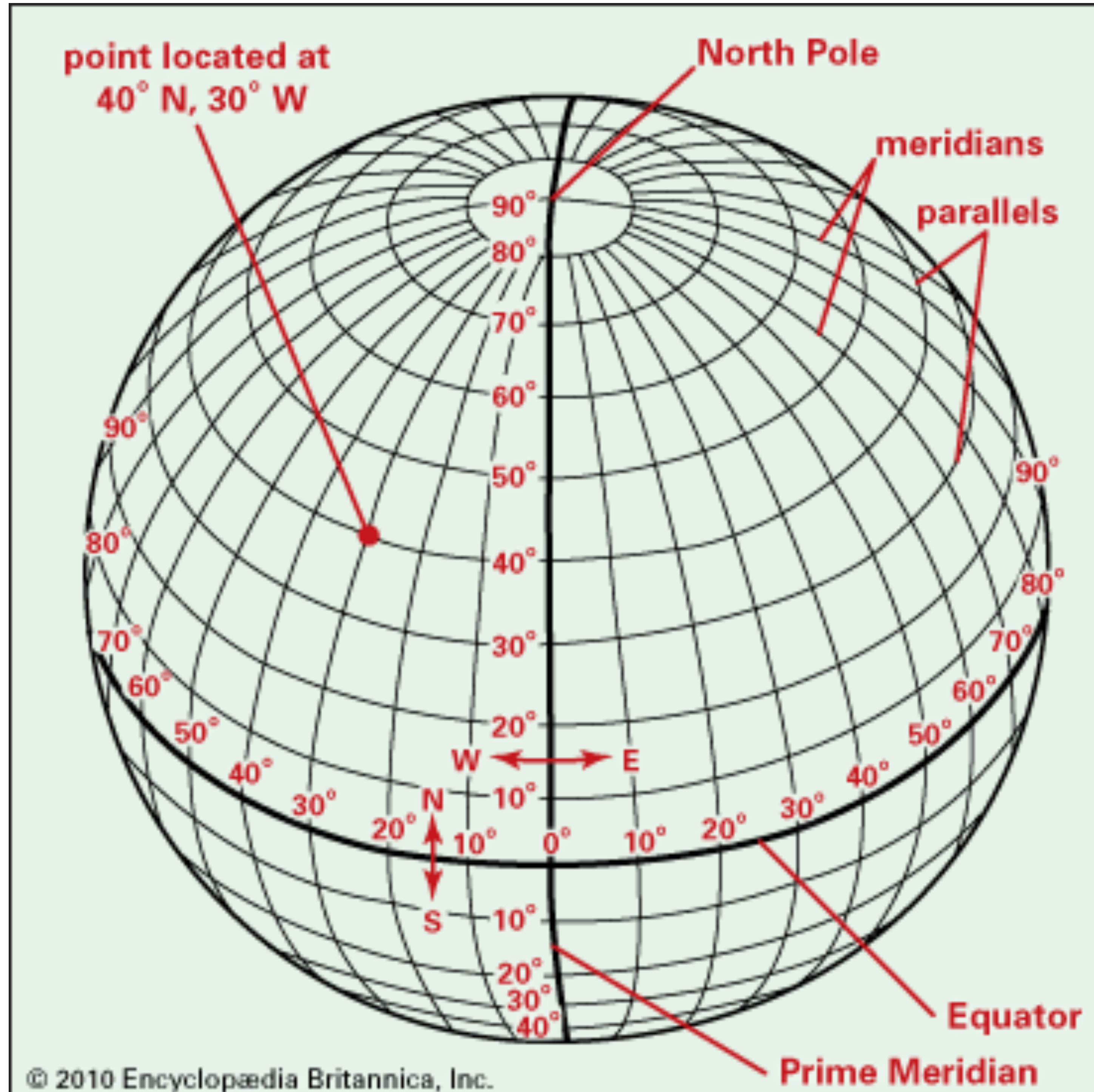
Parametric Surfaces

- How do we talk about points on a 2D surface in 3D space?
- Sometimes it's useful to have 2D coordinates for positions on the surface.
- This is called *parameterizing* the surface.
- Examples:
  - Cartesian coordinates on a rectangle
  - Cylindrical coordinates (θ, y) on a cylinder
  - Latitude and longitude on Earth's surface
  - Spherical coordinates (θ, ϕ) on a sphere

Example: Earth

Two coordinates (lat, lon) identify a position in 3D space.

This is possible because the earth is a 2D surface (manifold)



Example: Unit Sphere

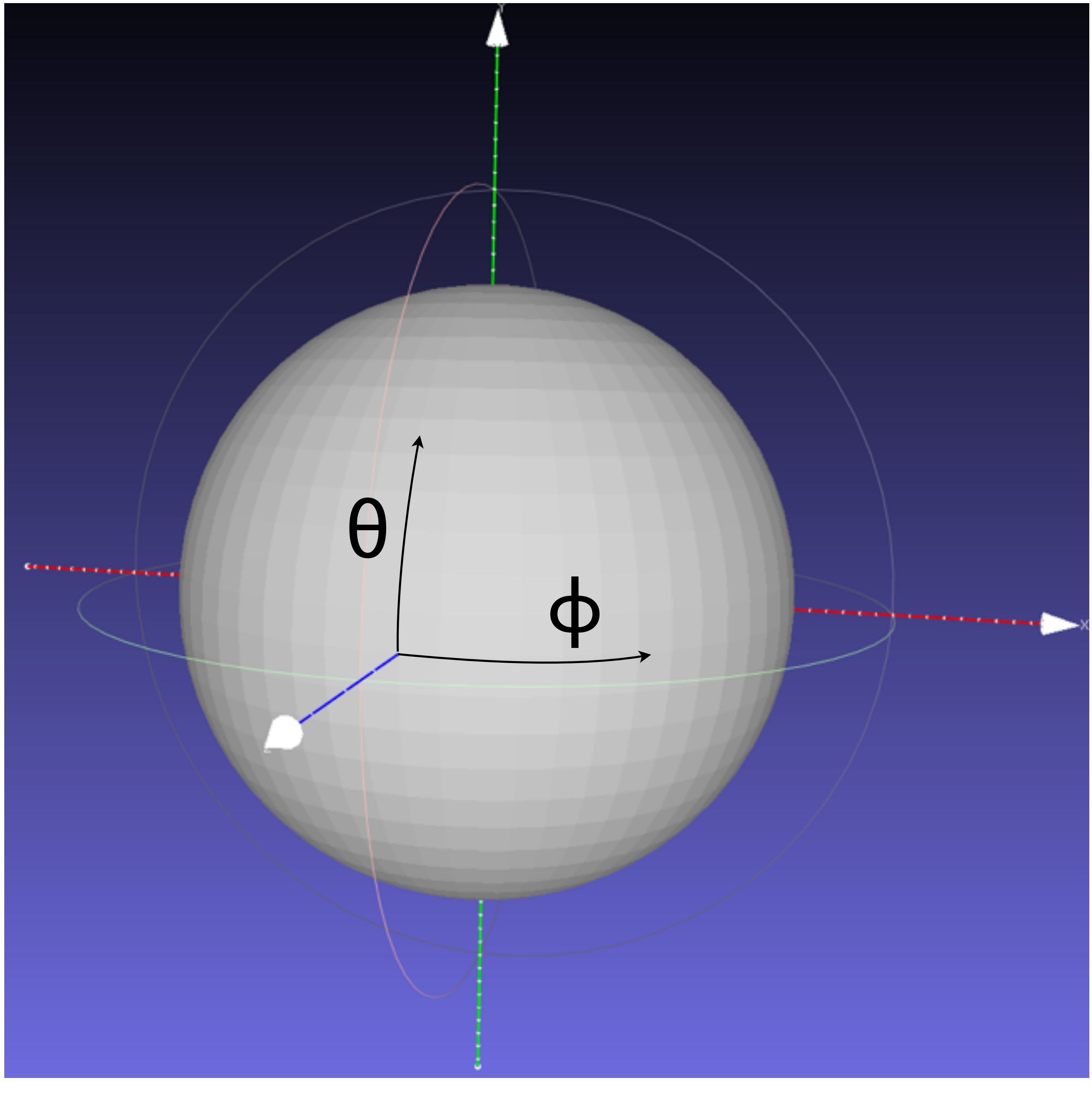
Position:

$$x = \cos\theta \sin\phi$$

$$y = \sin\theta$$

$$z = \cos\theta \cos\phi$$

What is the surface normal at (θ, ϕ)?



Example: Unit Sphere

Position:

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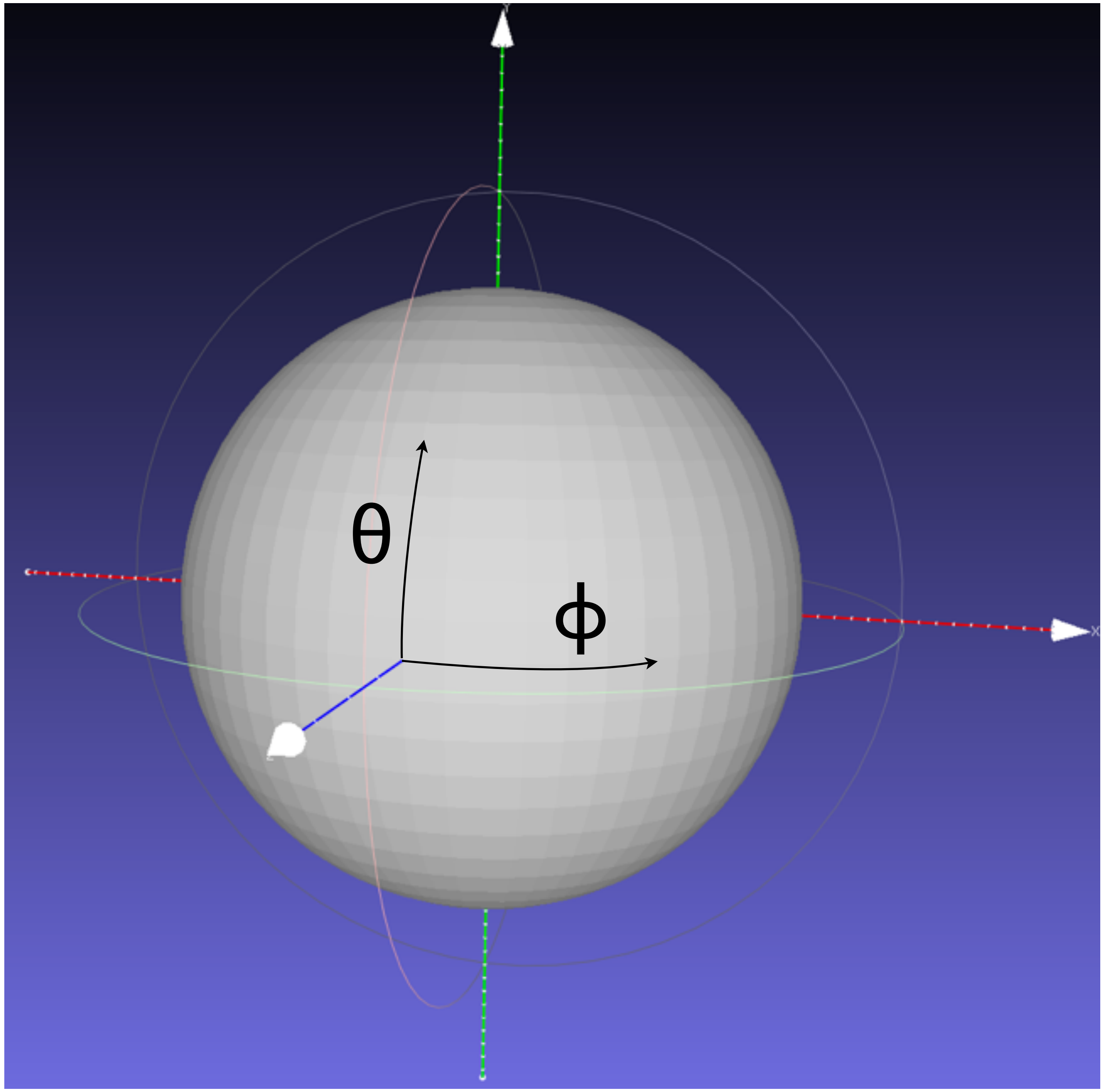
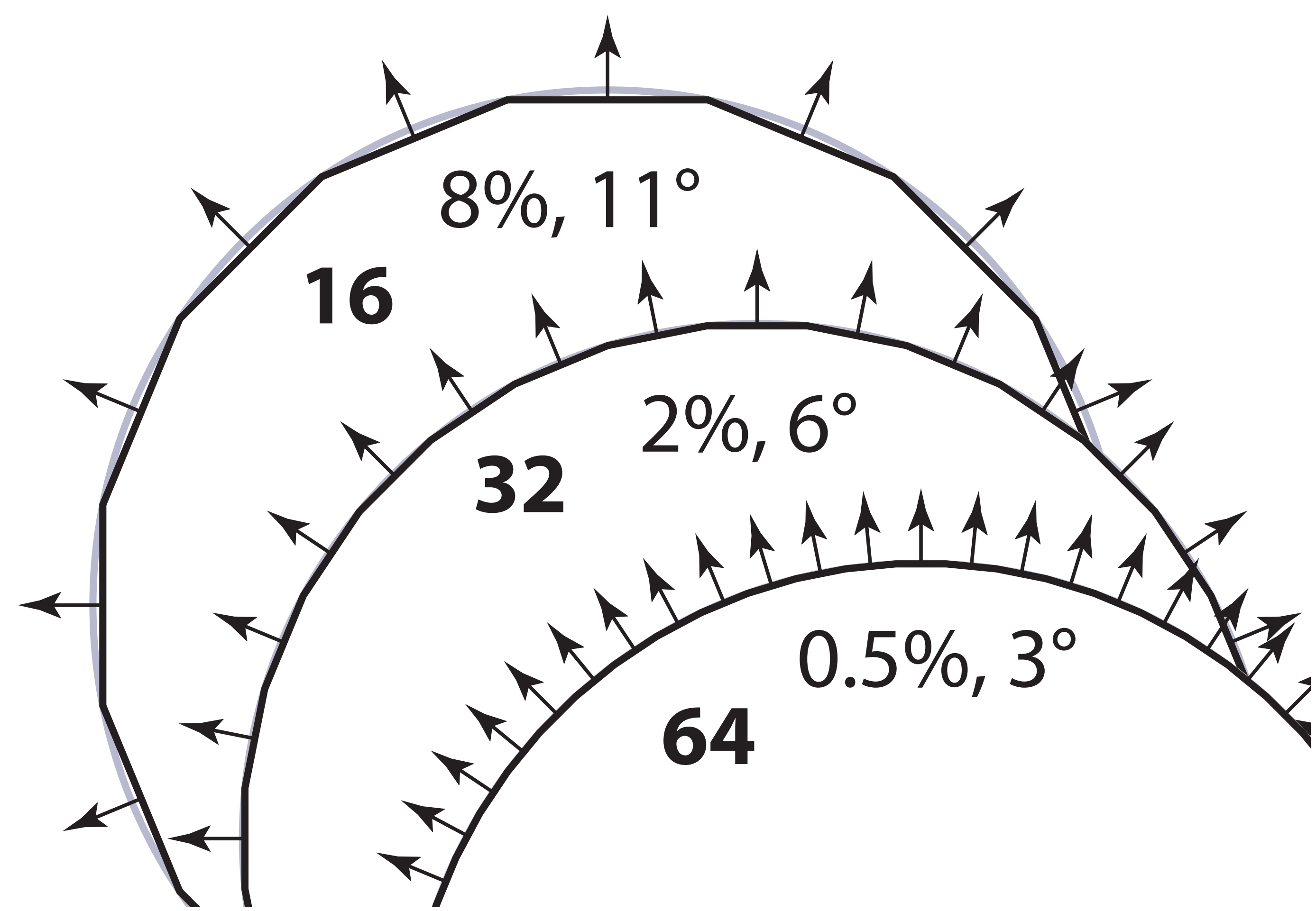
What is the surface normal at (θ, ϕ)?

Same as position!



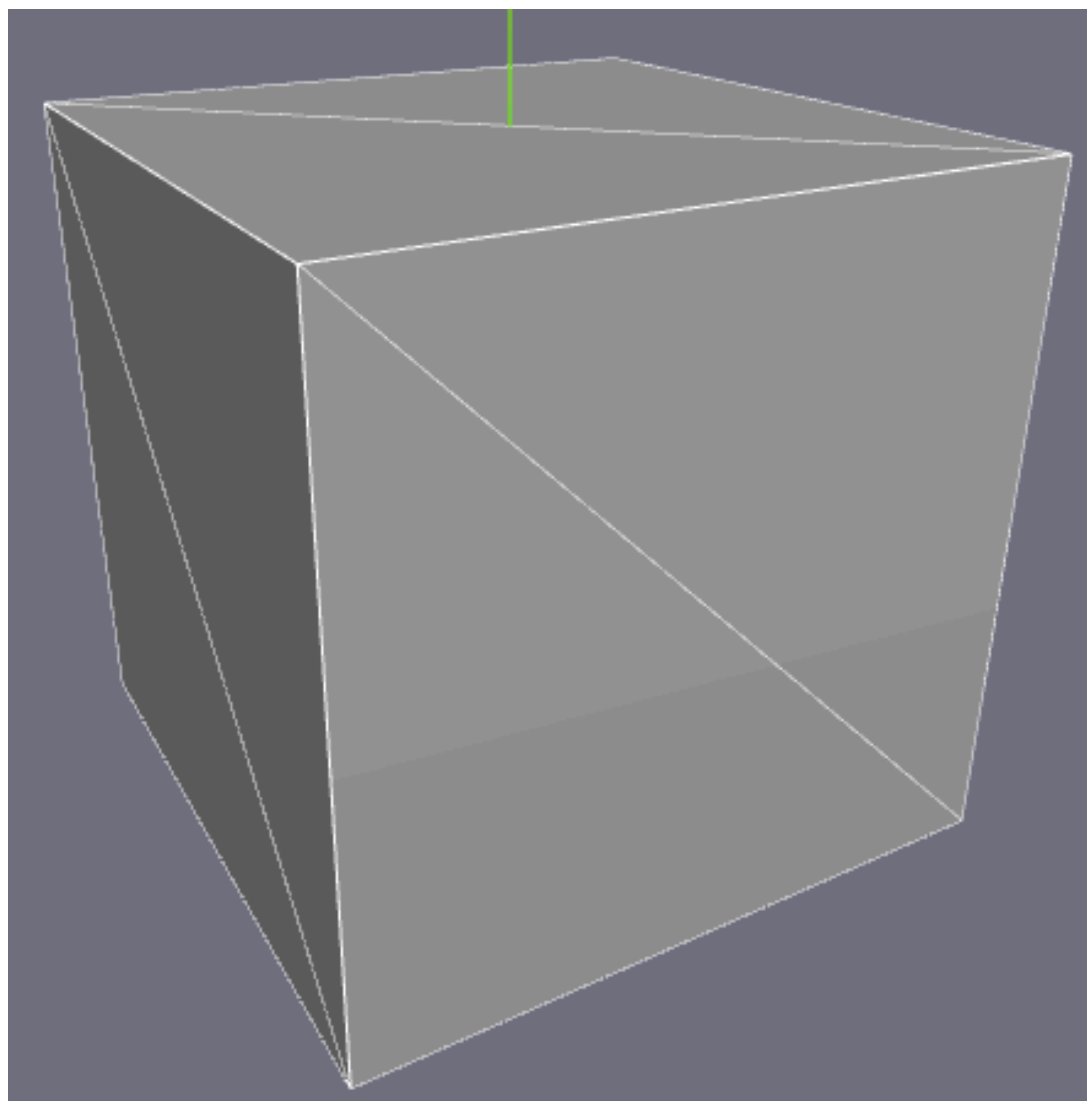
Why are normals important?

- Can't we just use more triangles?
- Error in surface normal shrinks slower than geometry
- Intuition - circle:



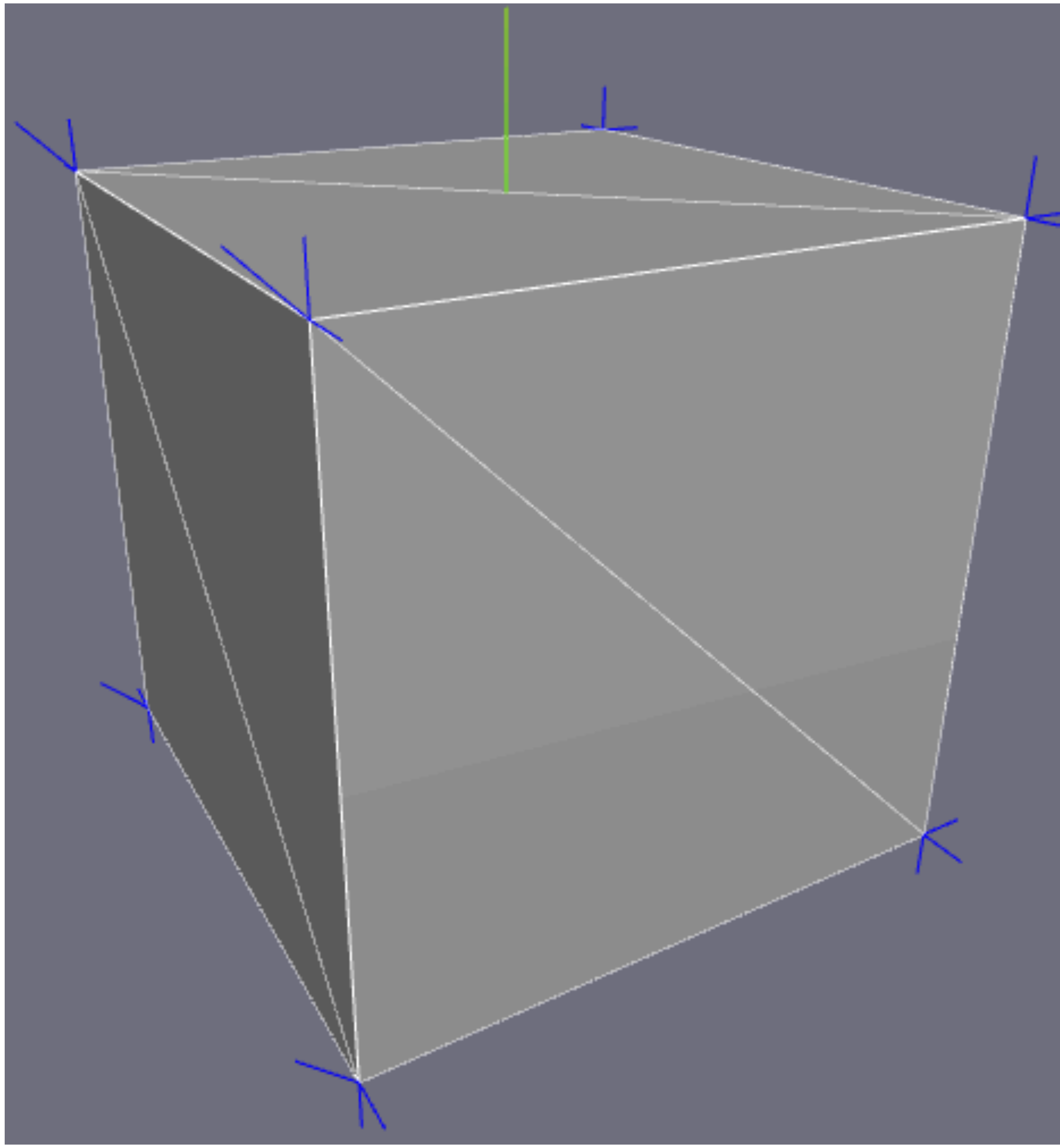
Normals at Discontinuities

- What is the vertex normal at the corner of a cube?



Normals at Discontinuities

- Vertex normal is not **unique**
- Depends which triangle!
- Idea: just like positions:
  - store normals in a list
  - each corner of a triangle has a position index and a normal index



Exercise

- Add normals to our pyramid mesh
  - List out all unique normals
  - Add a normal index to each triangle face corner