CS 563 Advanced Topics in Computer Graphics
Triangular Meshes

by Scott Ingram

Rendering Goals

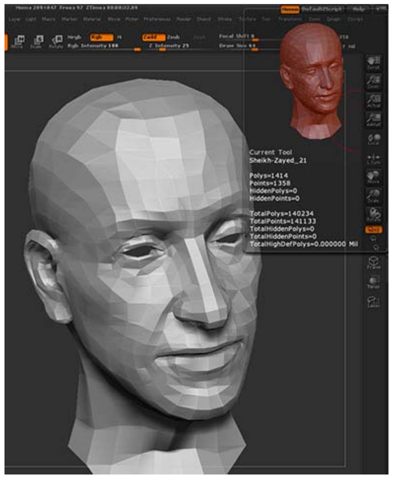
- Ultimate goal is to achieve photo realism when rendering objects
  - May be painful to build an model by using primitive shapes: spheres, planes, cones, torii, etc.
  - One solution… compose the model using a number of tessellated 2d shapes.

Triangular Meshes

- The 2D tessellated shapes most commonly used are triangles.
  - Advantages
    - Artist/Programmer tools for creating editing models
    - Simplifies math, allows for faster rendering
    - Hardware support for triangle mesh processing
  - Mesh Sources
    - Artist/Programmer created
    - Physically 'sourced'
      - Derived from laser scans
      - Derived from image scans
      - Derived Mechanically

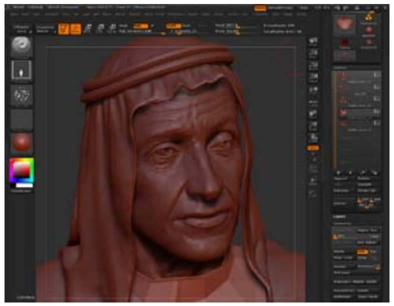
Mesh Sources

- Artist Derived: Artists uses Maya/Zbrush package to model real or imaginary object. Exports design to .ply file (or some other format) for use in a renderer



```
Current Tool
Sheikh-Zayed_21

Polys=1414
Points=1358
HiddenPolys=0
HiddenPoints=0

TotalPolys=140234
TotalPoints=141133
TotalHiddenPolys=0
TotalHiddenPoints=0
TotalHighDefPolys=0.000000 Mil
```

$\Rightarrow$

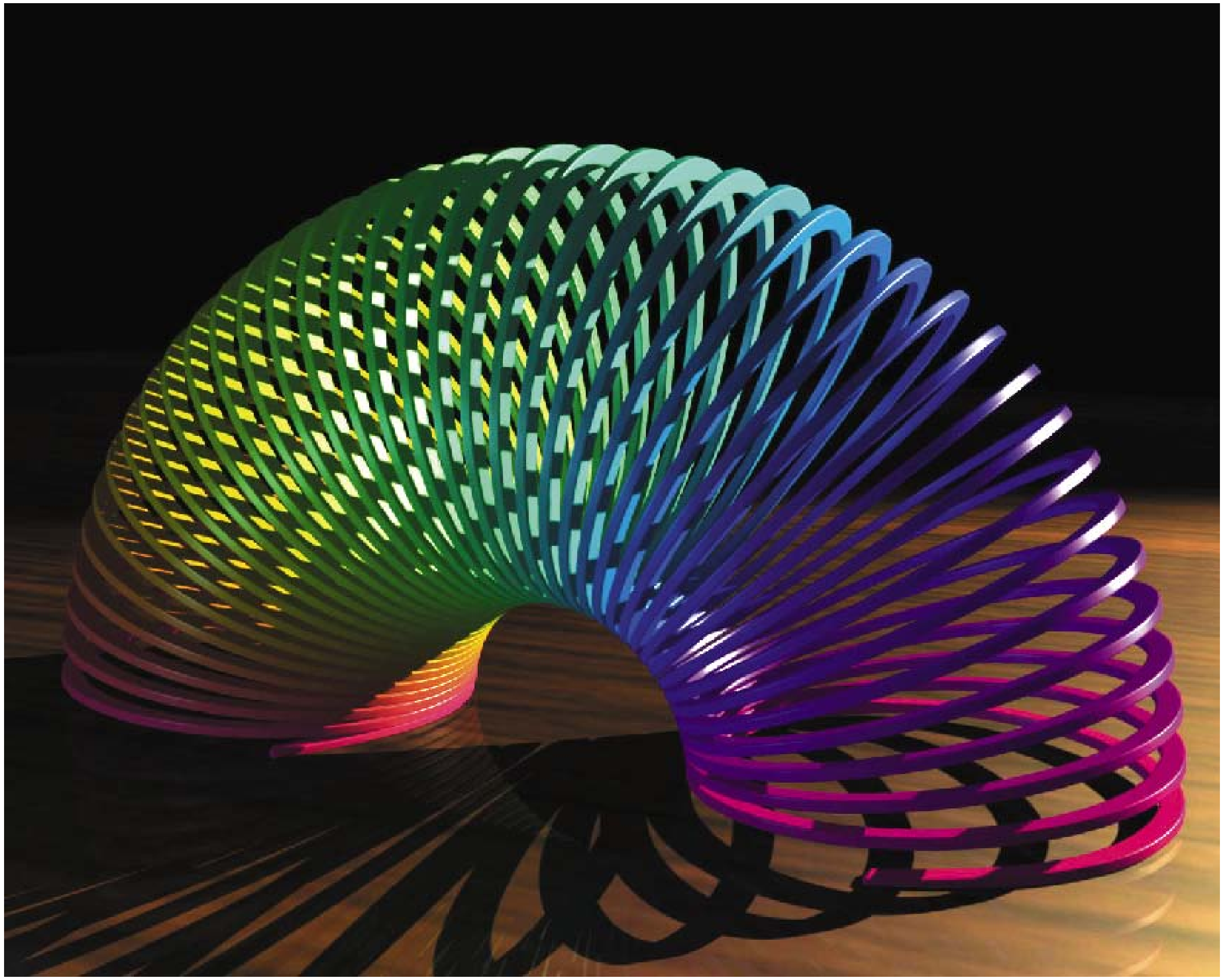


$\Rightarrow$

http://www.3dm3.com/visits/1096

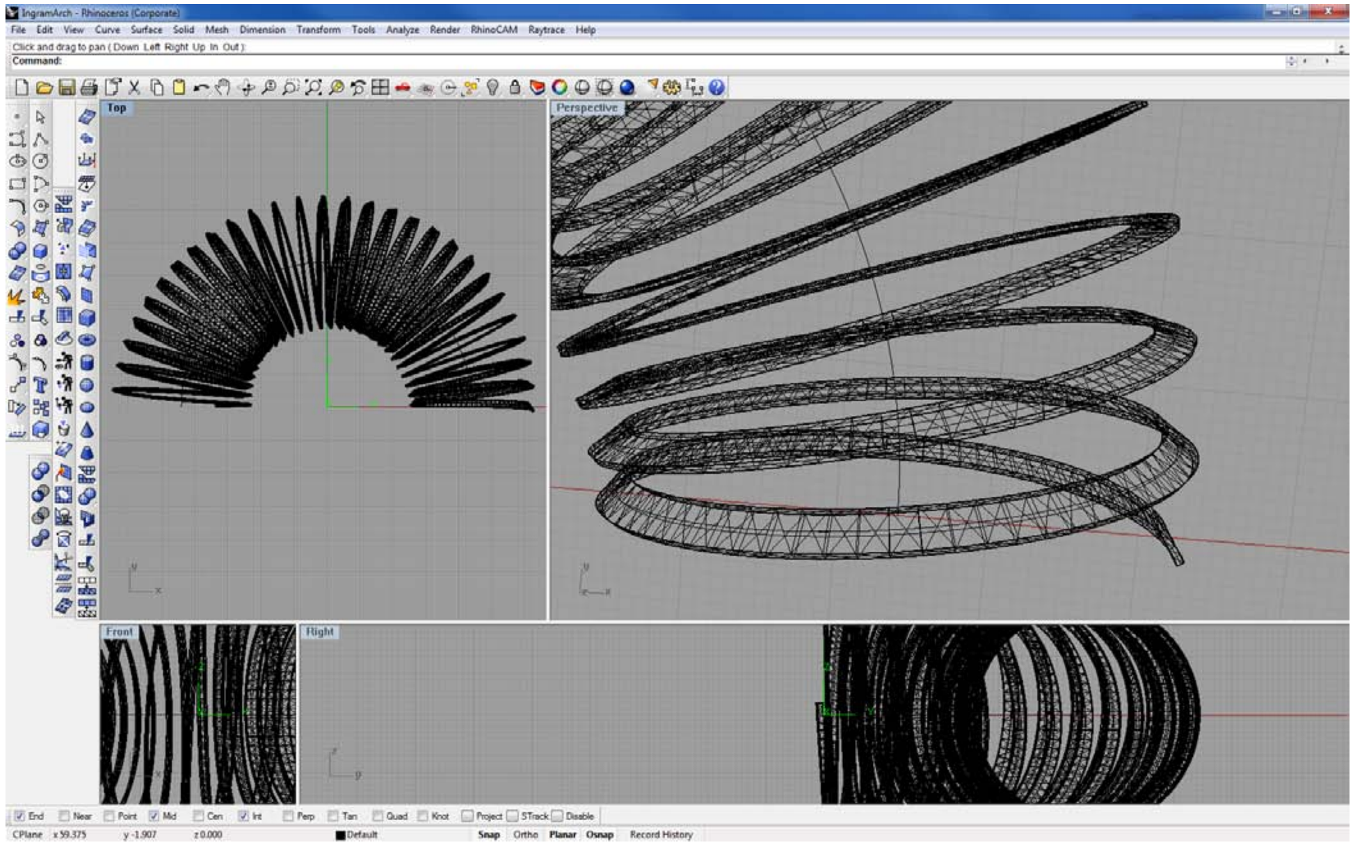
Mesh Sources

- Rainbow Arch by Steve Agland (p304, Figure16.11)



Mesh Sources

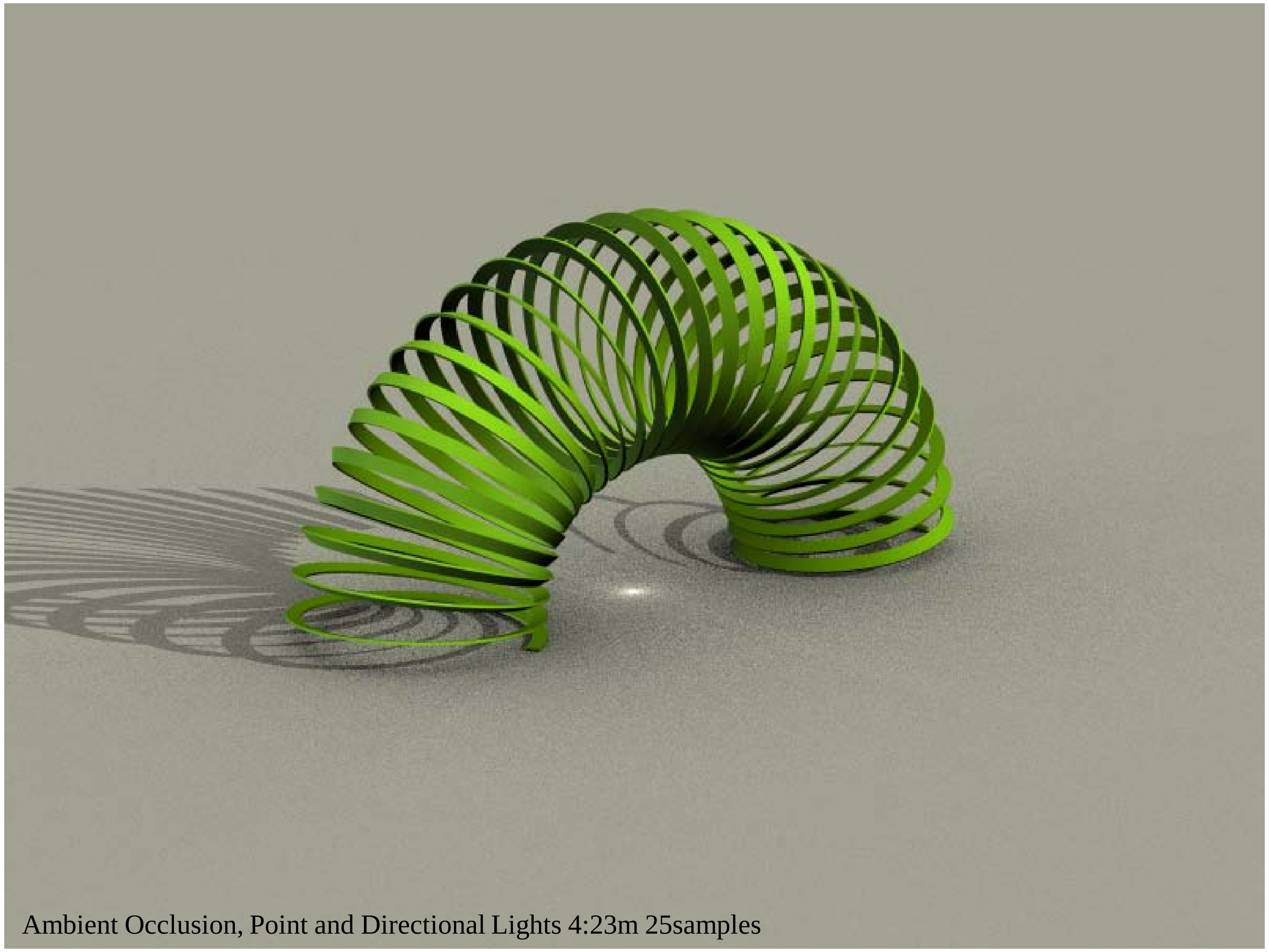
- Reproduction of Arch
  - Create arch line
  - Create Helix along arch line
  - Create sweep cross section
  - Sweep cross section along Helix path
  - Convert to Tri - Mesh, Export to .ply file (element vertex 81940)


IngramArch - Rhinoceros (Corporate)
File Edit View Curve Surface Solid Mesh Dimension Transform Tools Analyze Render RhinoCAM Raytrace Help
Top
Perspective
Front
Right
End Near Point Mid Cen Int Perp Tan Quad Knot Project STrack Disable
CPlane x 59.375 y -1.907 z 0.000 Default Snap Ortho Planar Osnap Record History

```
Click and drag to pan ( Down Left Right Up In Out ):
Command:
```

Mesh Sources

- Crude Reproduction


Ambient Occlusion, Point and Directional Lights 4:23m 25samples

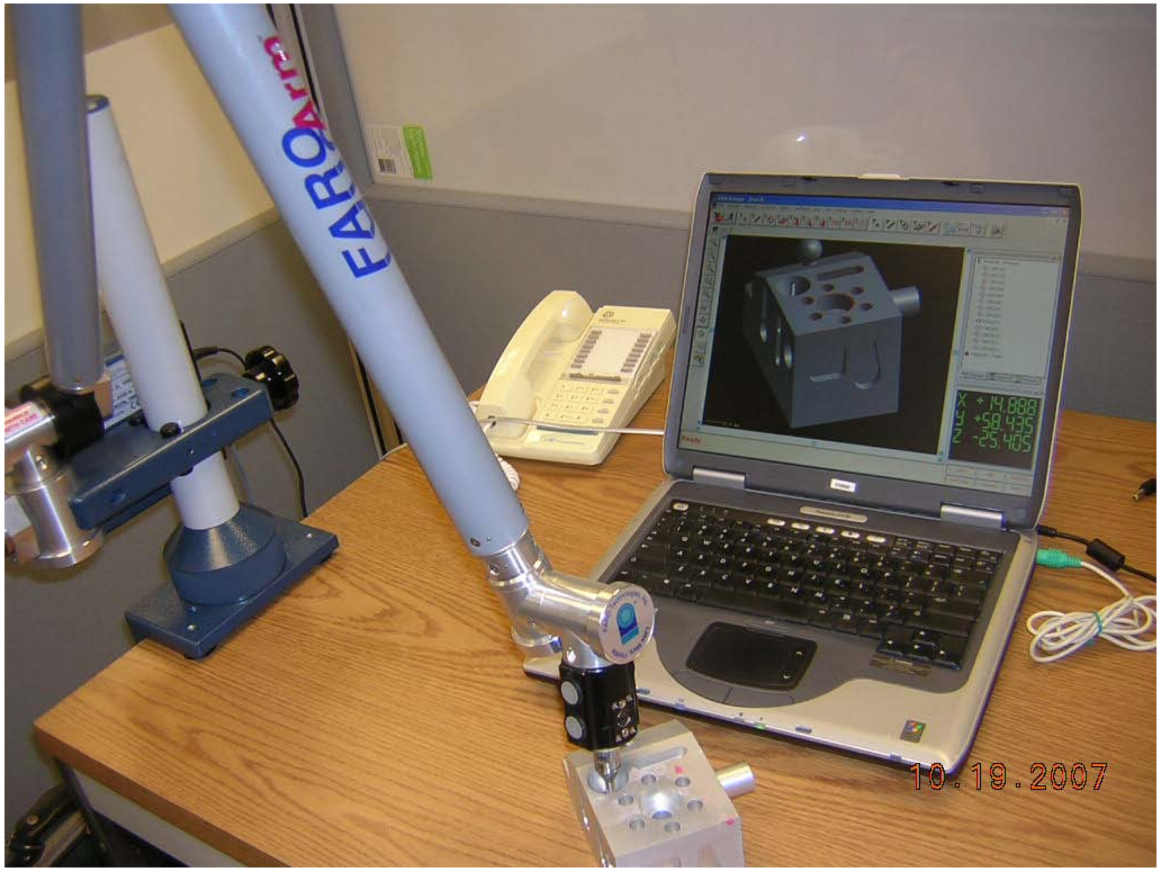
Mesh Sources

- Laser Scanned: hand held, or mounted

http://www.zcorp.com/en/Products/3D-Scanners/spage.aspx

Mesh Sources

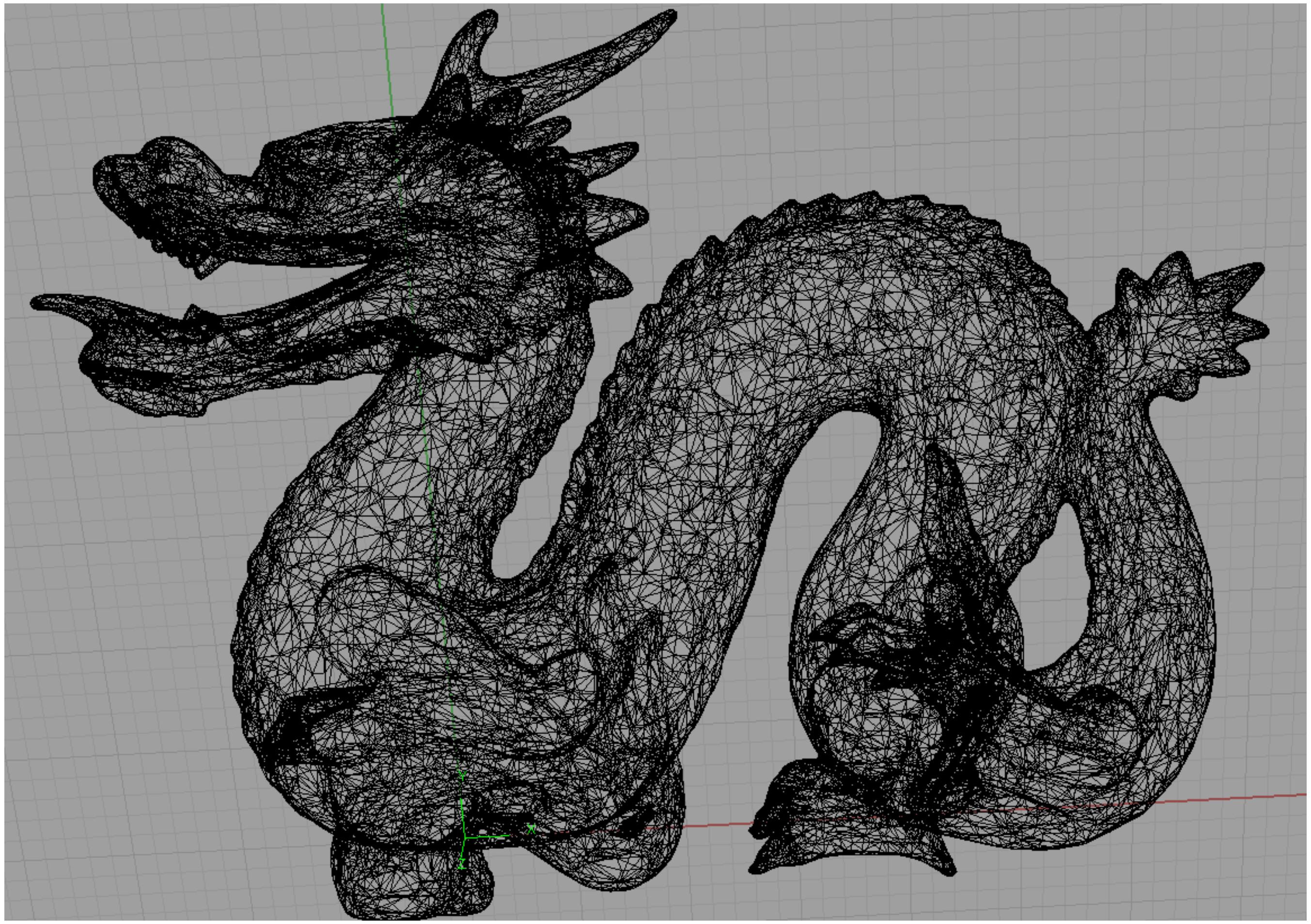
- Mechanical: User directs an articulated arm to record points of interest: http://www.faro.com/FaroArm/Home.htm



http://www.iqcmm.com/manager/FaroArm.JPG

Triangular Meshes

- Increase # of triangles…. increase the realism of the model

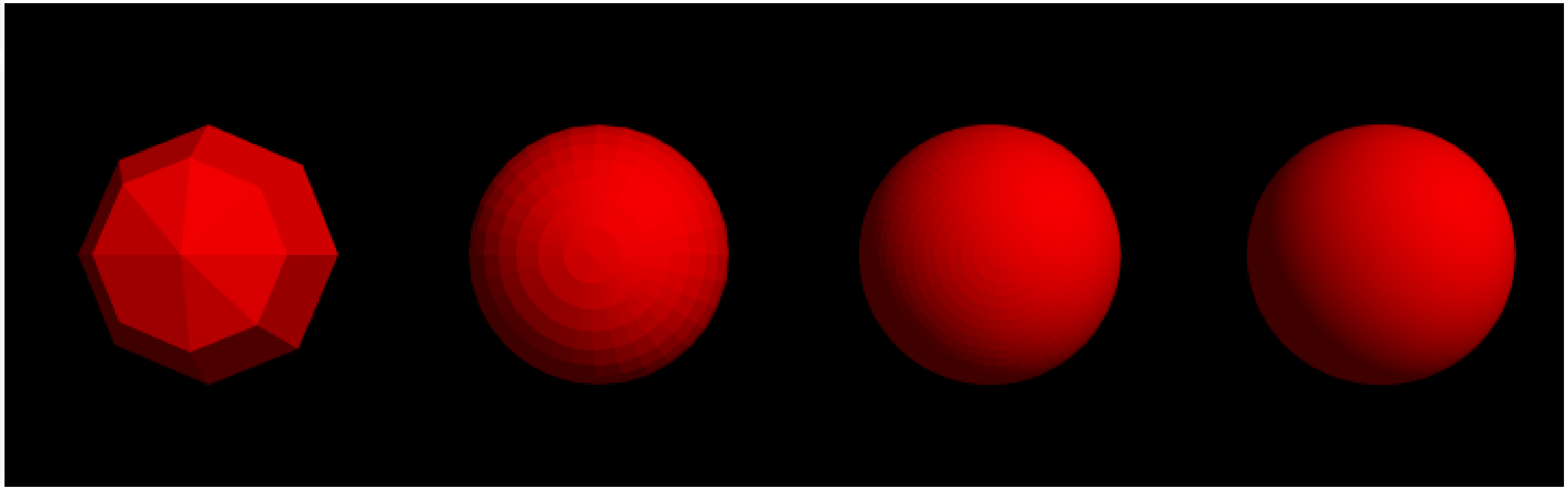


Tessellation

- Tessellation (a.k.a tiling)
  - Repetition of a shape
  - No overlaps , no gaps
  - Also know as tiling
  - In 2D....

Tessellating a Sphere

- Example: Sphere Tessellation

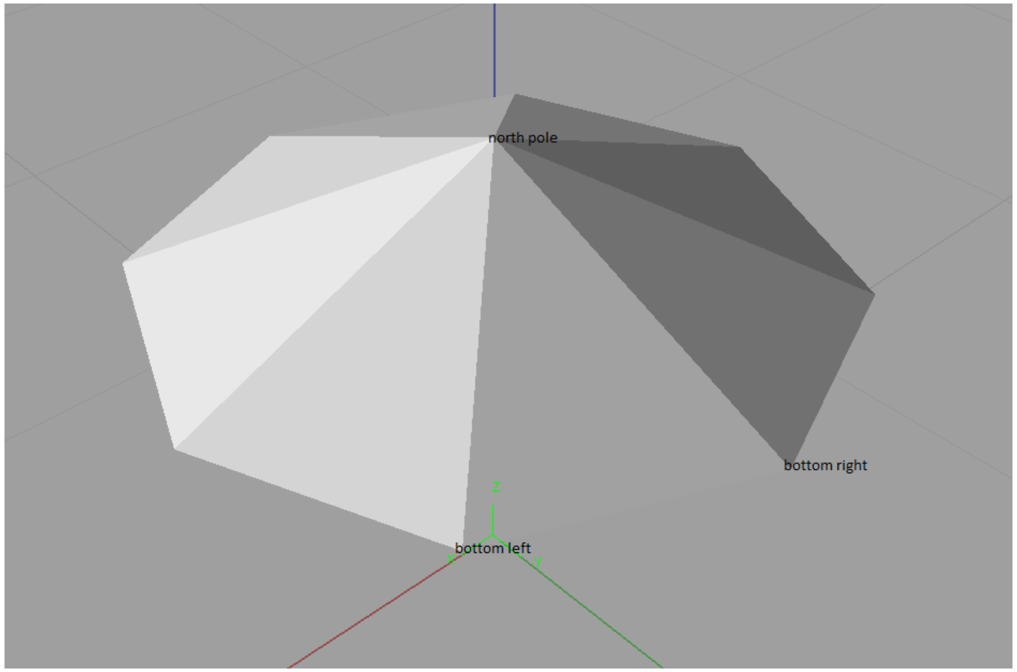


- m=8, n=4 m=32, n=16 m=64, n=32 m=128,n=64
- m = # in azimuth direction
- n = # in polar direction

Tessellating a Sphere (cont)

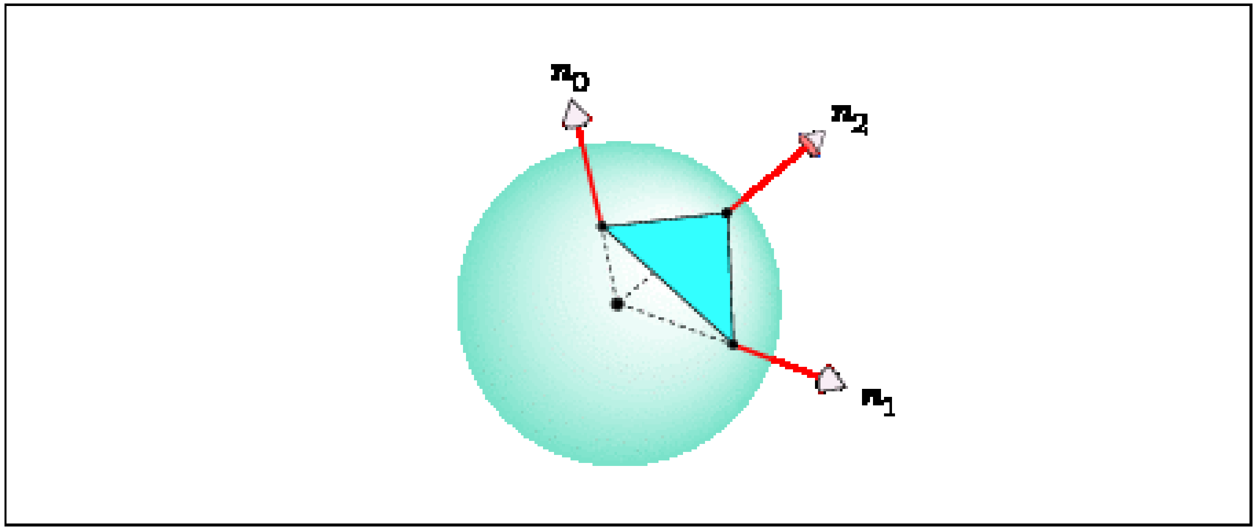
- tessellate_flat_sphere (author provided code)

```
//Sphere Tesselation Pseudo Code

pick 'North Pole' point
pick 'South Pole' point

//For triangles touching North Pole....
for (0 -> m-1)
   generate bottom left point
   generate bottom right point
   generate triangle (north pole, bot lft pnt, bot rgt pnt)

//For triangles touching South Pole....
for (0 -> m-1)
   generate top left point
   generate top right point
   generate triangle (south pole, top lft pnt, top rgt pnt)

//For 'stuff' in the middle
for (0 -> n-2)
  for (0 -> m-1)
//first triangle
                  generate bottom left
generate bottom right
generate top left
//second triangle
generate top right
generate top left
generate bottom right
```



Tessellating a Sphere (cont)

- It would be nice to be able to vary shading across the triangle

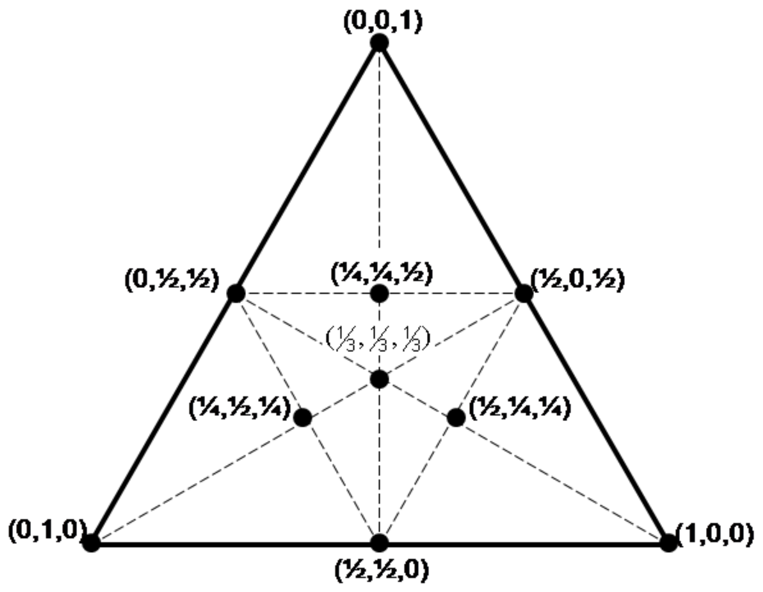


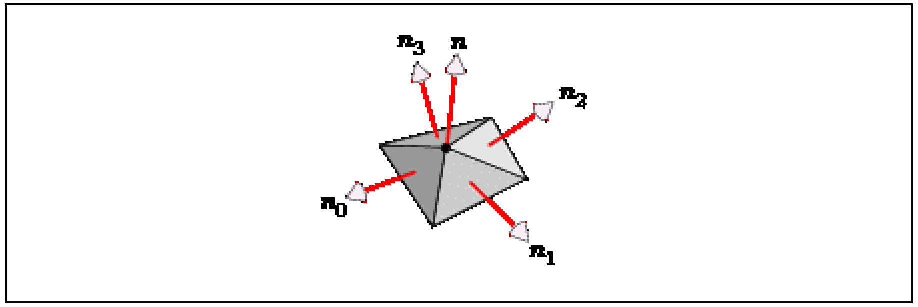
- The n0, n1, n2 normals of the sphere differ
- Gives the appearance of curvature rather than flat facets

Smooth Shading

- Interpolate the normals on the interior of the triangle.
- Continuous shading makes the triangles edges disappear
- Silhouette outline still maintains flat appearance
- Use Barycentric coordinates and interpolate

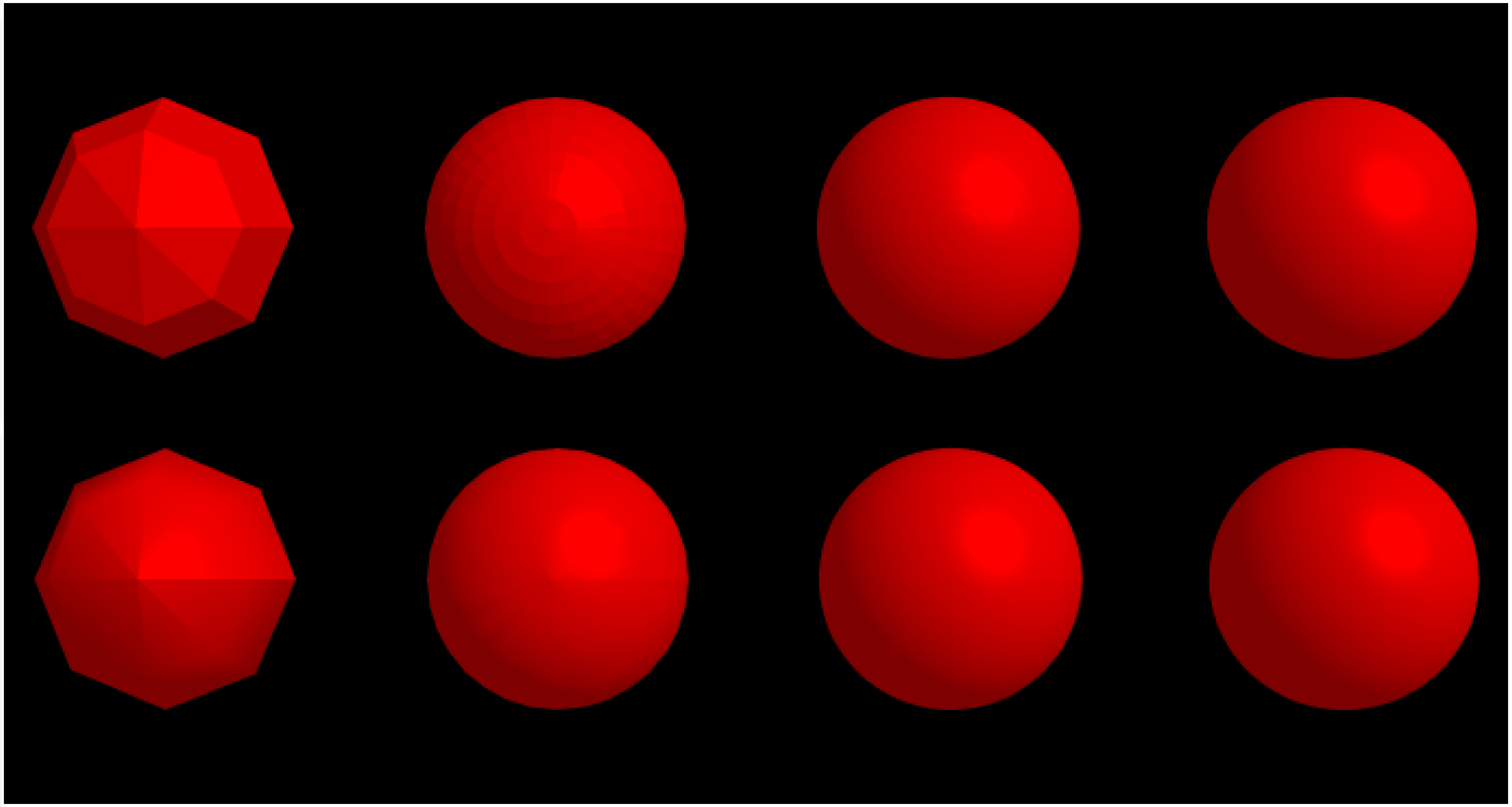
$$n = \square 1 - \square + \square\square n_0 \square\square n_1 \square\square n_2$$





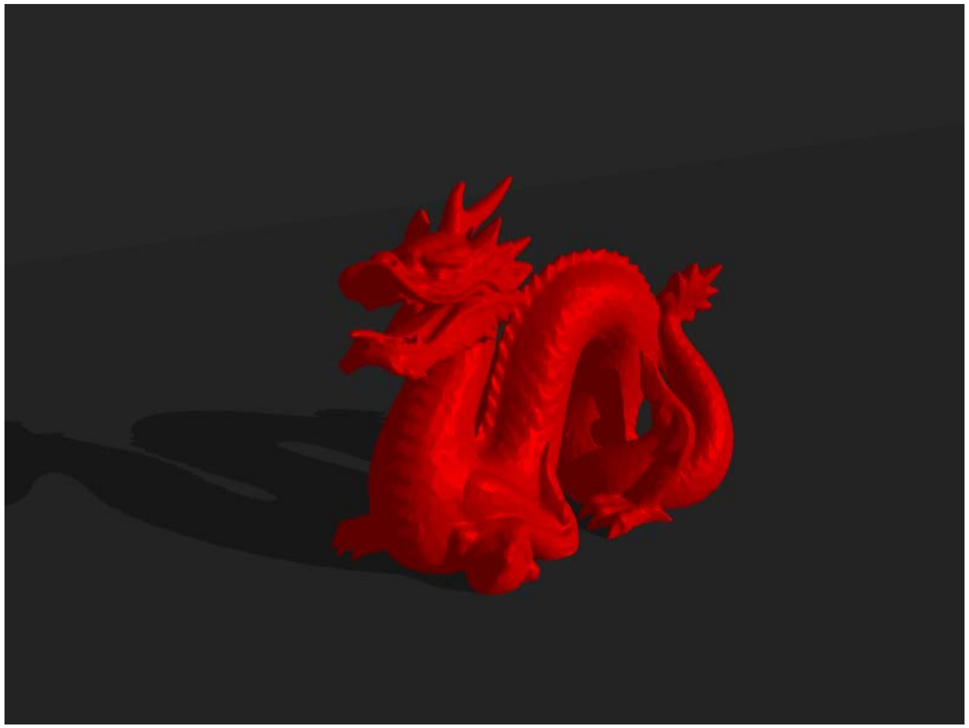
Smooth Shading(cont)

- Flat versus Smooth shading



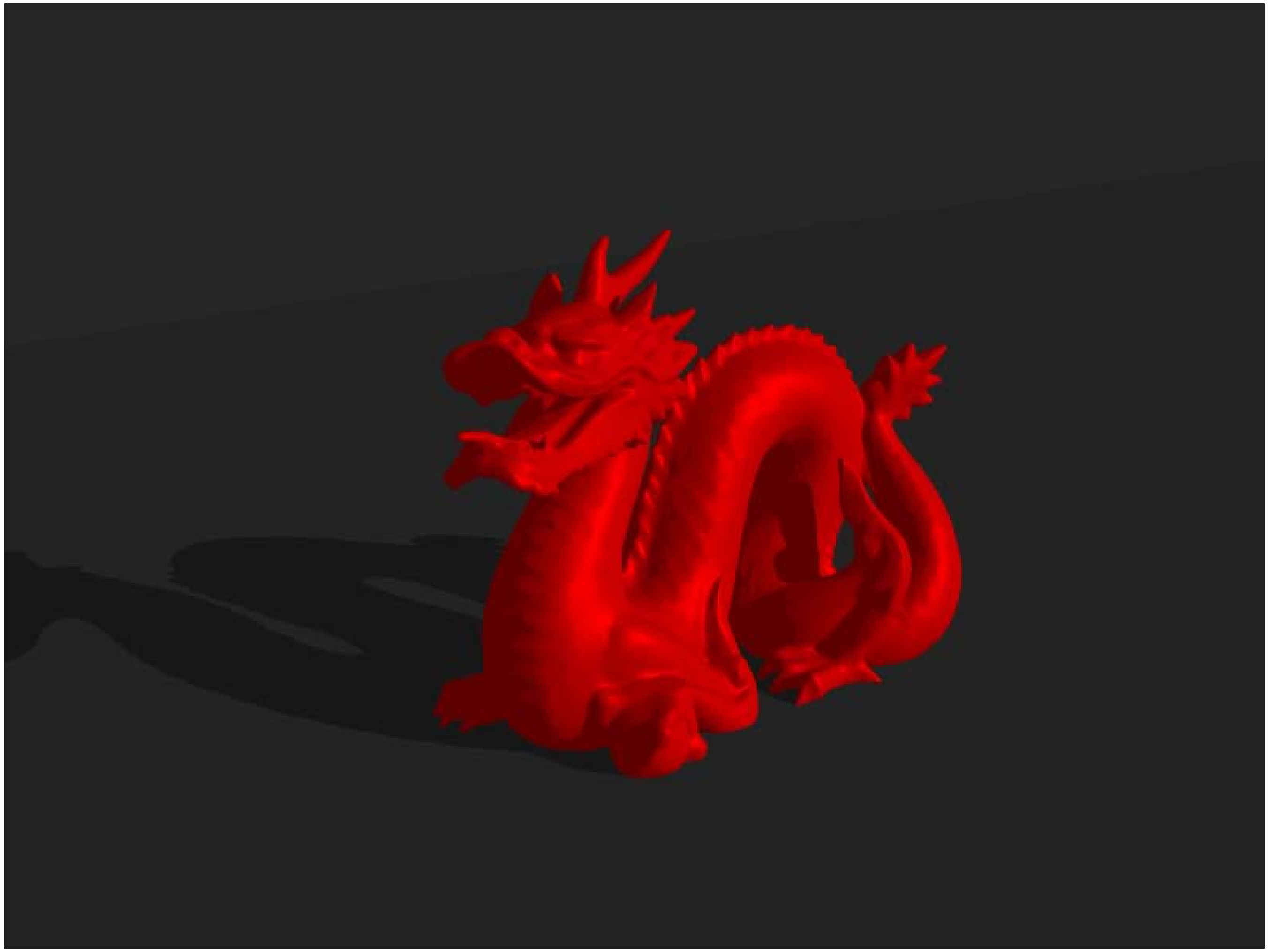
Smooth Shading(cont)

- Smooth Shading requires storage of the additional normals and as such requires more memory (?).
  - Performance impact with Spheres, not noticed
  - Performance impact with Dragon, also unnoticed 51s for flat, 52 seconds for smooth. Both cases ~36,668k memory used.



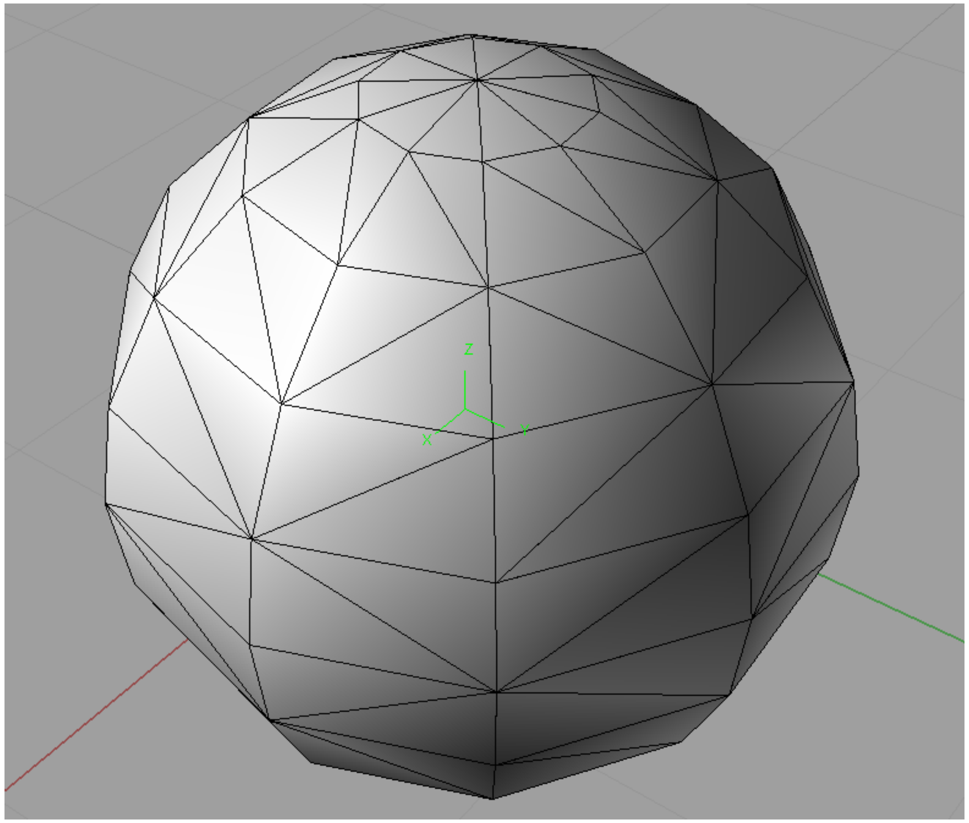
Smooth Shading(cont)

- Smooth shaded dragon



Mesh Data Structure

- Large Meshes = Memory hogs ('xyzrgb_statuette' = 185MB)
- A single vertex is shared by adjacent triangles (average of 6 for closed mesh)
- Save coordinates and normal for each vertex once



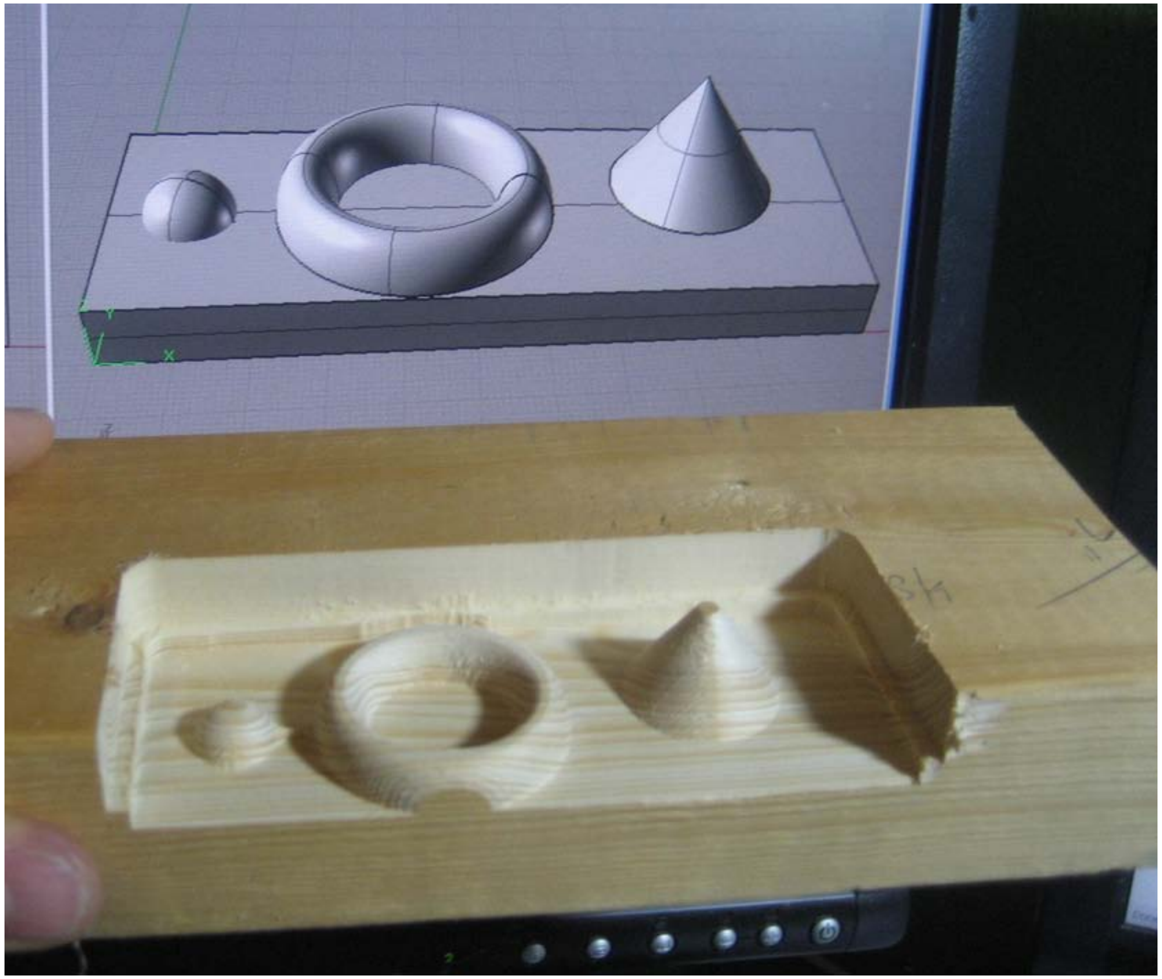
PLY Files

- Sample PLY file

```
ply
format ascii 1.0
comment made by anonymous
comment this file is a cube
element vertex 8
property float32 x
property float32 y
property float32 z
element face 6
property list uint8 int32 vertex_index
end_header
0 0 0
0 0 1
0 1 1
0 1 0
1 0 0
1 0 1
1 1 1
1 1 0
4 0 1 2 3
4 7 6 5 4
4 0 4 5 1
4 1 5 6 2
4 2 6 7 3
4 3 7 4 0
```

Mesh Resources

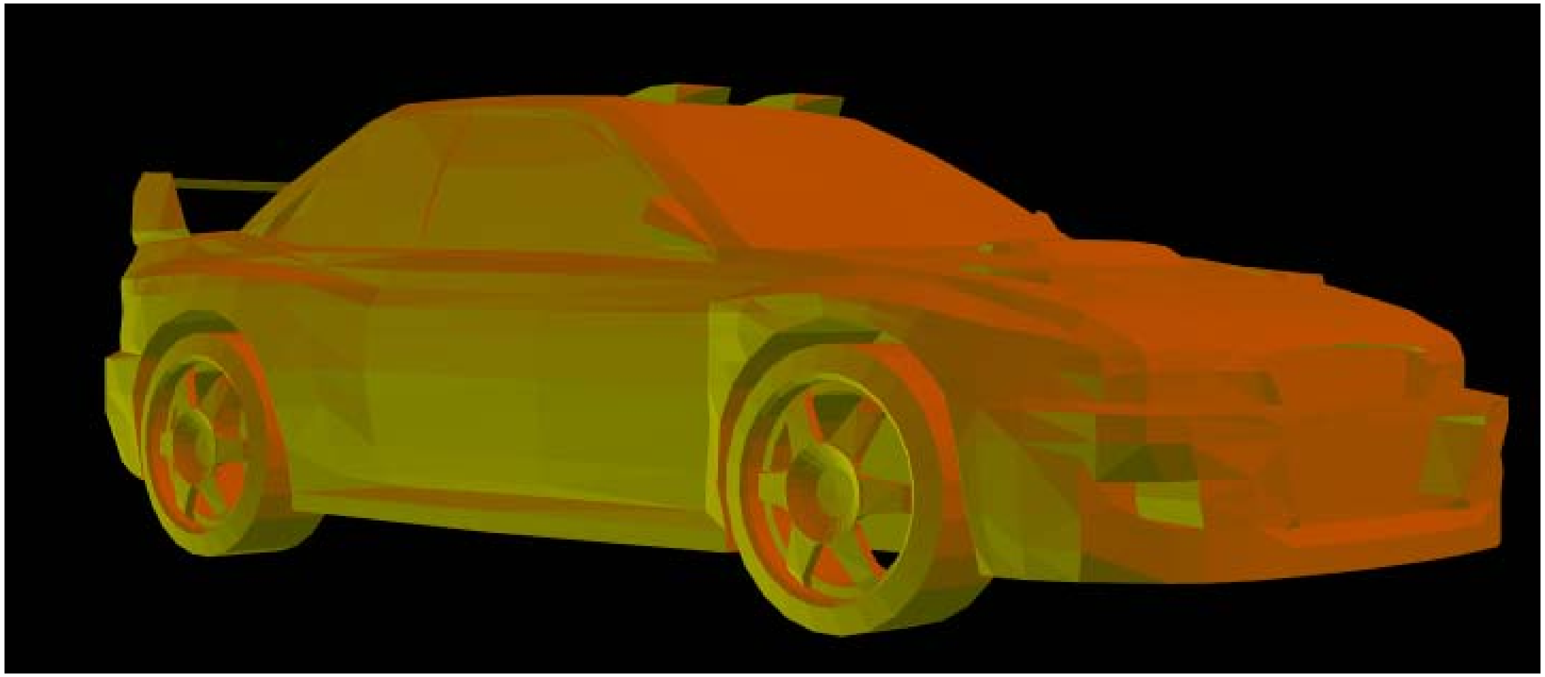
- Rhino3d: Popular (?) CAD/CAM package for Industrial, Architectural, Jewelry, etc. Various 3rd-party plug ins are available for car modeling, virtual clay modeling, 3d prototyping, CNC tool paths ...



Mesh Resources

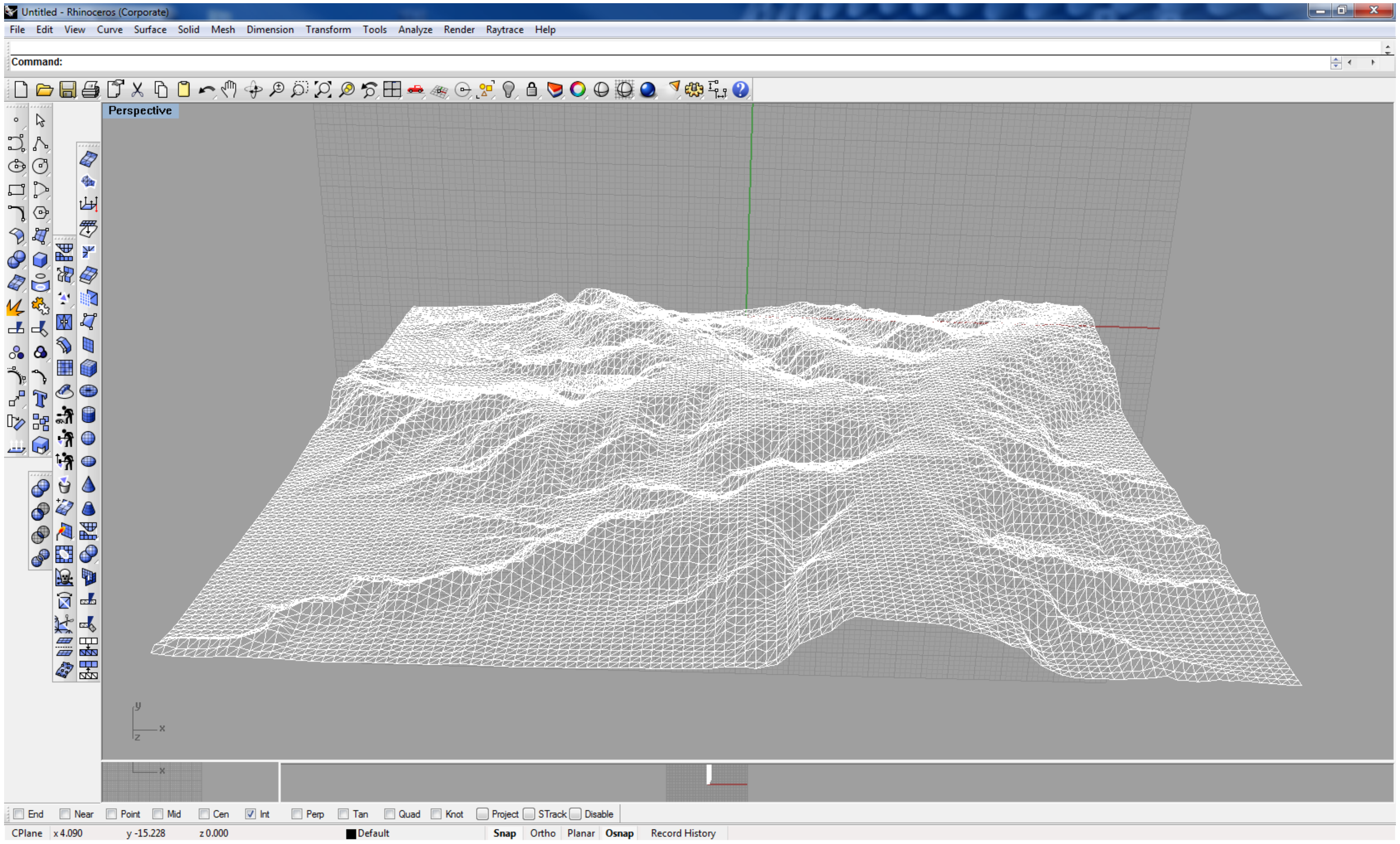
- Rhino3d:
  - Allows import of many different model formats:

  3dm, igs, vda, dwg, dxf, 3ds, lwo, stl, obj, ***ply,*** skp
  - Example: Imported .lwo model from http://dmi.chez-alice.fr/models1.html exported as .ply file and then rendered



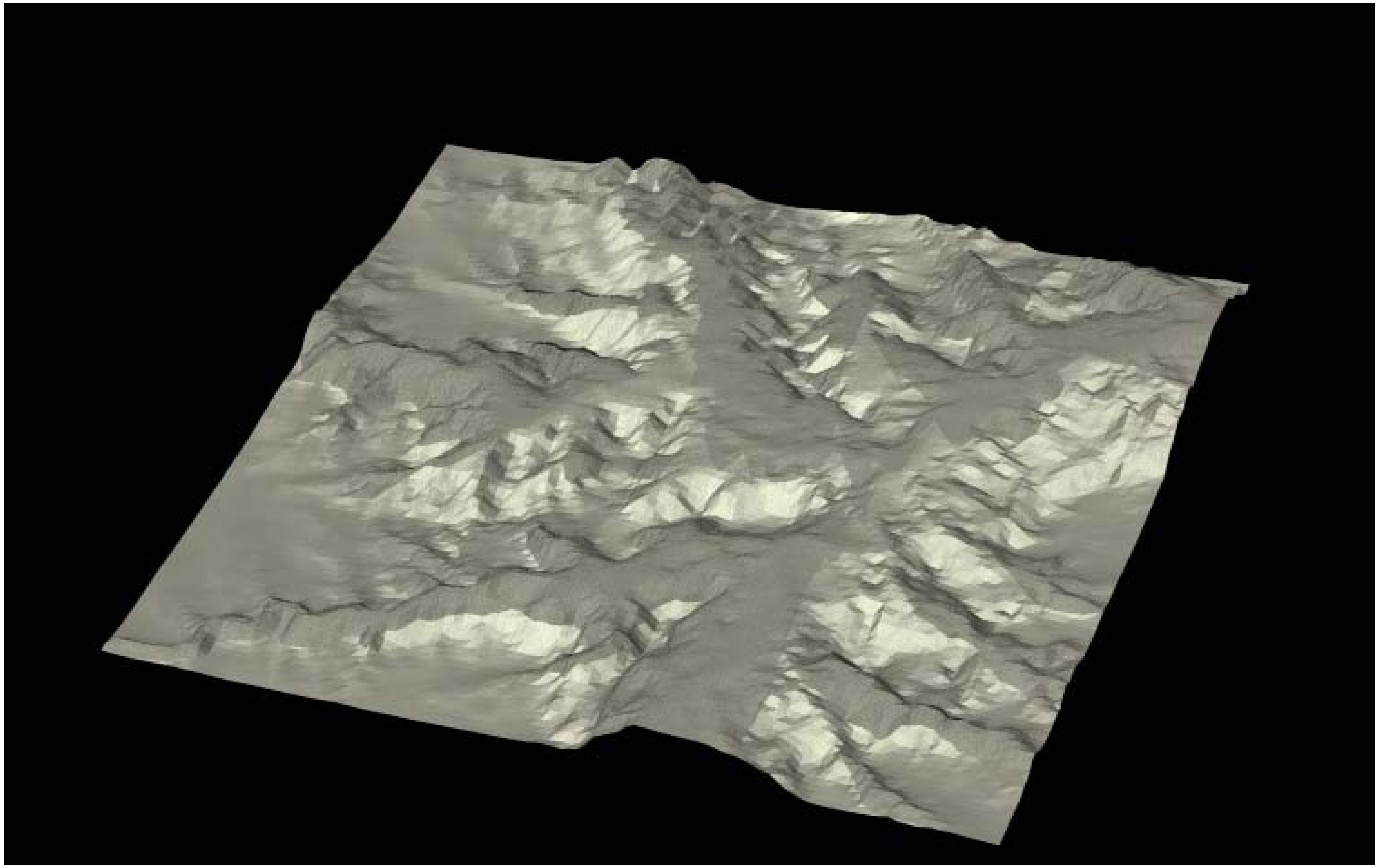
Mesh Resources

- Google Sketchup Model (from http://sketchup.google.com/3dwarehouse/):
  - Import .skp model into Rhino3D (or other package)
  - Scale model if needed (reverse axis)


Untitled - Rhinoceros (Corporate)
File Edit View Curve Surface Solid Mesh Dimension Transform Tools Analyze Render Raytrace Help
Command:
Perspective
End Near Point Mid Cen Int Perp Tan Quad Knot Project STrack Disable
CPlane x 4.090 y -15.228 z 0.000 Default Snap Ortho Planar Osnap Record History

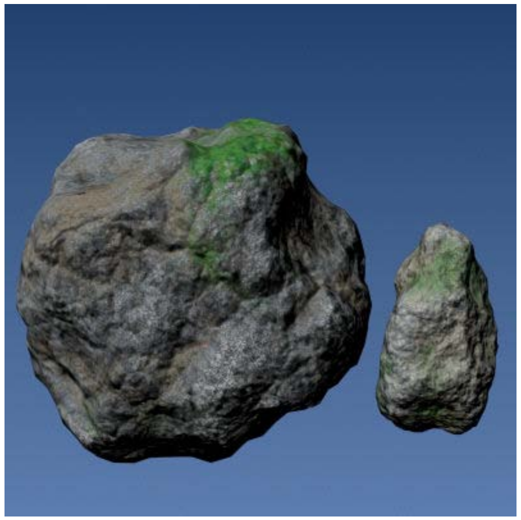
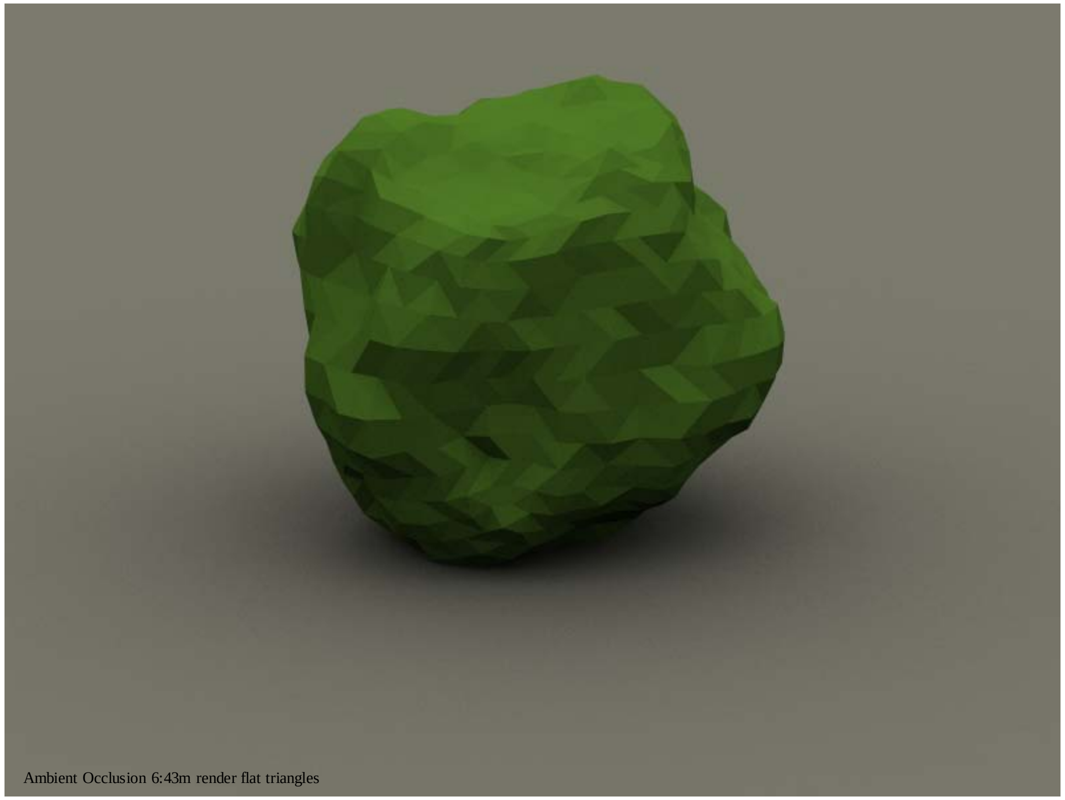
Mesh Resources

- Export to .ply format, property list uchar uint vertex_index => property list uchar uint vertex_indices



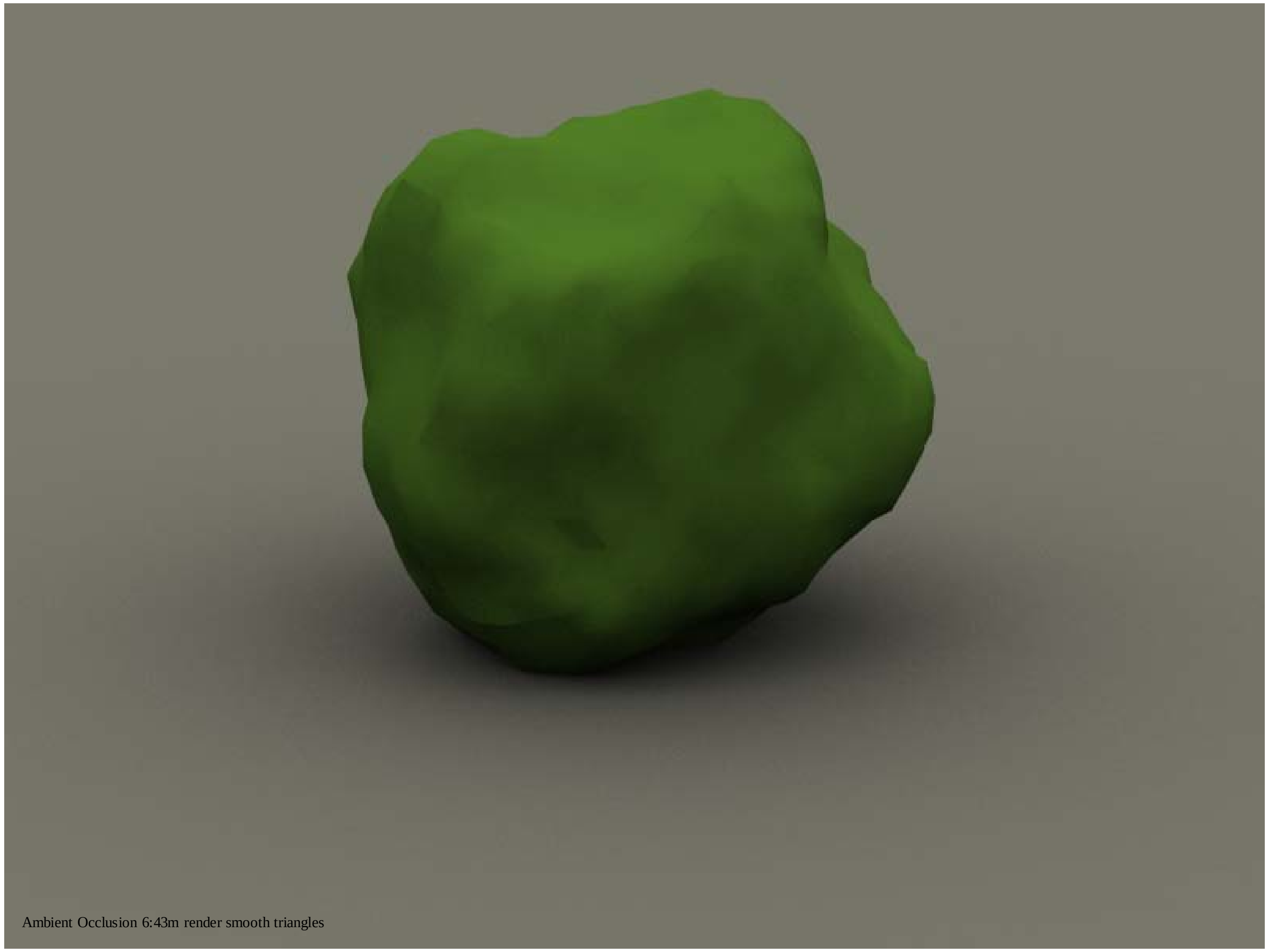
Mesh Resources

- TurboSquid (http://www.turbosquid.com/) is a 3d Marketplace that provides artists an outlet for selling models. Some free models exist on the site…

Mesh Resources

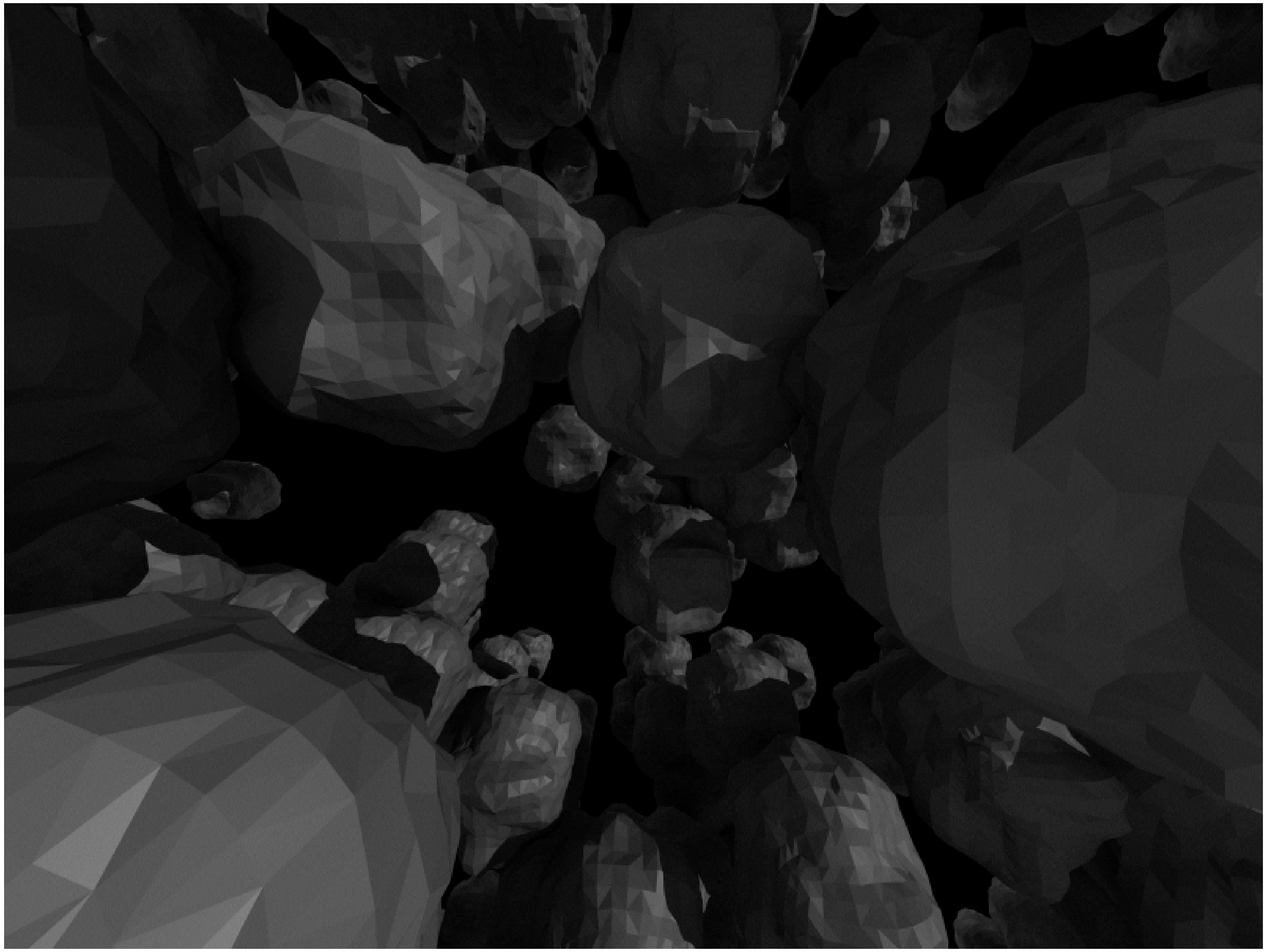
- w/smooth shaded triangles



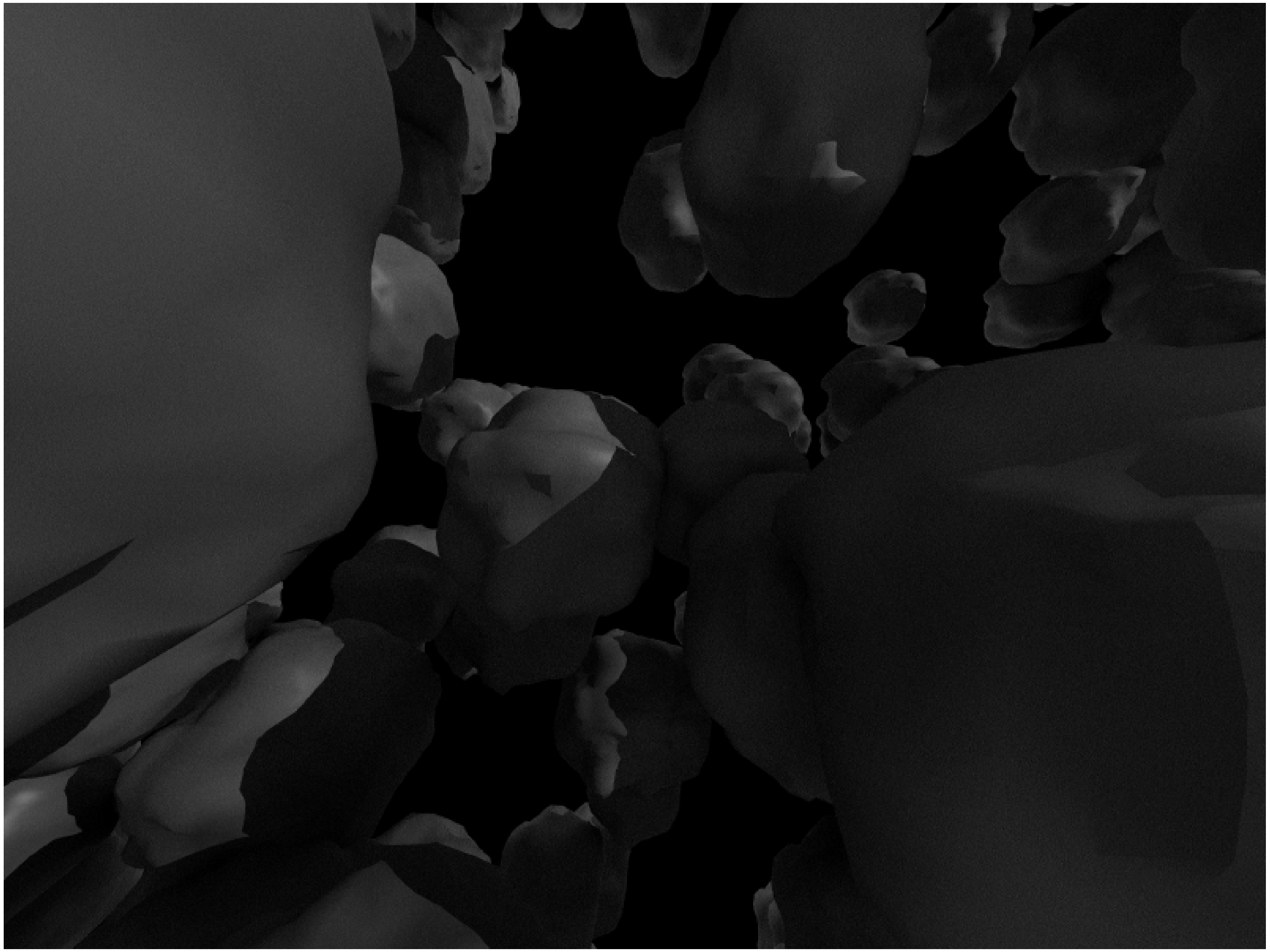
Hierarchical Grids

- Hierarchical Grids: Create instances that contain some number of an object. Why?

Example : Asteroid Field.... (**7** hour render time, 4.5M memory used, 1 Stone 4.1M)



Hierarchical Grids



Mesh Resources

- Vehicles:

http://dmi.chez-alice.fr/models1.html

http://www.planit3d.com/source/meshes_files/vehicles01.htm

http://www.3dtotal.com/pages/meshes/meshvehicles.php

- Human Forms:

http://www.3dtotal.com/pages/meshes/meshhuman_a.php

- Furniture, Architecture:

http://archive3d.net/

http://www.3dmodelfree.com/

- Space :

http://hayabusa.sci.isas.jaxa.jp/shape.pl

http://www.nasa.gov/multimedia/3d_resources/3d-models-gallery.htmlhttp://space.jpl.nasa.gov/models/

- Various:

http://www.cc.gatech.edu/projects/large_models/

References

- Suffern, Kevin (2007). Ray Tracing from the Ground Up. p. 473-490
- http://www.3dm3.com/visits/1096
- http://www.iqcmm.com/
- http://www.zcorp.com