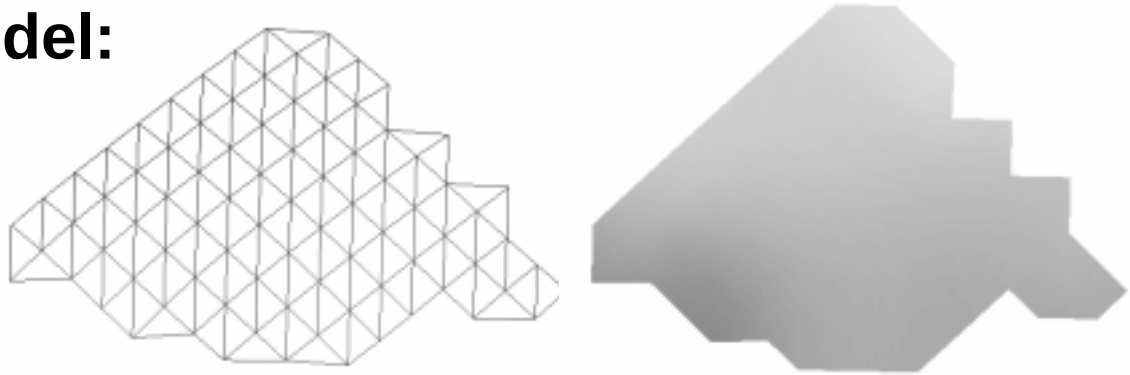
DAWN TO DUSK

All the Polygons You Can Eat

Chris Maughan

Object: Create Scalable Content that Looks High Resolution

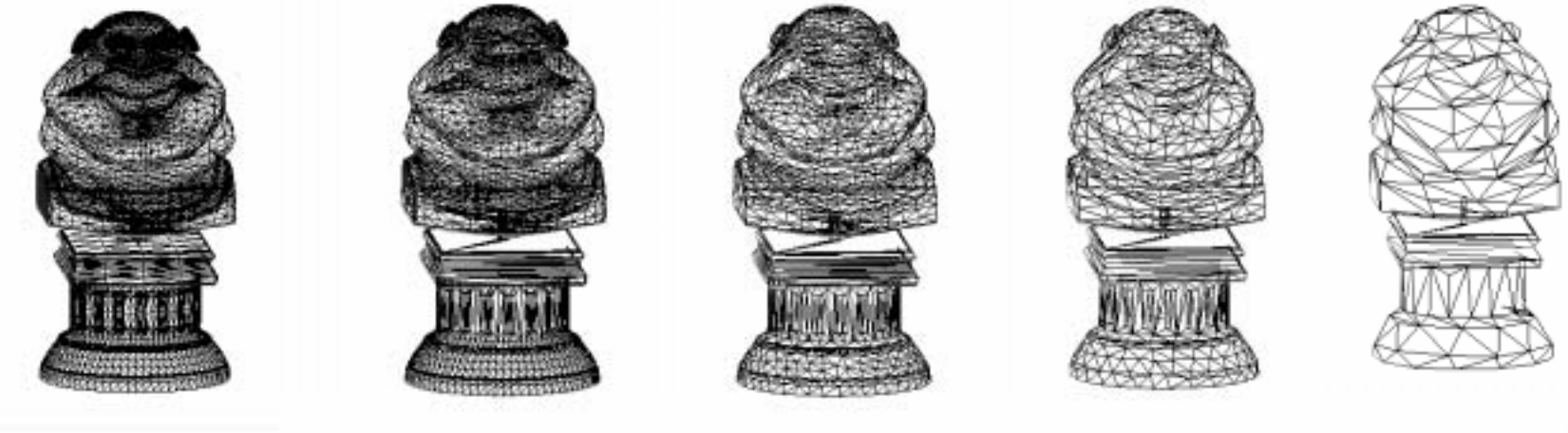
- We want this model:



- To be lit like this

Automatically Create Levels of Detail

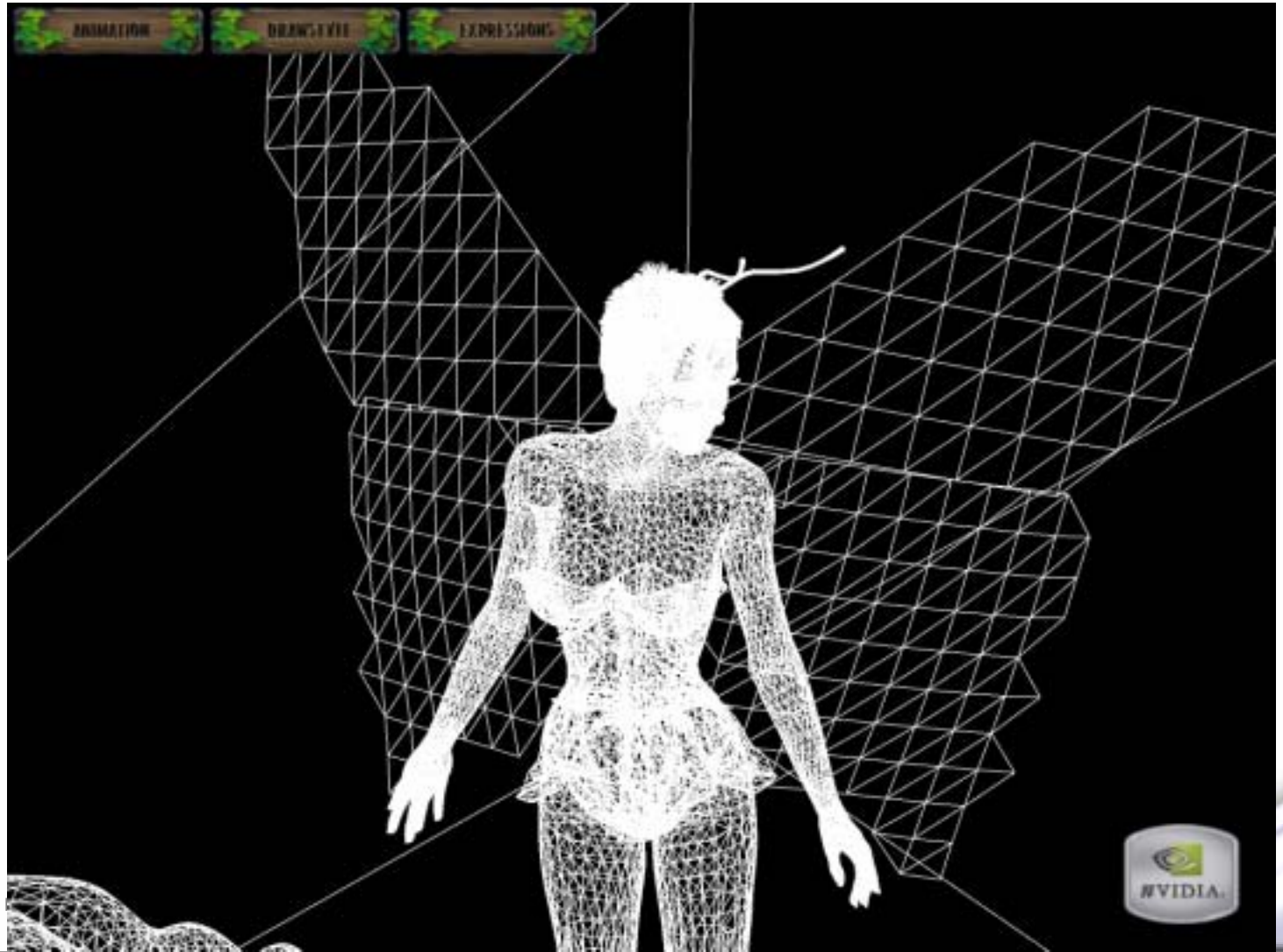
- **From this model:**



19k 9k 4k 2k 500

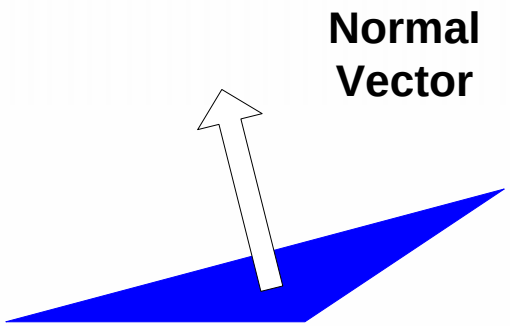
Real World Example

In Wire Frame



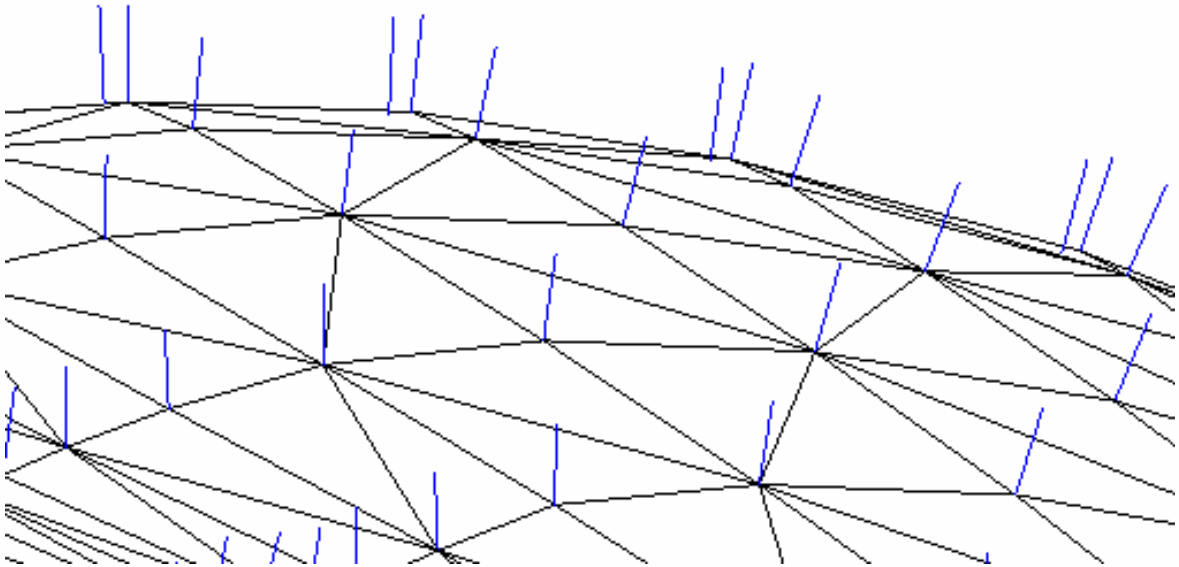
What is a Face Normal?

- A vector is normal to a surface when its direction is perpendicular to the plane which contains this surface
- When this vector is equal to 1 unit, the vector is normalized
- The direction the triangle is facing, or the ‘up’ direction



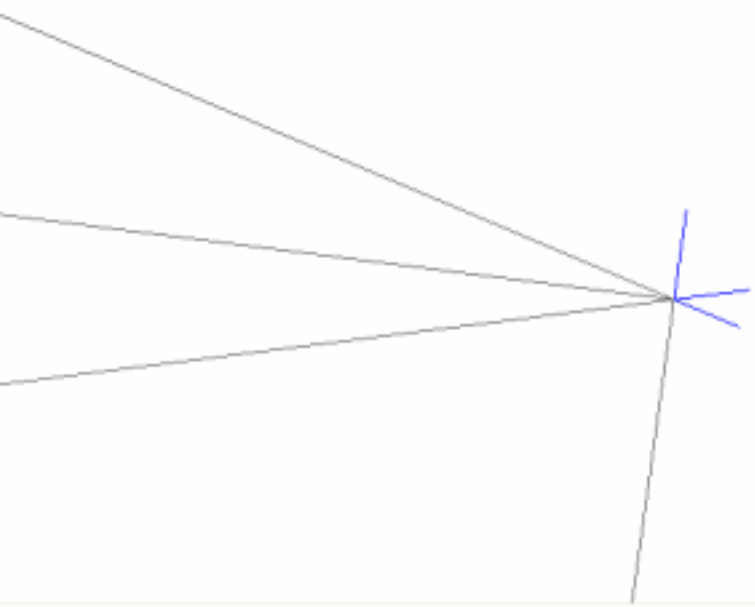
What is a Vertex Normal?

- Summing all the face normal and normalizing the result yields our vertex normal
- This vector is the vertex normal and is used for vertex lighting



Multiple Normals per Vertex

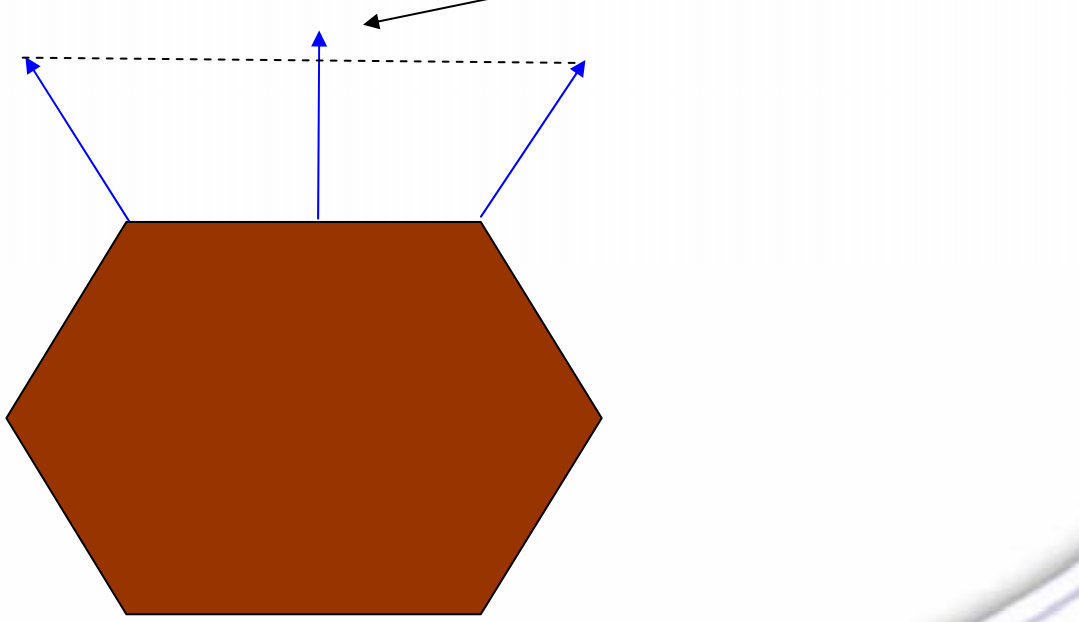
- **Sharp edges or borders of smoothing groups do not share normal**
  - **Mulitiple normals per vertex**



Multiple normals on a cube corner

Normals

- **Normal are interplated across a face**
- **Must still remain normalized**



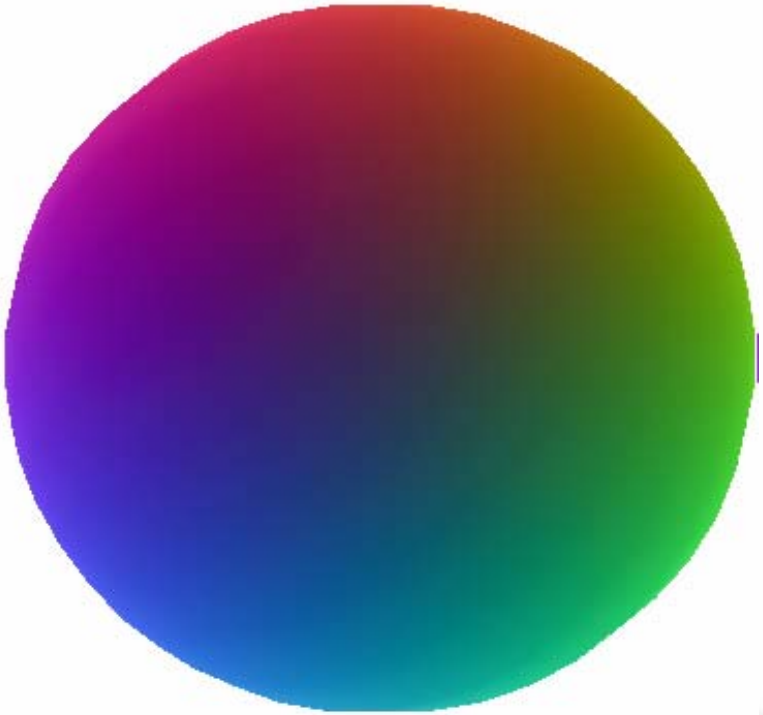
What is a Normal Map?

- **A texture map that encodes the normal direction.**
- **Directions are 3-D vectors encoded in RGB channel**
- **Map directions [-1,1] to color 0 to 255**
- **Could use floating point textures, too**

Map	to	Color
-1		0
0		128
+1		255

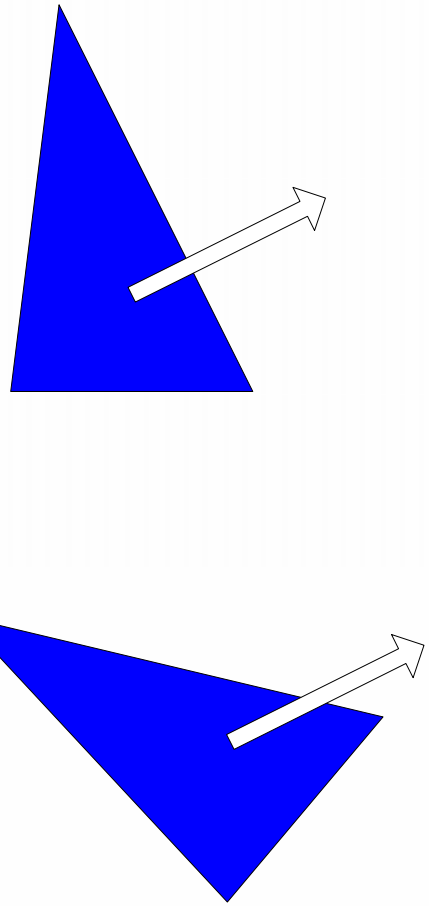
Normals Displayed as Color

- These are “object space” normals stored in the texture.

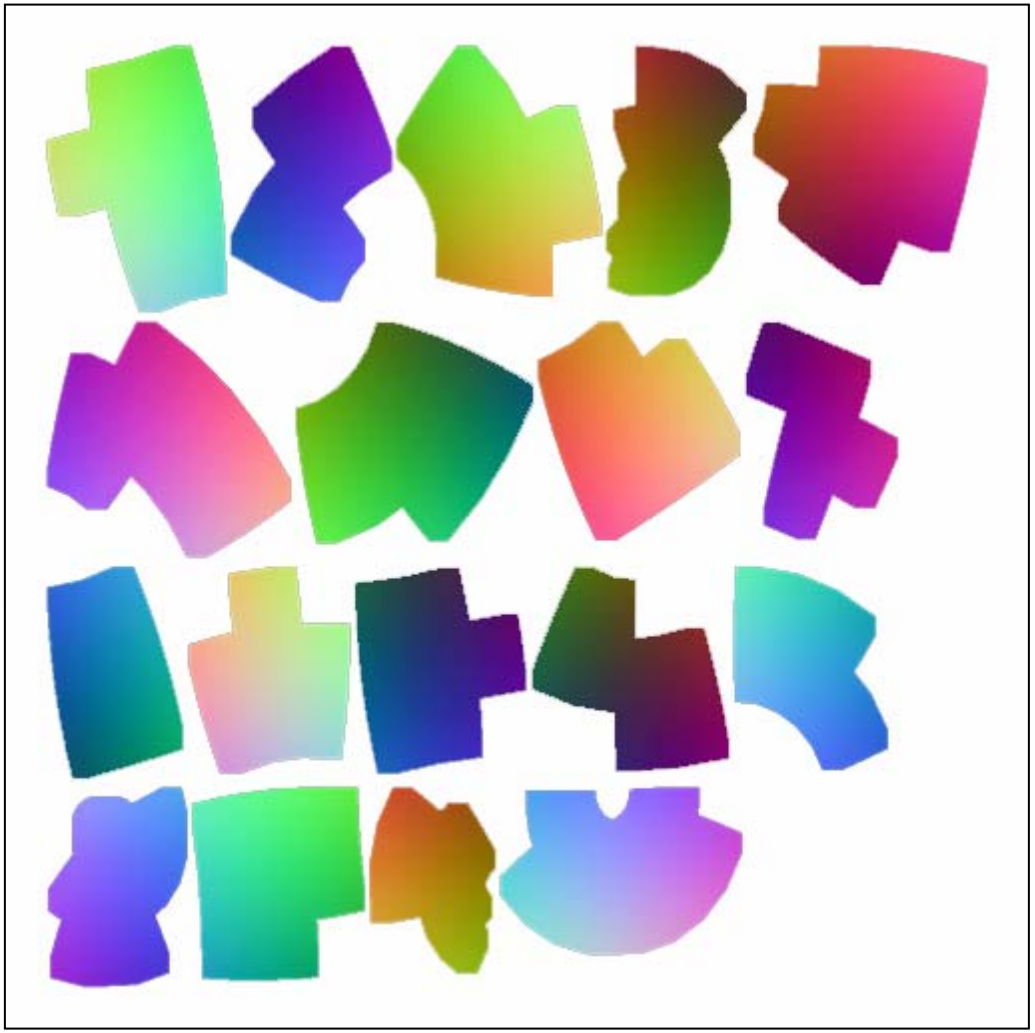


Object Space Normals

- They always point in the same direction, even if the model is deformed
- Arrow is normal stored in the normal map
- Triangle is rotated, but normal does not
- Harder for deformations
  - Light needs to be rotated to account for deformations



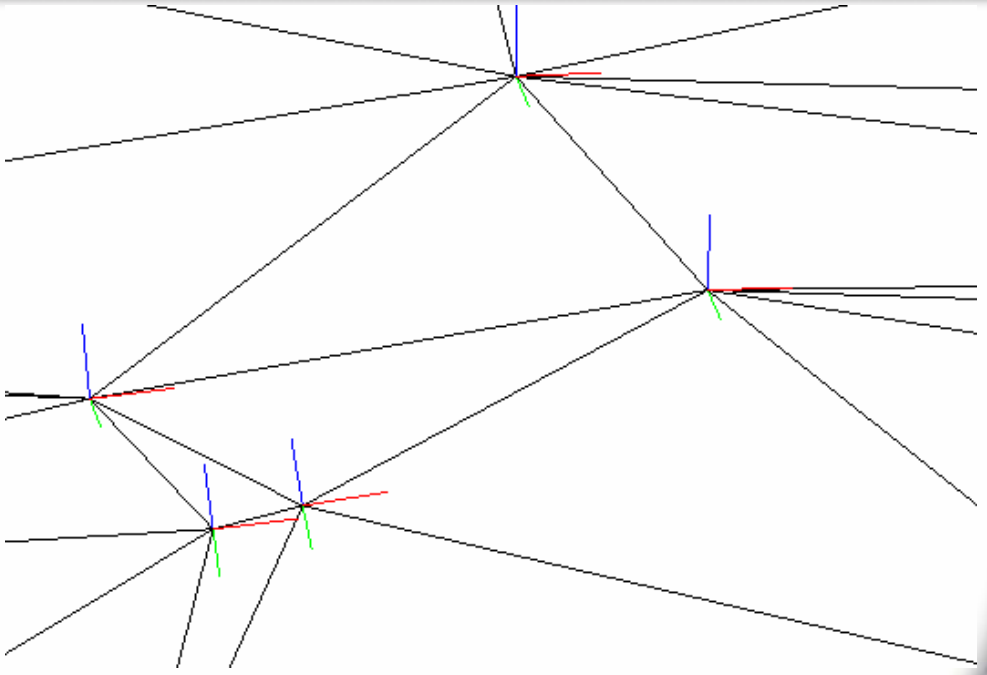
Normal Map



- For the sphere:

Tangent Space

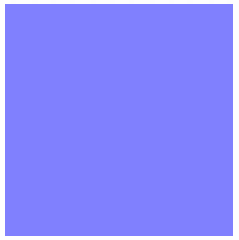
- Local coordinate system defined per vertex
- Allow relative normals, or normals defined in this local space
- Rotate the light into this space, or the normal into object space
- Coordinate system may be rotated by the deformation
- Tangent space transforms object Space to tangent Space



Normal, tangent and binormal define tangent space matrix

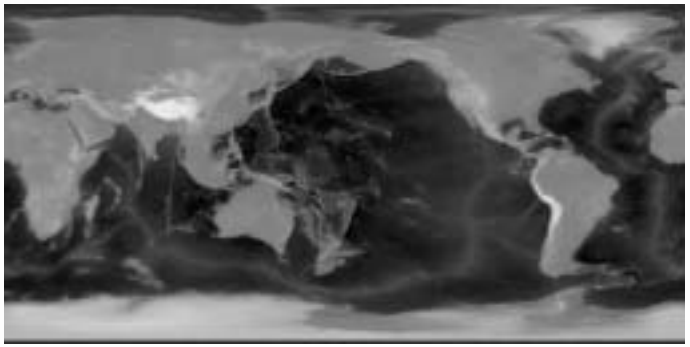
Tangent Space Normals

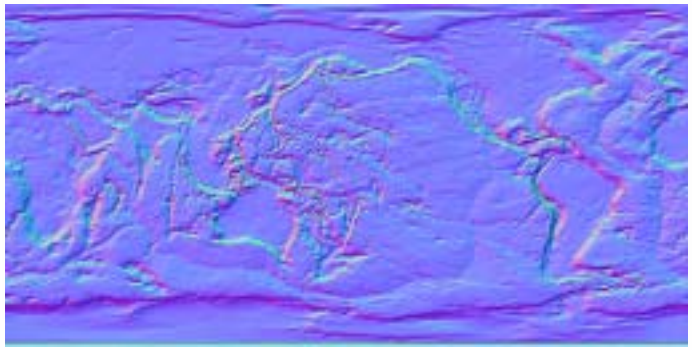
- Texel normals are relative to the face normal
- The vector (0,0,1) is considered the ‘up’ direction and coincident with the face normal
- (0,0,1) is stored as color (128,128,255)



How to Create a Normal Map?

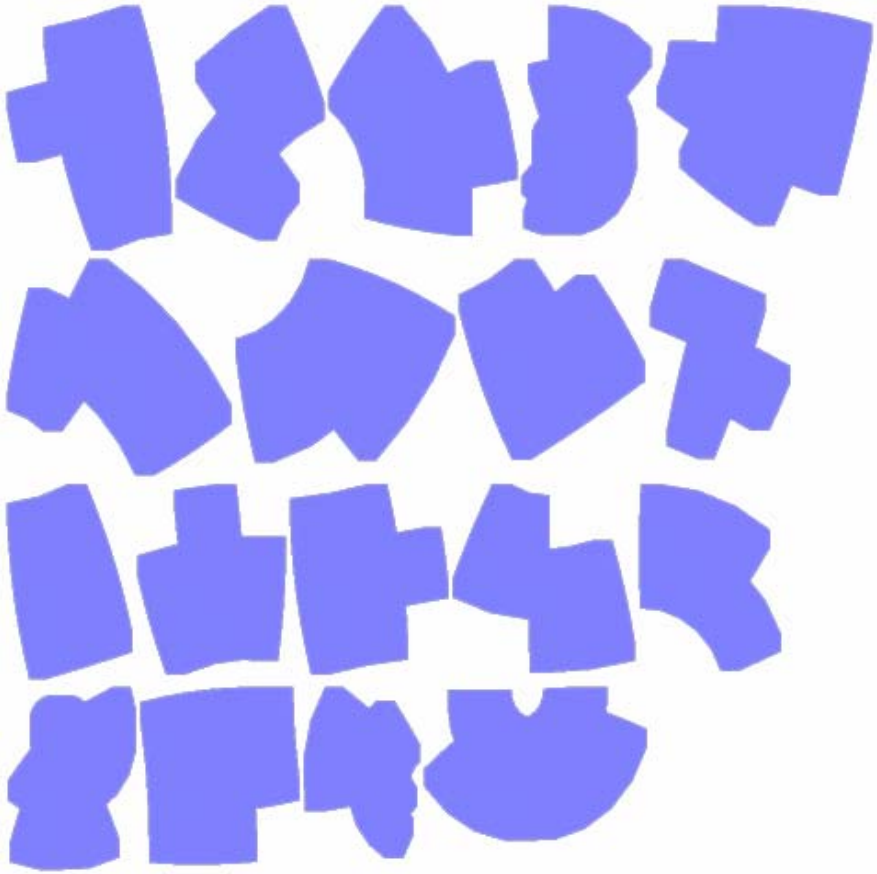
- **Use 2D Images, using the Normal Map Plugin for Photoshop:**





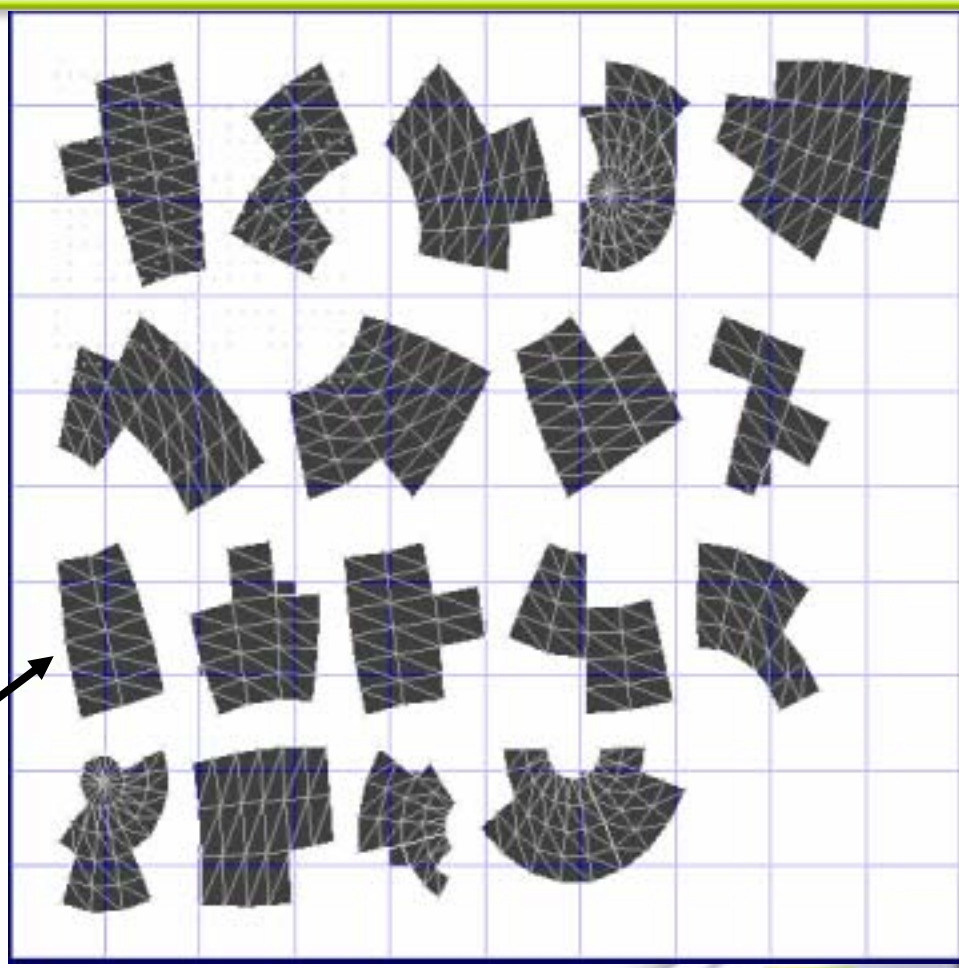
Tangent Space Normal Map

- For the sphere, the tangent space normal map



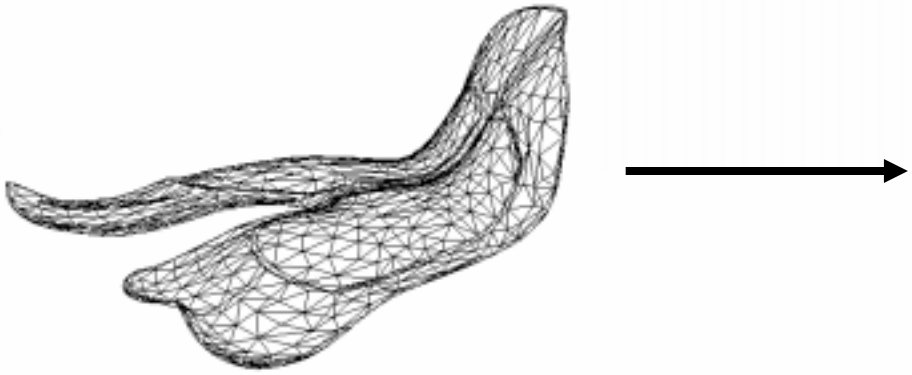
Charts

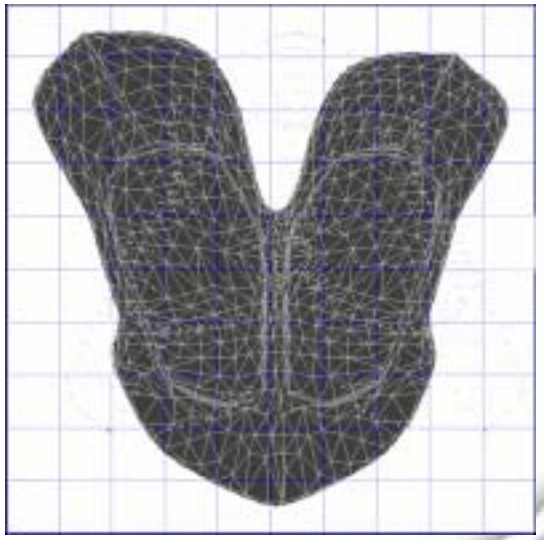
- **Set of faces bounded by texture seams are grouped into charts. A set of charts is an *Atlas***



One Chart

- Needs one connected border
- Not required to be flat
- No flipped triangles
- Can be automatically generated

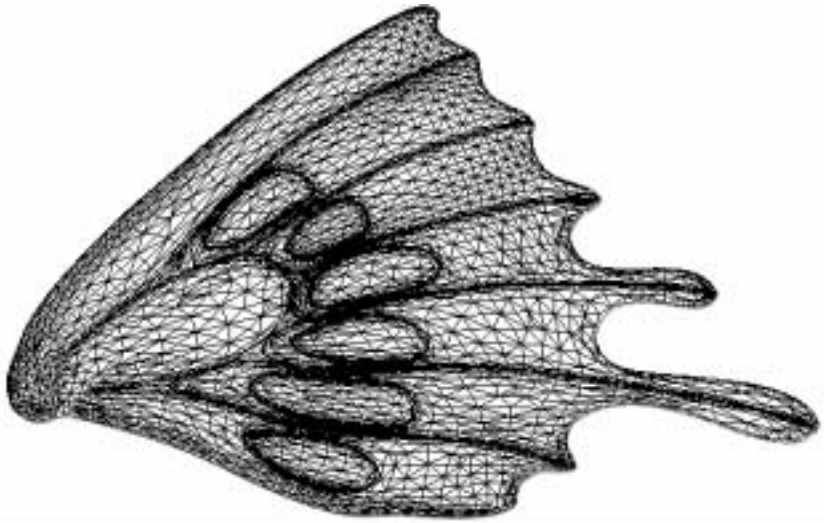




Automatically generated

Reference Model

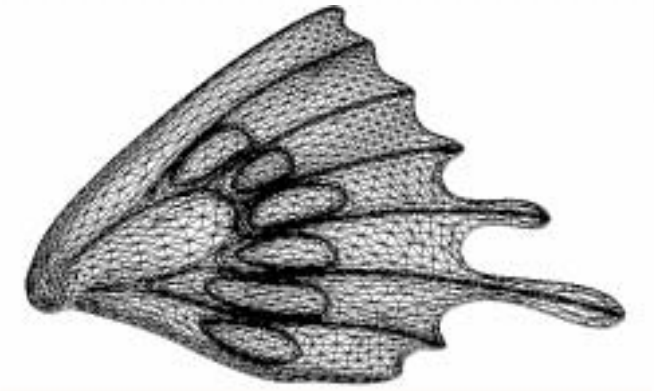
- High resolution model used as a reference
- Used for:
  - Calculating decal texture coordinates
  - Source of normals
  - Sampled data points



Part of Dawn’s wing

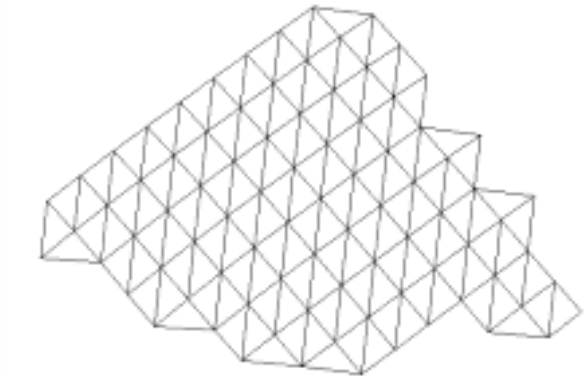
Working Model

- **Model that is simplified to create LODs**
- **May be same as reference model or a hand simplified model**
- **Does not need texture coordinates, these can be automatically generated**



Same as reference

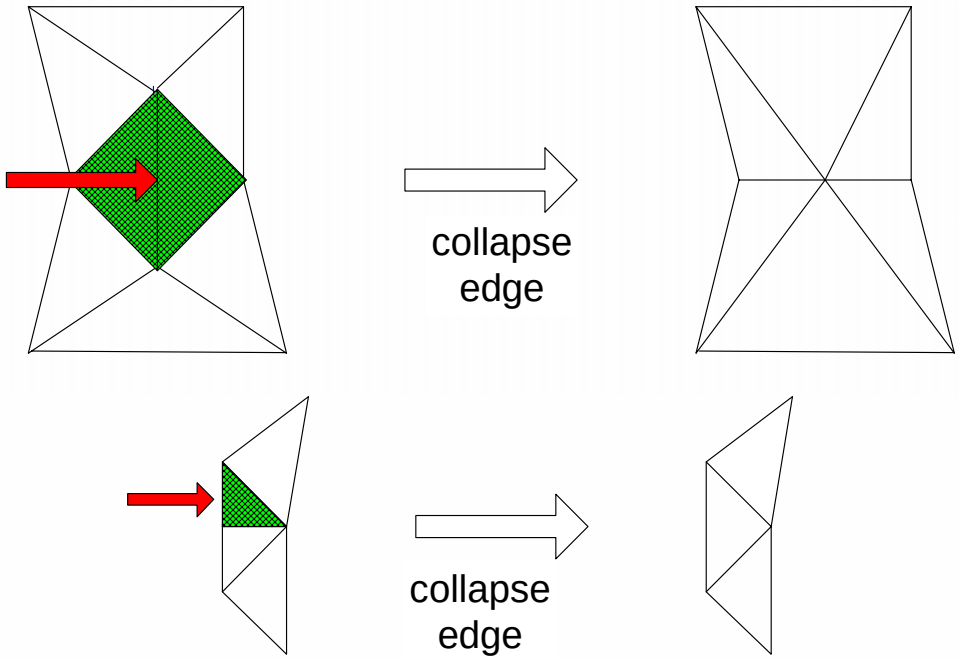
or



Manually simplified

Simplification

- Edge collapse method
- removes one or two face

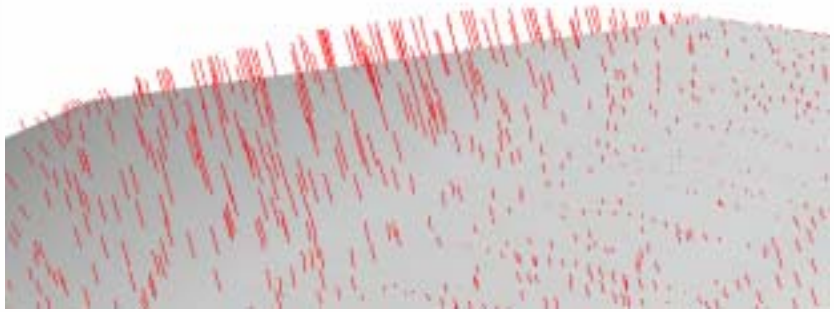


Simplification History

- Edge collapses based on weight
- Three Methods: QEM, Volume and EMIN
- Collapse each edge, one at a time and record all collapses
- Allows undo of collapses
- Assignment to LOD for additional processing
- Option to make a progressive mesh
  - One vertex is collapsed into another during edge collapase

Data Points

- **Random sampling of Reference Model to obtain data points**
- **Used for optimization and EMIN simplification**
- **Used to fit working model to reference model**
- **Sampled on edges and surface**

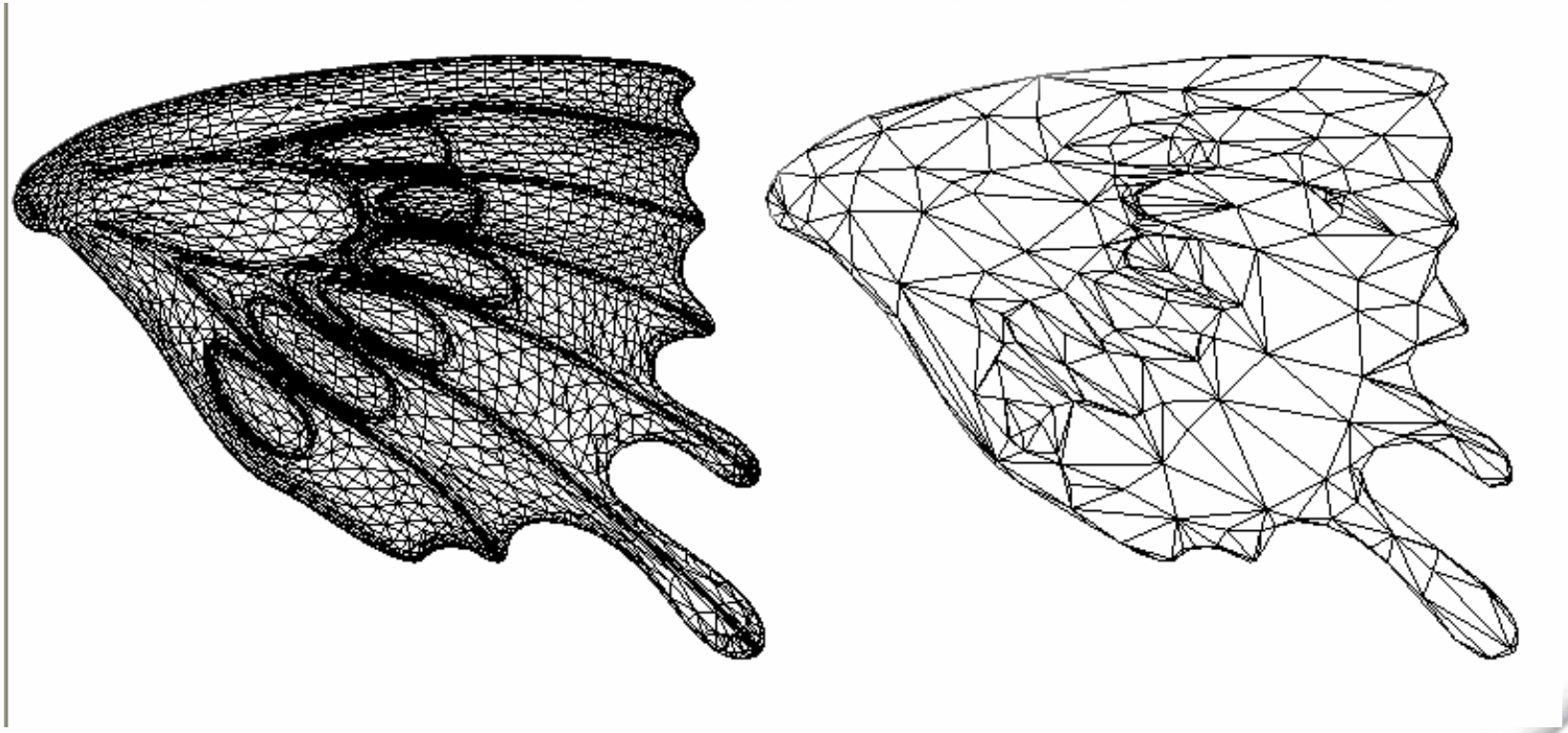


Line drawn from sampled data point to surface of working model

Optimization

- Set parameters
- Attempts to achieve a balance between forces
- One solution based on weighting values
- Hugues Hoppe’s technique
- Spring based, finds minimum energy
- Based on distance to reference model using sample data points
- May collapse, split or flip edges
- Treats distance to reference model as a spring

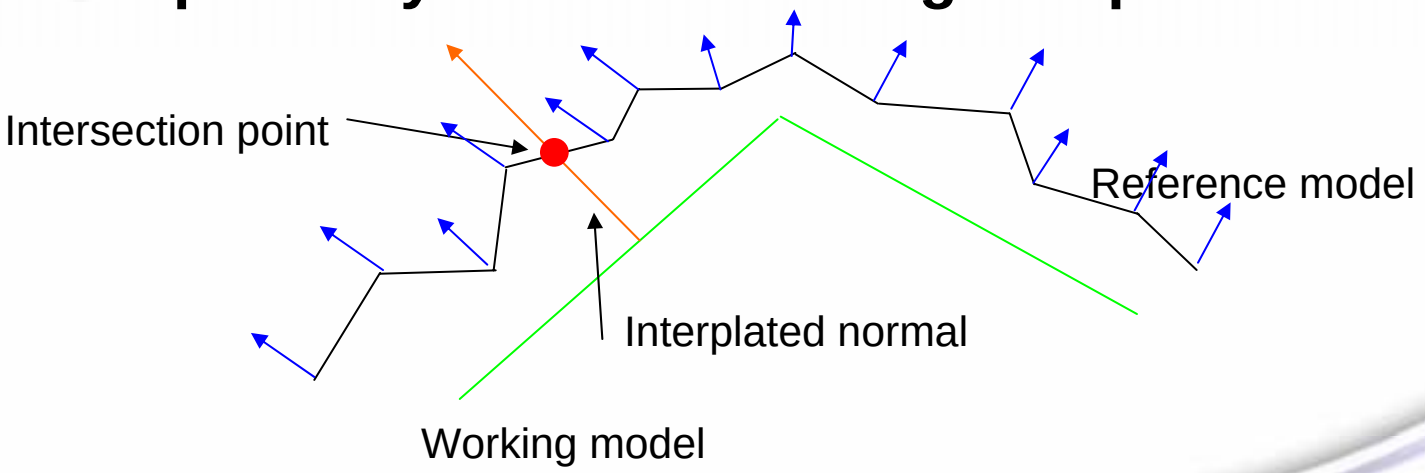
Optimize example



optimize

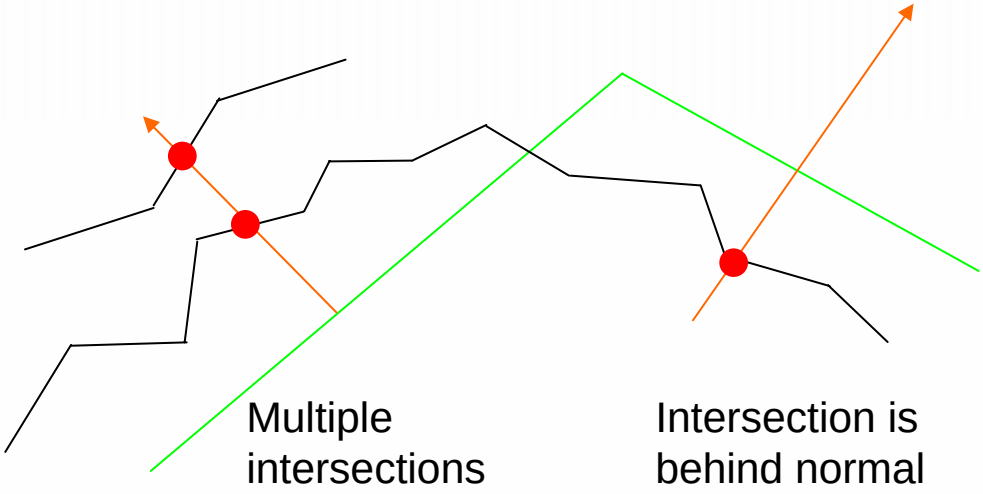
Ray Casting

- Using the interpolate normals on the working model, cast a ray to the reference model
- Intersection point is used to calculate the object space normal
- Stored into the normal map
- Optionally rotated into tangent space



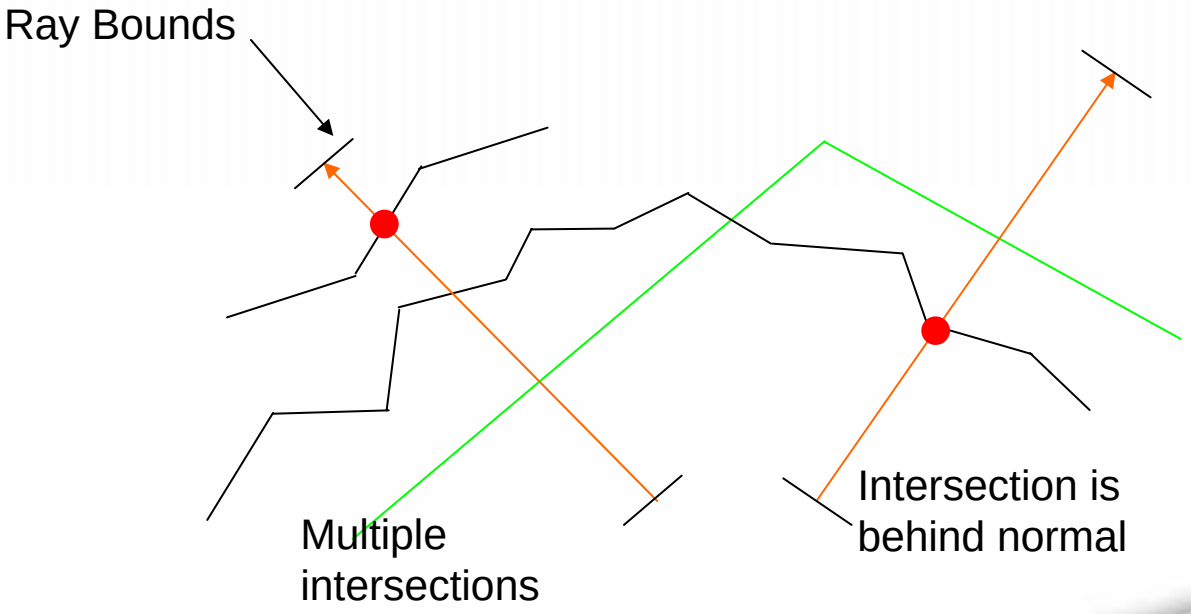
Ray Casting Methods

- There are many ways to cast a ray into the reference model
- Two here are
  - Farthest within bounds
  - closest



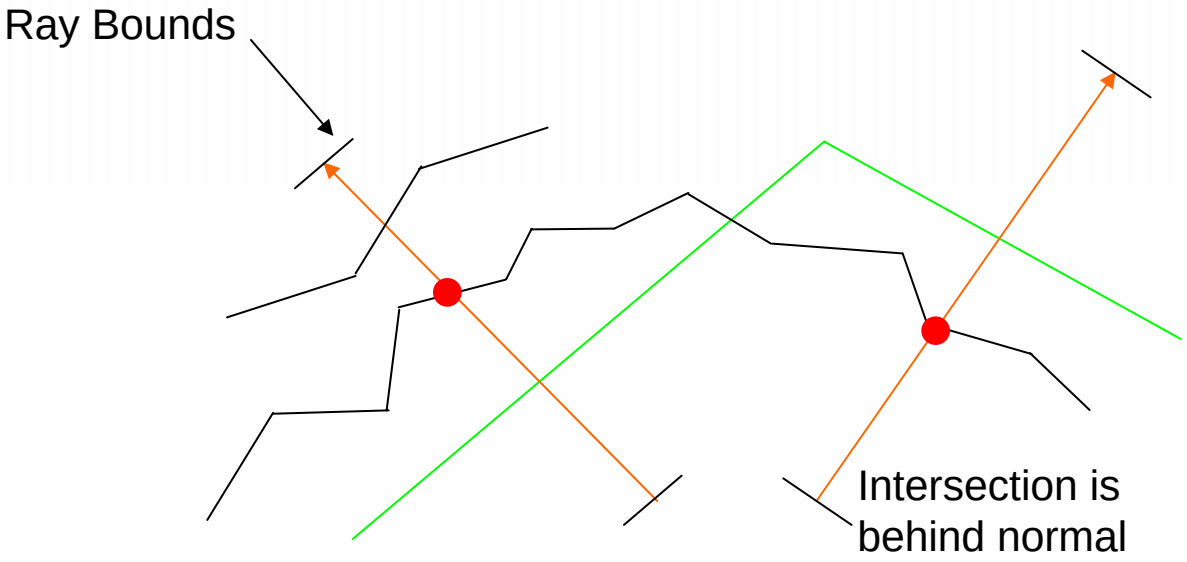
Ray Casting Methods: Farthest Within Bounds

- **Define a distance away from the working model, locate the farthest away**
- **Both in front and behind face**



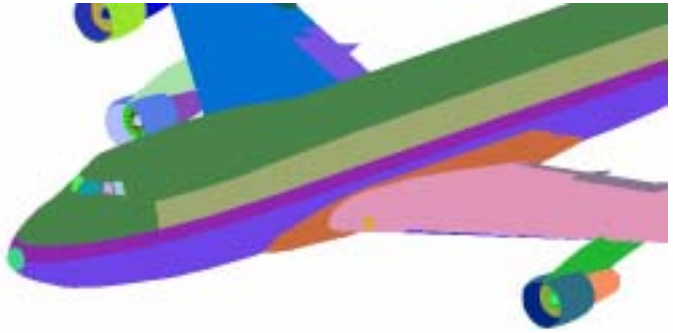
Ray Casting Methods: Closest

- Take the closest intersection to the face
- Sometimes bounded ray fails



Seam

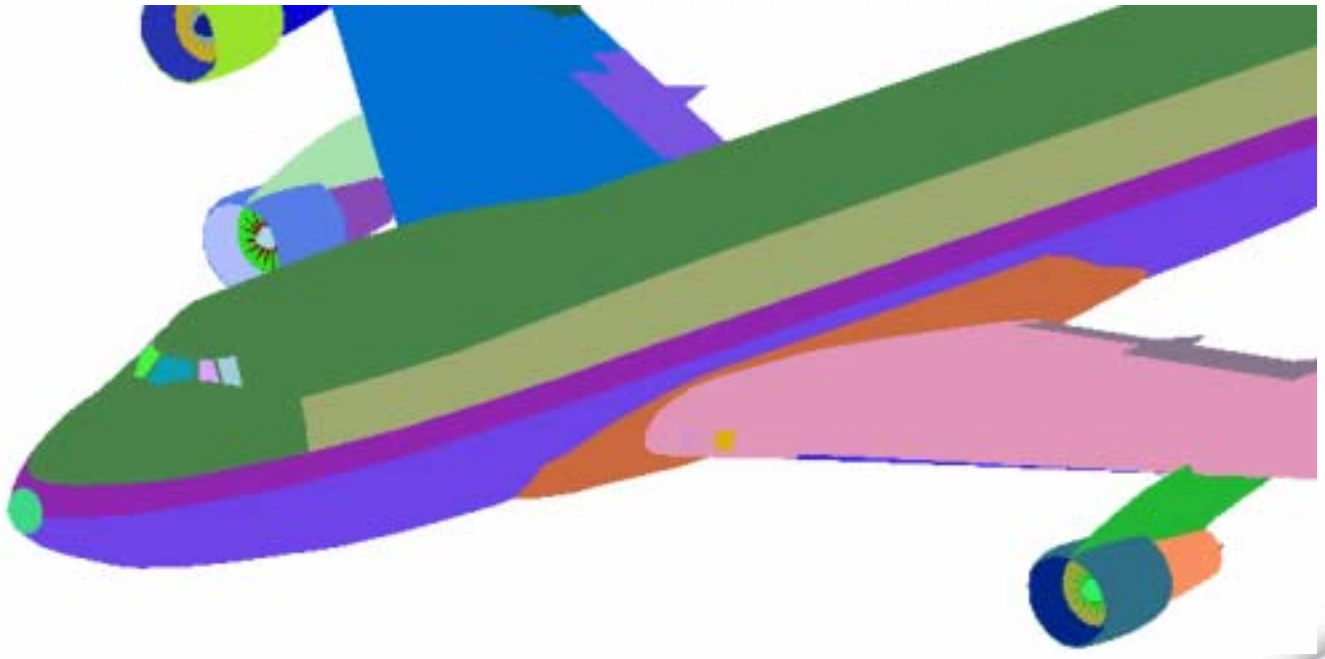
- **Any vertex that shares a position with another vertex and all the attributes do not match**
- **Discontinuity in color, texture coordinates, normal etc.**
- **Simplification can try to maintain seam positions**



Seams are borders between materials

Attribute Group

- A group of faces that are bordered by seams



Attribute Groups by color

Attribute Group Matching

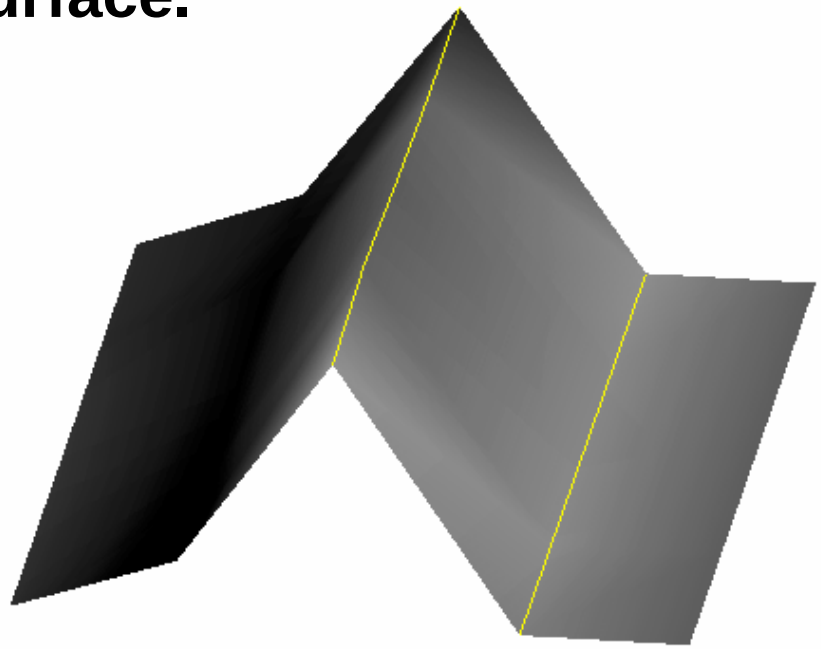
- Match Attribute Groups from low res model to reference model
- For Simplification and Normal Map Generation

Reference Model

Lo res model

Sharp Edge

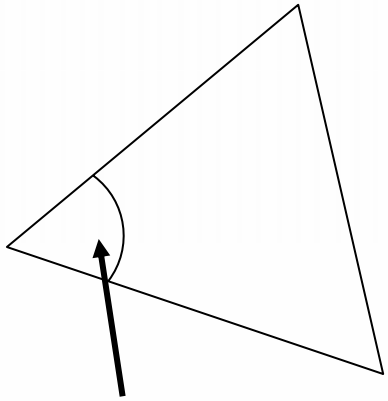
- **Angle between two faces that exceeds a specified values**
- **Typical values for sharp edge is 140 degrees. 180 is a flat surface.**



Sharp edges shown as yellow

Corner Angle

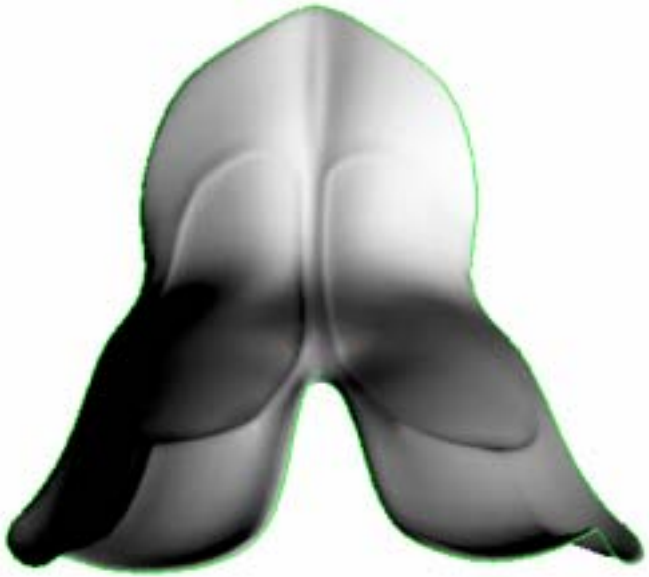
- Angle between two edges on one face
- Small corner angles produce slivers



Corner angle

Boundary

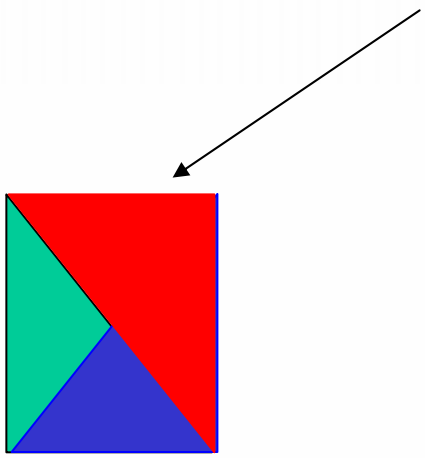
- **Edge that has only one face attached**
- **Defines the perimeter of a model**



Boundary shown in green

Bad Geometry: Folded Edges

- Two faces that share an edge
- Coplanar
- Face in opposite directions
- Simplification may have trouble with this



Shared edge between green and blue faces

Bad Geometry

- Three or more face sharing an edge
- Simplification may have trouble with this

Simplification Options

- Attempt to preserve seams, sharp edges or boundaries
- Check topology after collapse so no bad geometry is created
- When edge is collapsed (p2 → p1), placement of p1:
  - Optimal position
  - Any where along edge
  - Endpoints (p1 or p2) or edge midpoint
  - Endpoints only (vertex removal). Can be used if you have weighted vertices

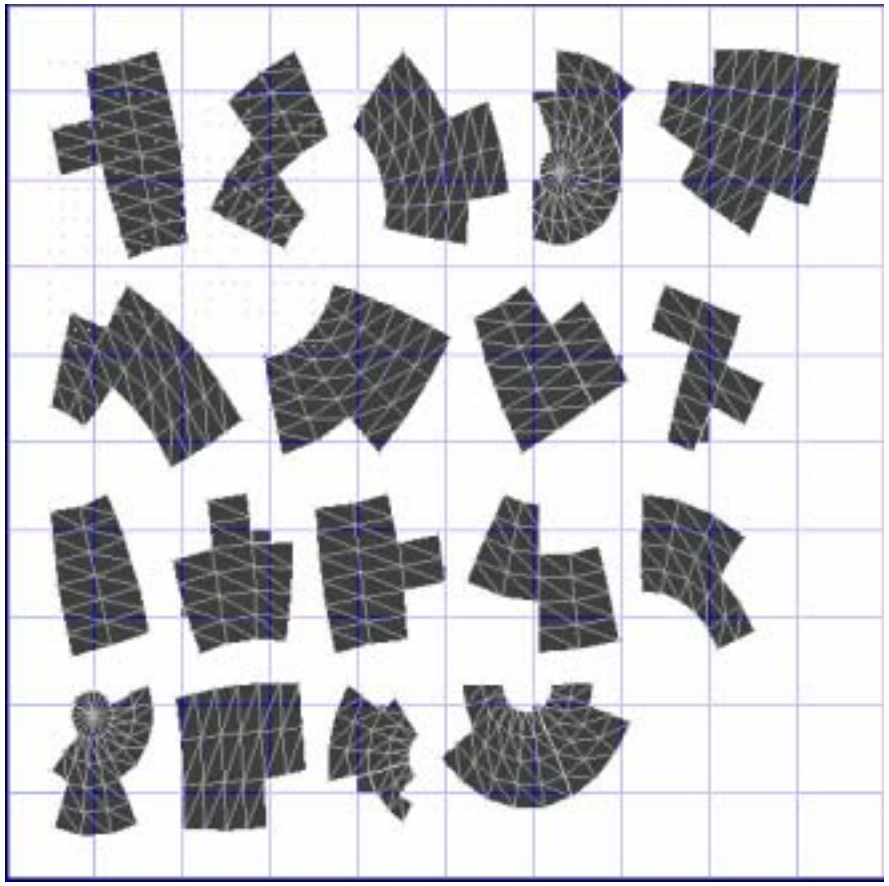
Fitting to a Reference Model

- After simplification, fit all vertices in the working model to the reference model
- Tries to make a better match of low res models to high res models
- Uses sampled data points

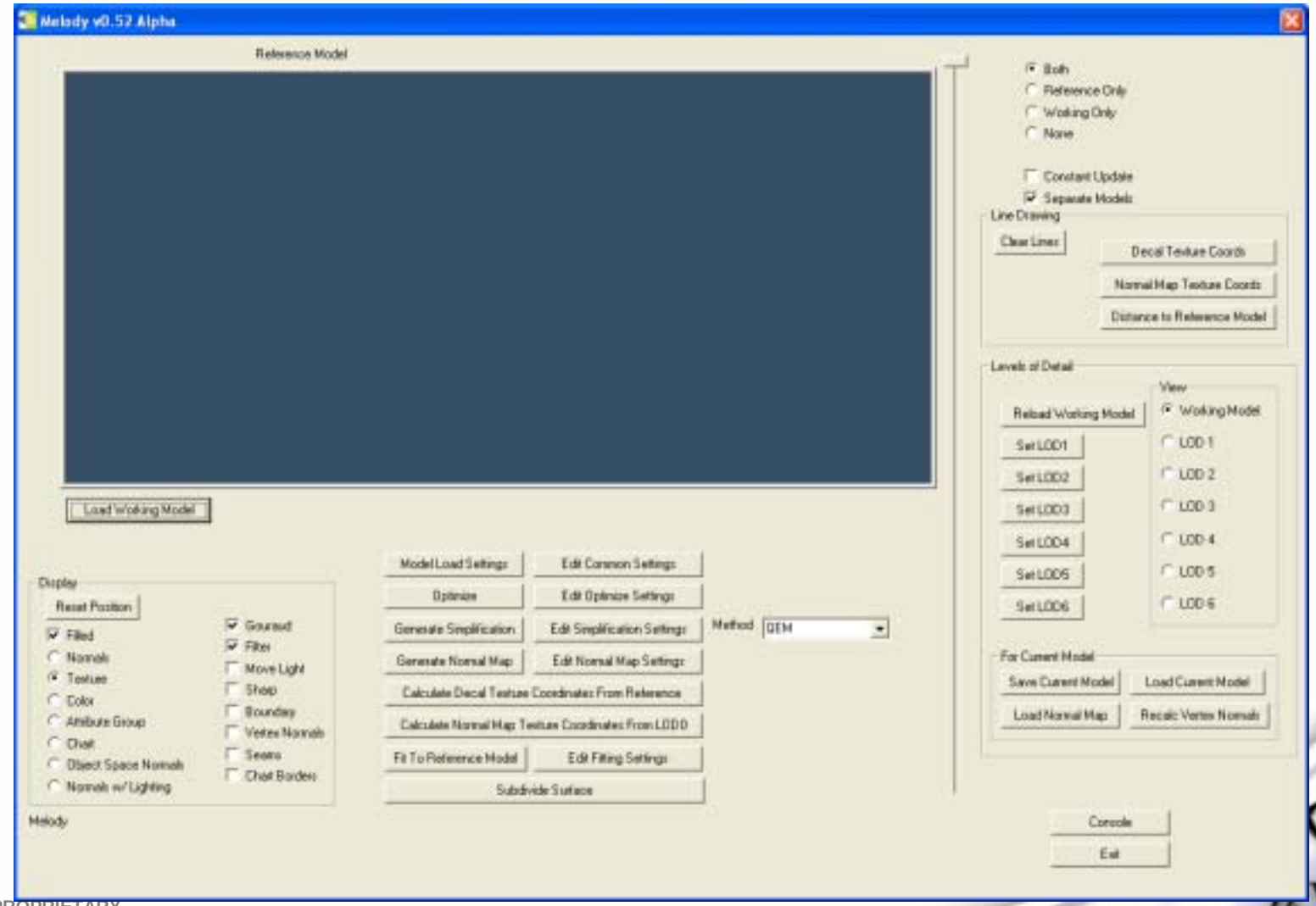
Texture Coordinate Generation by Charts

- Each face starts as a chart
- Combine charts until some criteria is met
  - Flatness
  - regular
- Flatten the charts onto a plane
- Reposition so face area is preserved and no flips occur

Atlas Automatically Created for a Sphere



Melody



Links to Related Material

- http://developer.nvidia.com/
- http://research.microsoft.com/~hhoppe/
- http://talika.eii.us.es/~titan/magica/
- http://www.cbloom.com/3d/galaxy3/index.html
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- http://graphics.cs.uiuc.edu/~garland/research/quadrics.html
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- http://www.loria.fr/~levy/Papers/2002/s2002_lscm.pdf
- http://deas.harvard.edu/~pvs/research/tmpm/