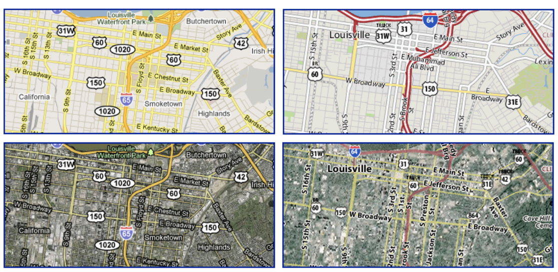
Level Of Detail
Simplification
Compression

Today's Class

- Consistency in Online Maps
- Image Simplification Example: Map Making
- 3D Geometry Compression/Optimization/ Simplification
- Mesh Processing in VTK
- More on Mesh Simplification/Subdivision
- Discussion: Your Readings & Progress Reports

Consistency (or lack of) in Online Maps



Justin O'Beirne http://www.41latitude.com/post/1059847167/consistency

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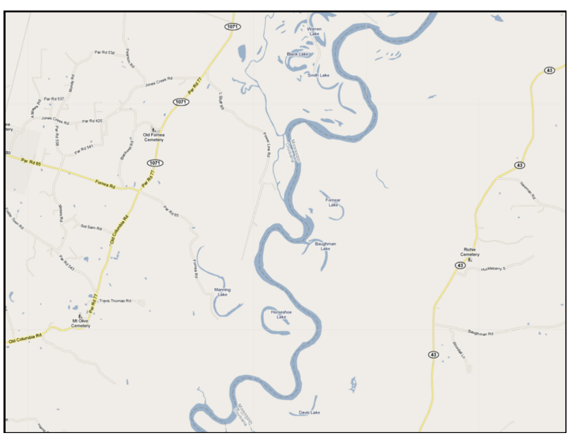

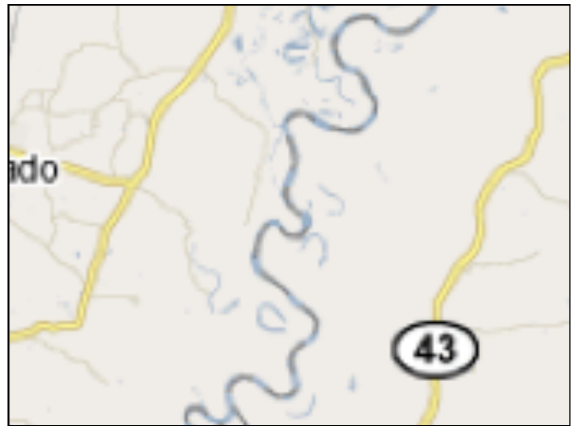

Image Simplification/Compression

- Pixel-based vs. Vector Graphics (image formats)
- Application-Specific Requirements
  - Detail Accuracy vs. Summary
- Example: Map making
  - Ok to summarize small ponds as “wetland area”?
  - Ok to eliminate islands < 1 sq mile?
  - Ok to not draw 2 lane highways/small roads?
  - Draw variation in thickness of river or fixed width?
  - Ok to simplify complex coastline/complex river path?

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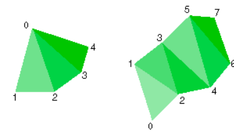
3D Geometry Simplification Goals

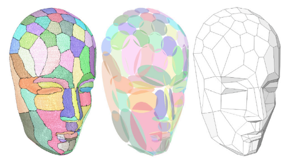
- Compression?
  - Reduce storage space/data transfer
    - Reduce # of vertices/triangles
    - Reduce representation cost for each coordinate data value (double/float/int/short/char/etc.)
- OpenGL draw cost?
  - Optimize # of vertices/triangles sent to graphics card
    - vertex array
    - quads vs. triangles vs. triangle strip vs. triangle fan
- Simplify Geometry/Connectivity/Topology

Triangle Strips / Triangle Fans

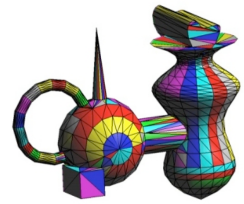
- Up to 66% more efficient?



http://techpubs.sgi.com/library/tpl/cgi-bin/getdoc.cgi?coll=nt&db=bks&fname=/SGI_Developer/Optimizer_PG/ch03.html



Cohen-Steiner, Alliez & Desbrun
Variational Shape Approximation
SIGGRAPH 2004



http://www.integrityware.com/products/poplib/poplib.html

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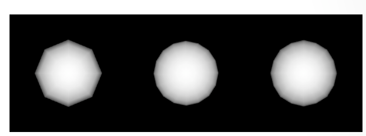
Introduction to VTK: Mesh Processing

What is a mesh?

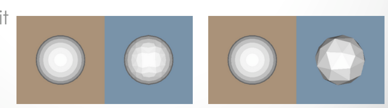
- Set of points and triangles (or generally, polygons) defined on the points
- Discrete representation of a continuous surface

What can we do with it?

- Smooth/subdivide it



- Decimate it



Subdivision

- Make a mesh look "better"
- Add more triangles
- Hopefully in good/smart/clever positions so that the new mesh looks "smoother" than the old one
- VTK Filters
  - vtkButterflySubdivisionFilter
  - vtkLoopSubdivisionFilter
  - vtkLinearSubdivisionFilter
  - vtkWindowedSincPolyDataFilter

Subdivision in VTK

```
vtkLinearSubdivisionFilter* subdivisionFilter =
  vtkLinearSubdivisionFilter::New();

subdivisionFilter->SetInputConnection(originalMesh->GetProducerPort());

subdivisionFilter->SetNumberOfSubdivisions(2);

subdivisionFilter->Update();
```

Example: http://www.vtk.org/Wiki/VTK/Examples/Cxx/Meshes/Subdivision

Decimation

- Reduce the number of triangles
- Hopefully in good/smart/clever ways so that the new mesh looks similar to the old one
- Often done for more efficient processing
- VTK Filters
  - vtkDecimatePro
  - vtkQuadricClustering
  - vtkQuadricDecimation

Decimation in VTK

```
vtkQuadricDecimation* decimateFilter =
  vtkQuadricDecimation::New();

decimateFilter->SetInputConnection(inputPolyData->GetProducerPort());

decimateFilter->Update();
```

Examples:
http://www.vtk.org/Wiki/VTK/Examples/Cxx/Meshes/QuadricDecimation
http://www.vtk.org/Wiki/VTK/Examples/Cxx/Meshes/QuadricClustering
http://www.vtk.org/Wiki/VTK/Examples/Cxx/Meshes/Decimation

Level of Detail (LOD)

- Adaptively change the number of triangles in a mesh based on whether or not you will be able to tell the difference in the rendering
- If the mesh is far away from the camera, you will not be able to see the fine detail, so don't waste time rendering it
- In the extreme case, the whole mesh is rendered in only ONE pixel, so whether it has 10,000 or just 10 triangles, it will look the same

LOD in VTK

- Create a mapper for each version of the mesh
- Instead of creating multiple actors, create a vtkLODProp3D which you will add all of the mappers to
- You can also specify properties (color, shading, etc (vtkProperty)) for each renderer

LOD in VTK

```
vtkLODProp3D* prop =
  vtkLODProp3D::New();

prop->AddLOD(lowResMapper, propertyLowRes, 0.0);

prop->AddLOD(highResMapper, propertyHighRes, 0.0);
```

(The last parameter is the approximate rendering time for the specified actor. Setting it to zero indicates that you do not have an initial guess of the time.)

Example:
http://www.vtk.org/Wiki/VTK/Examples/Cxx/Visualization/LODProp3D

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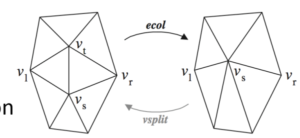
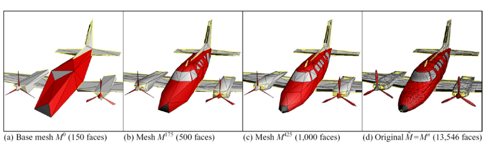
Mesh Simplification

- Local operation: edge collapse
- Choose collapse that has the least impact on geometry & discrete/ scalar attributes





(a) Base mesh M^0 (150 faces) (b) Mesh M^{175} (500 faces) (c) Mesh M^{425} (1,000 faces) (d) Original $\hat{M}=M^n$ (13,546 faces)

Hugues Hoppe "Progressive Meshes" SIGGRAPH 1996

Selective Refinement

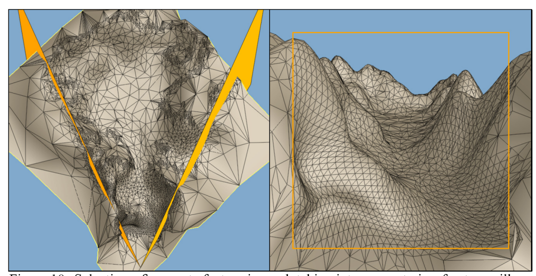
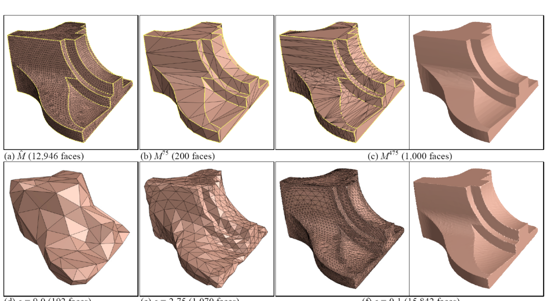


Figure 10: Selective refinement of a terrain mesh taking into account view frustum, silhouette regions, and projected screen size of faces (7,438 faces).

Hugues Hoppe "Progressive Meshes" SIGGRAPH 1996

Preserving Discontinuity Curves



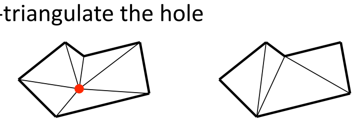
(a) $\hat{M}$ (12,946 faces) (b) M^{75} (200 faces) (c) M^{475} (1,000 faces)
(d) ϵ = 9.0 (192 faces) (e) ϵ = 2.75 (1,070 faces) (f) ϵ = 0.1 (15,842 faces)

Figure 12: Approximations of a mesh $\hat{M}$ using (b–c) the PM representation, and (d–f) the MRA scheme of Eck et al. [7]. As demonstrated, MRA cannot recover $\hat{M}$ exactly, cannot deal effectively with surface creases, and produces approximating meshes of inferior quality.

Hugues Hoppe "Progressive Meshes" SIGGRAPH 1996

Other Simplification Strategies

- Remove a vertex & surrounding triangles, re-triangulate the hole



- Merge Nearby Vertices
  - will likely change the topology…

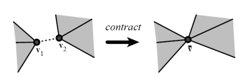


Figure 2: **Non-edge contraction.** When non-edge pairs are contracted, unconnected sections of the model are joined. The dashed line indicates the two vertices being contracted together.

from Garland & Heckbert, "Surface Simplification Using Quadric Error Metrics" SIGGRAPH 1997

When to Preserve Topology?

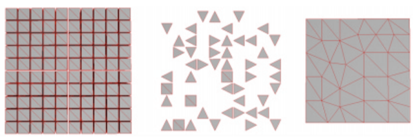
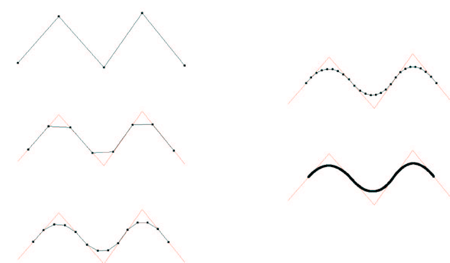


Figure 3: On the left is a regular grid of 100 closely spaced cubes. In the middle, an approximation built using only edge contractions demonstrates unacceptable fragmentation. On the right, the result of using more general pair contractions to achieve aggregation is an approximation much closer to the original.

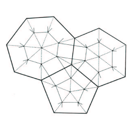
from Garland & Heckbert, "Surface Simplification Using Quadric Error Metrics" SIGGRAPH 1997

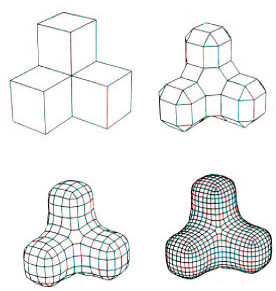
Line Subdivision: Chaikin's Algorithm



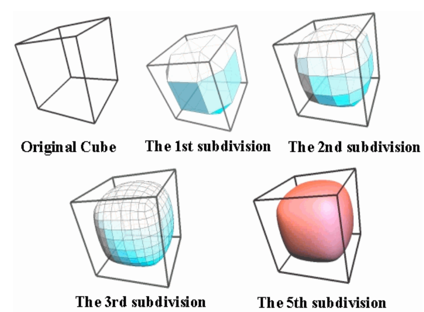
Doo-Sabin Subdivision

Idea: introduce a new vertex for each face
At the midpoint of old vertex, face centroid



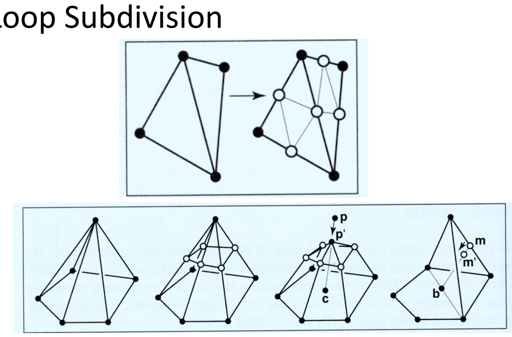


Doo-Sabin Subdivision



http://www.ke.ics.saitama-u.ac.jp/xuz/pic/doo-sabin.gif

Loop Subdivision



Shirley, Fundamentals of Computer Graphics

Loop Subdivision

Subdivision Rules. The masks for the Loop scheme are shown in Figure 4.3. For boundaries and edges tagged as *crease* edges, special rules are used. These rules produce a cubic spline curve along the boundary/crease. The curve only depends on control points on the boundary/crease.

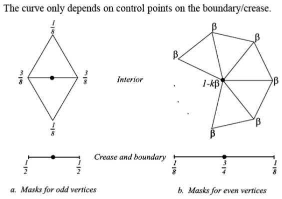


Figure 4.3: *Loop subdivision: in the picture above,* β *can be chosen to be either* $\frac{1}{n}(5/8-(\frac{3}{8}+\frac{1}{4}\cos\frac{2\pi}{n})^2)$ *(original choice of Loop [16]), or, for* $n > 3$, $\beta = \frac{3}{8n}$ *as proposed by Warren [33]. For* $n = 3$, $\beta = 3/16$ *can be used.*

SIGGRAPH 2000 course notes
Subdivision for Modeling and Animation (page 70)

Catmull Clark Subdivision

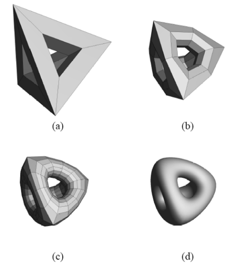


Figure 3: Recursive subdivision of a topologically complicated mesh: (a) the control mesh; (b) after one subdivision step; (c) after two subdivision steps; (d) the limit surface.

$$e_j^{i+1} = \frac{v^i + e_j^i + f_{j-1}^{i+1} + f_j^{i+1}}{4}, \quad (1)$$

where subscripts are taken modulo the valence of the central vertex v^0. (The valence of a vertex is the number of edges incident to it.) Finally, a vertex point v^i is computed as

$$v^{i+1} = \frac{n-2}{n} v^i + \frac{1}{n^2} \sum_j e_j^i + \frac{1}{n^2} \sum_j f_j^{i+1} \quad (2)$$

Vertices of valence 4 are called ordinary; others are called extraordinary.

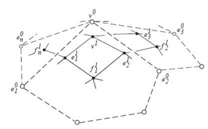
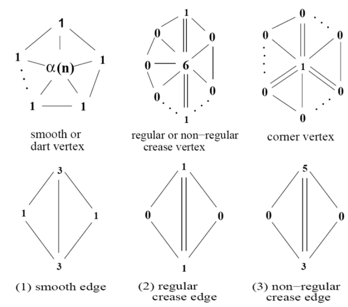


Figure 4: The situation around a vertex v^0 of valence n.

"Subdivision Surfaces in Character Animation", DeRose, Kass & Truong, SIGGRAPH 1998

Adding creases to Loop Subdivision

- Vertex & edge masks
- Limit masks
  - Position
  - Tangent



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