Polygonal Model Simplification

Geometric Model

Power plant (13 Million Triangles)

Geometric Simplification

- Replace complex objects with simpler objects
- Reduces transformation & communication time

- Note: Rasterization time doesn’t change
  - Replacements should cover similar number of pixels

Geometric Simplification - Example

courtesy of Division and Viewpoint

Automatic Simplification

- Pre-process
  - Create appropriate representation
    - multi-resolution
- Run-time
  - Extract appropriate resolution model based on viewing parameters and rendering load

Issues Needs to be Considered

1. What are the input restrictions?
2. How much is primitive count reduced?
3. How fast are primitives rendered?
4. How good can the results look?
5. How much space is used?
6. How much pre-processing
7. How much run-timing

Outline

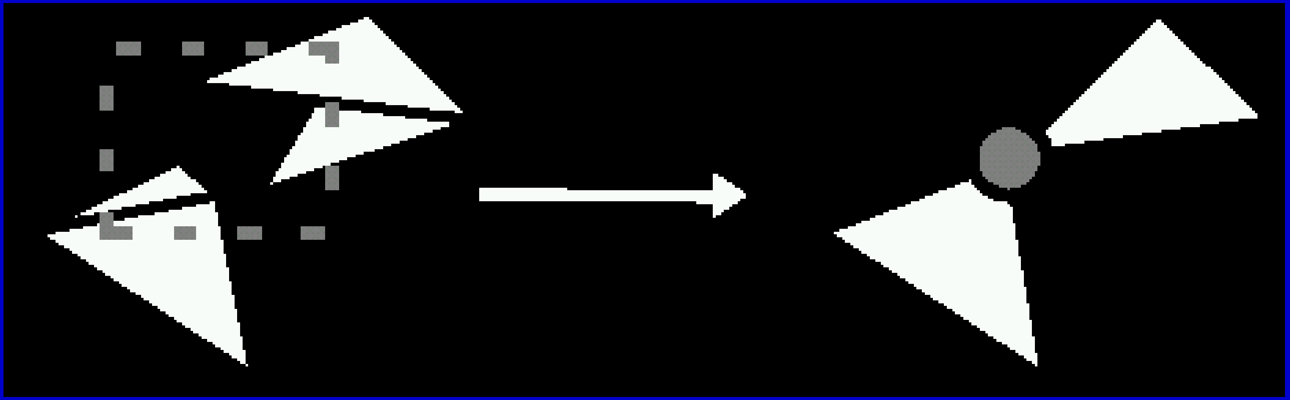
- Performing Simplification
  - Simplification Operations
  - Error Measures
- Using Simplification
  - Static Representations
  - Dynamic Representations

Simplification Operations

Types of operations
- Vertex cluster
- Vertex remove
- Edge collapse
- Vertex pair

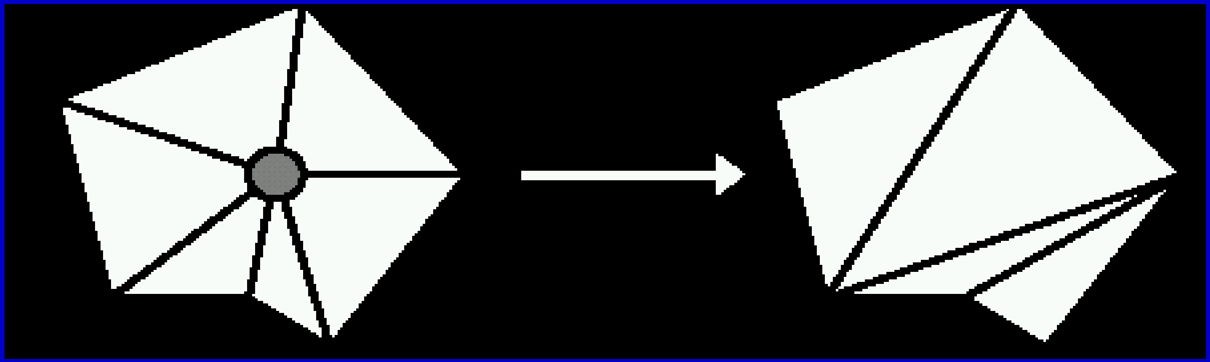
Each operation reduces model complexity by small amount, but applying many operations in succession can achieve large reductions

Vertex Cluster



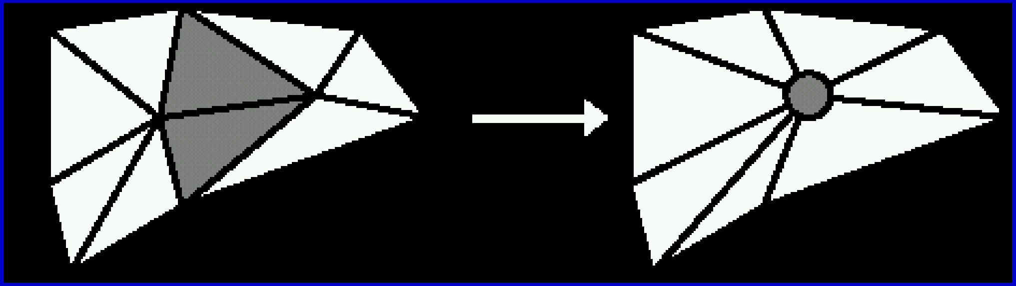
- Merge vertices based on geometric proximity
- Triangles with repeated vertices degenerate to edge or point
- General and robust
- Not usually attractive

Vertex Remove



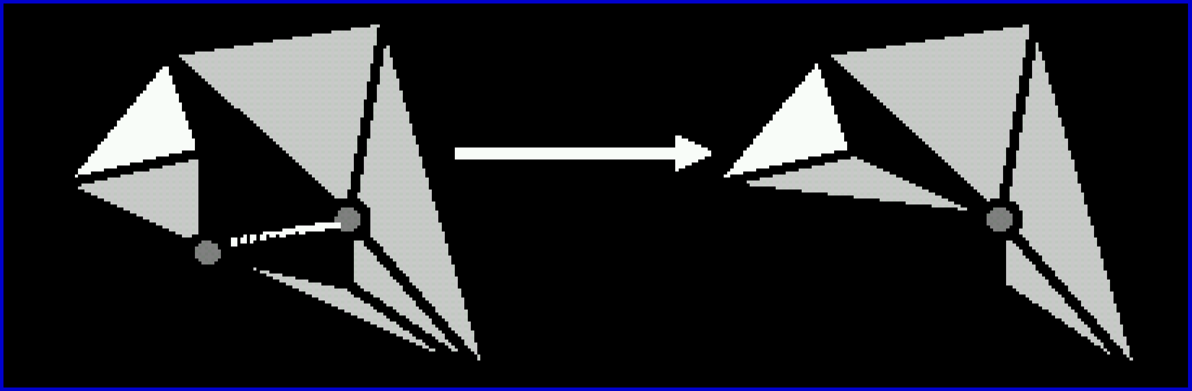
- Remove vertex and adjacent faces
- Fill hole with new triangles
  - many possible triangulations
- Requires manifold surface around vertex surface
- Preserves local topological structure
  - typically more attractive

Edge Collapse



- Merge two edge vertices to one
  - choose position and attributes for vertex
- Delete degenerate triangles
  - those containing both vertices
- Smooth transitions

Vertex Pair



- Merge any two vertices
  - based on geometry, topology, etc.
- More flexibility than edge collapse
- More local control than vertex cluster

Operation Considerations

- Attention to topology promotes better appearance
- Allowing non-manifolds increases robustness and ability to simplify
- Collapse-type operations allow smooth transitions
- Vertex remove affects smaller portion of mesh than edge collapse
- Subset of vertex remove equivalent to subset of edge collapse

Performing Simplification

- Measure cost of possible operations according to error measure
  - Crucial to simplification quality
- Place operations in queue according to error
- Perform operations in queue
  - After each operation, re-evaluate error of operations in neighborhood operations

Error Measurements

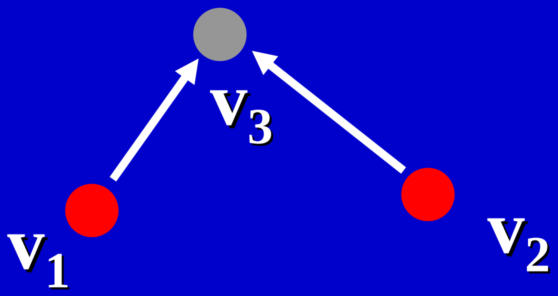
- Guide simplification process
  - Making better choices produces better simplifications
- Know quality of results
  - Object-space error bounds describes quality
- Balance quality for large environments
  - What error bound for a given polygon count

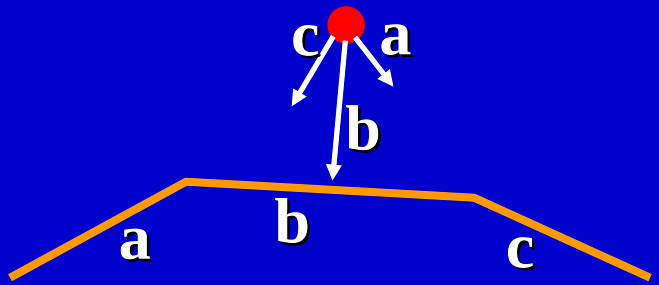
Geometric Error Metrics

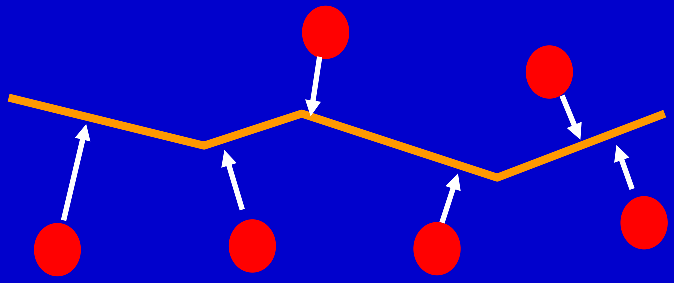
- Promote accurate 3D shape preservation
- Also preserves screen-space shape

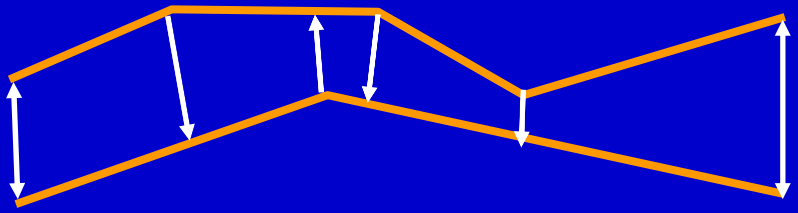
- Some Error Metrics:
  - Vertex-Vertex Distance
  - Vertex-Plane Distance
  - Point-Surface Distance
  - Surface-Surface Distance

Geometric Error Metrics









Attribute Error Metrics

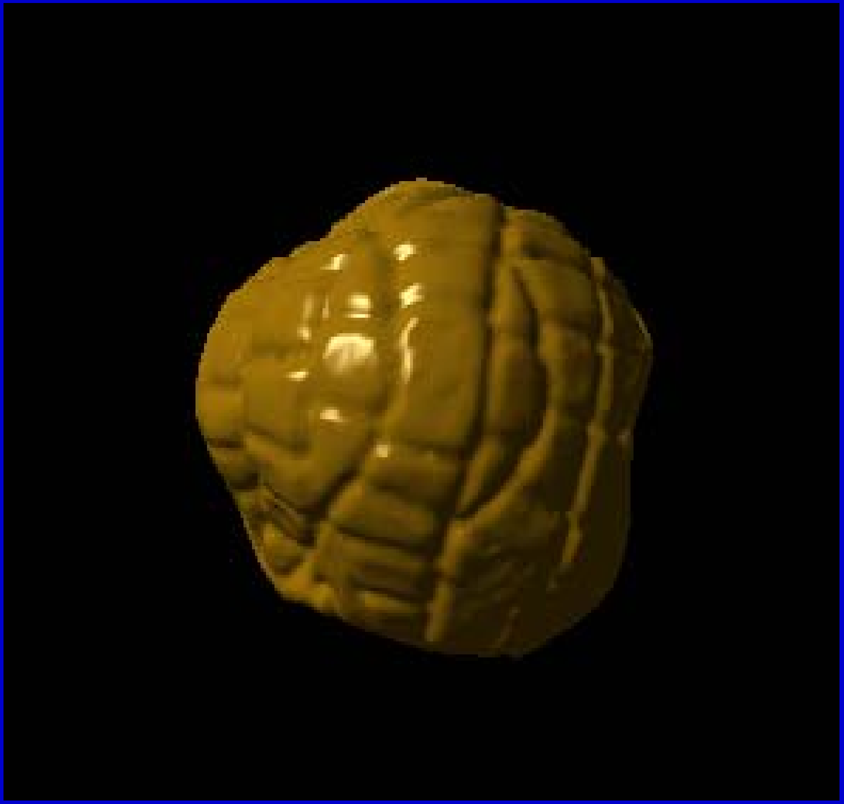
- Attributes include colors, normals, and texture coordinates
- Promote accuracy of final pixel colors
  - Vertex-Vertex Distance
  - Vertex-Plane Distance
  - Point-Surface Distance
  - Surface-Surface Distance

Appearance Preservation

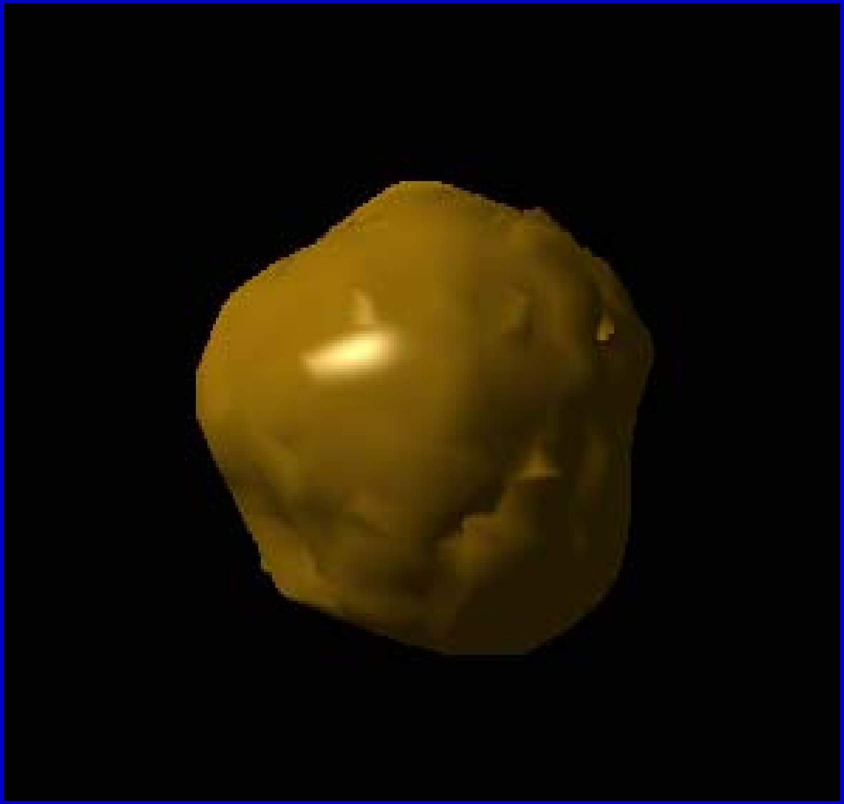
- Preserve three appearance attributes:
  - Surface Position
  - Surface Curvature
  - Material Color

- Each may require different sampling

Normals Undersampled

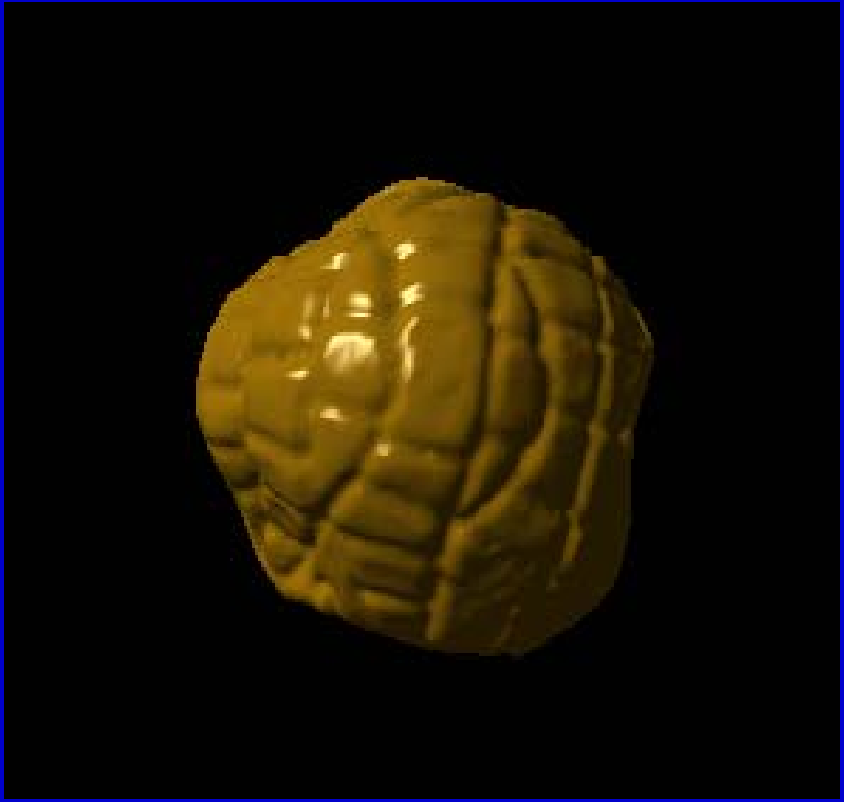


13,433 triangles

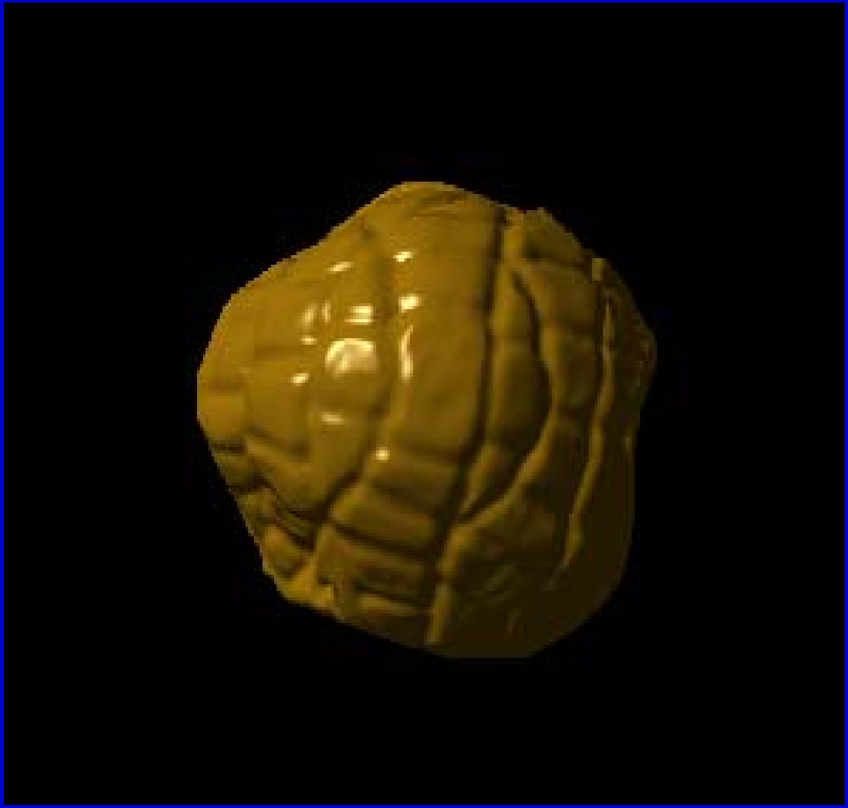


1,749 triangles

Normals Properly Sampled



13,433 triangles



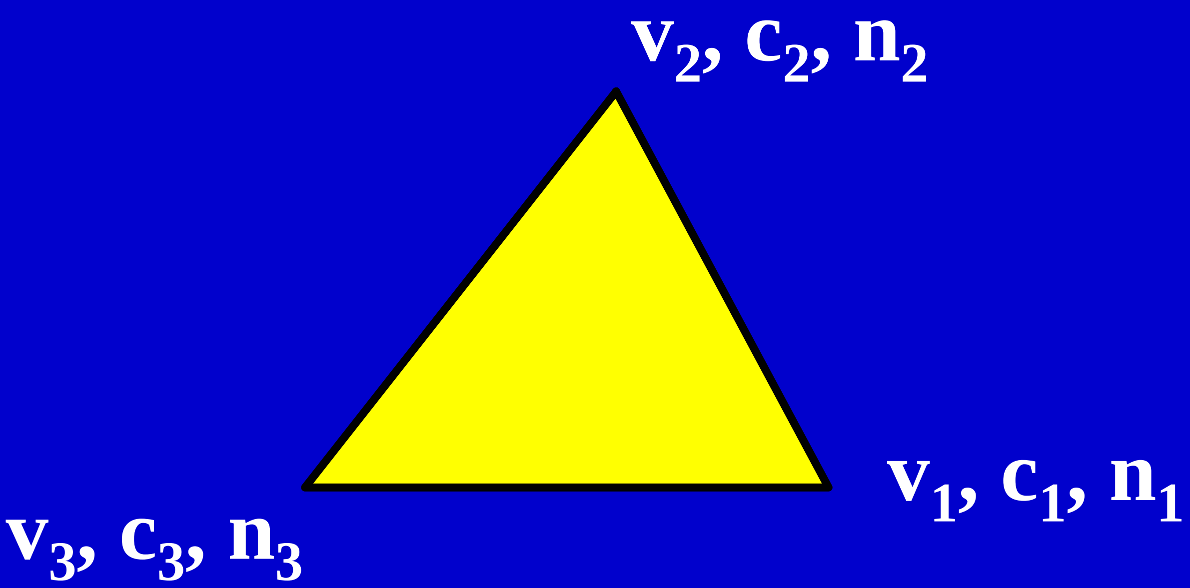
1,749 triangles

Example: Appearance-Preserving Simplification

[Cohen et al. Siggraph 98]

- Colors and normals stored in texture and normal maps
- Texture deviation computed using parametric correspondence
- Preserves colors and normals, bounding texture motion in object and screen space

Traditional Polygonal Representation



v_2, c_2, n_2

v_1, c_1, n_1

v_3, c_3, n_3

v = vertex coordinate = (x,y,z)

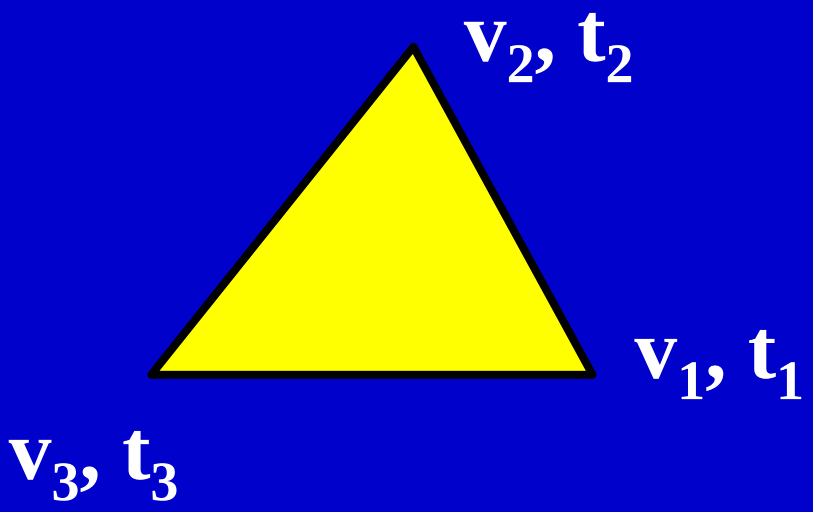
c = color = (r,g,b)

n = normal = (n_x,n_y,n_z)

Traditional Simplification

- Filters surface position, colors, and normals
- Must filter all three *equally*

Decoupled Representation



texture map

		c_2	
	c_3	c_1	

normal map

		n_2	
	n_3	n_1	

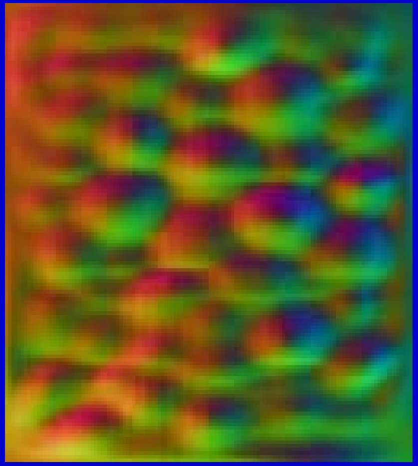
v = vertex coordinate = (x,y,z)
t = texture coordinate = (u,v)
c = color = (r,g,b)
n = normal vector = (n_x,n_y,n_z)

Decoupled Approach

- Simplification filters surface position and texture coordinates
- Color and normal attributes filtered per-pixel (mip-mapping, etc.)

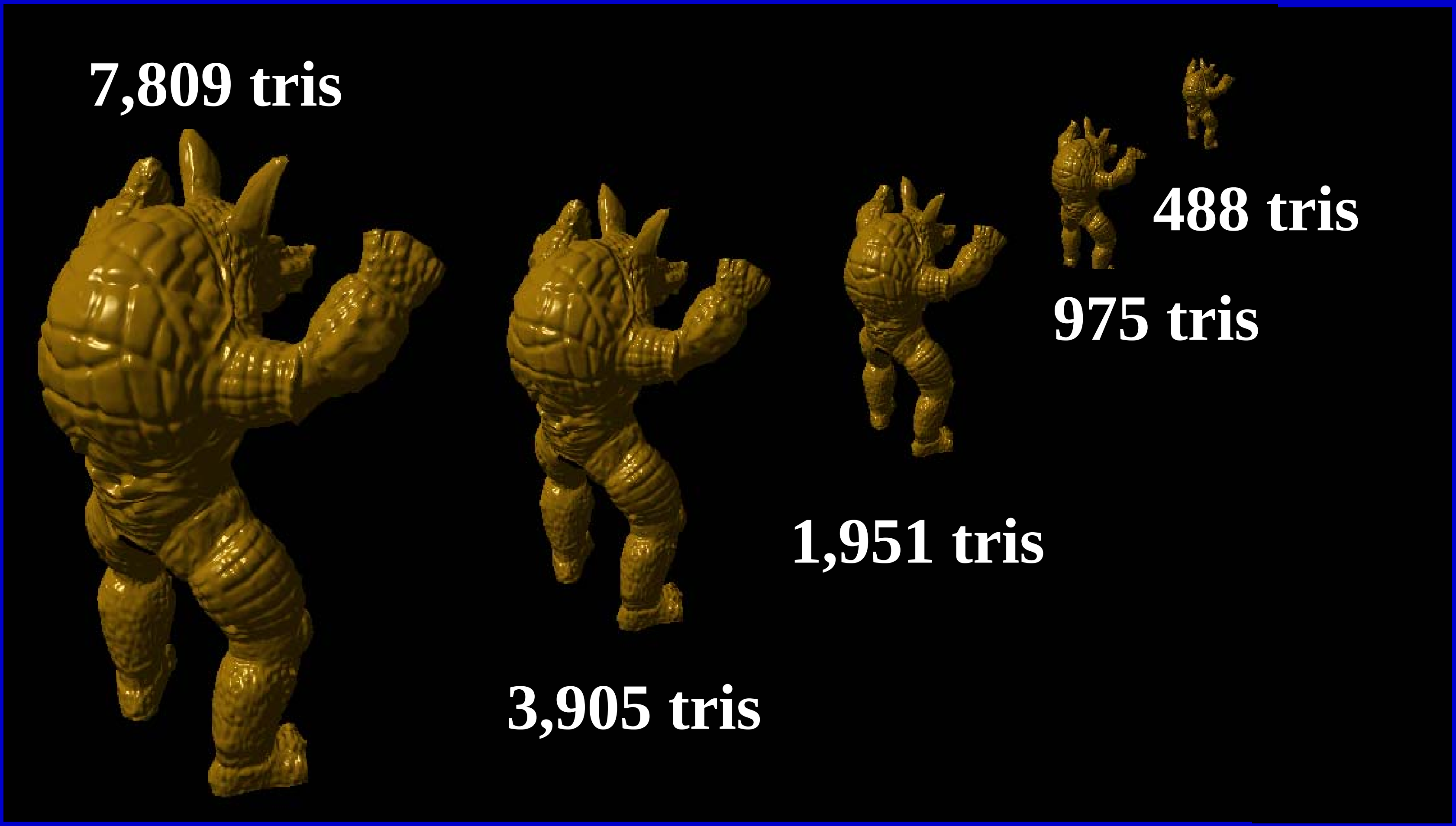
Sample Normal Map

polygonal surface patch



normal map

Appearance-Preserving Results



Appearance-Preserving Simplification

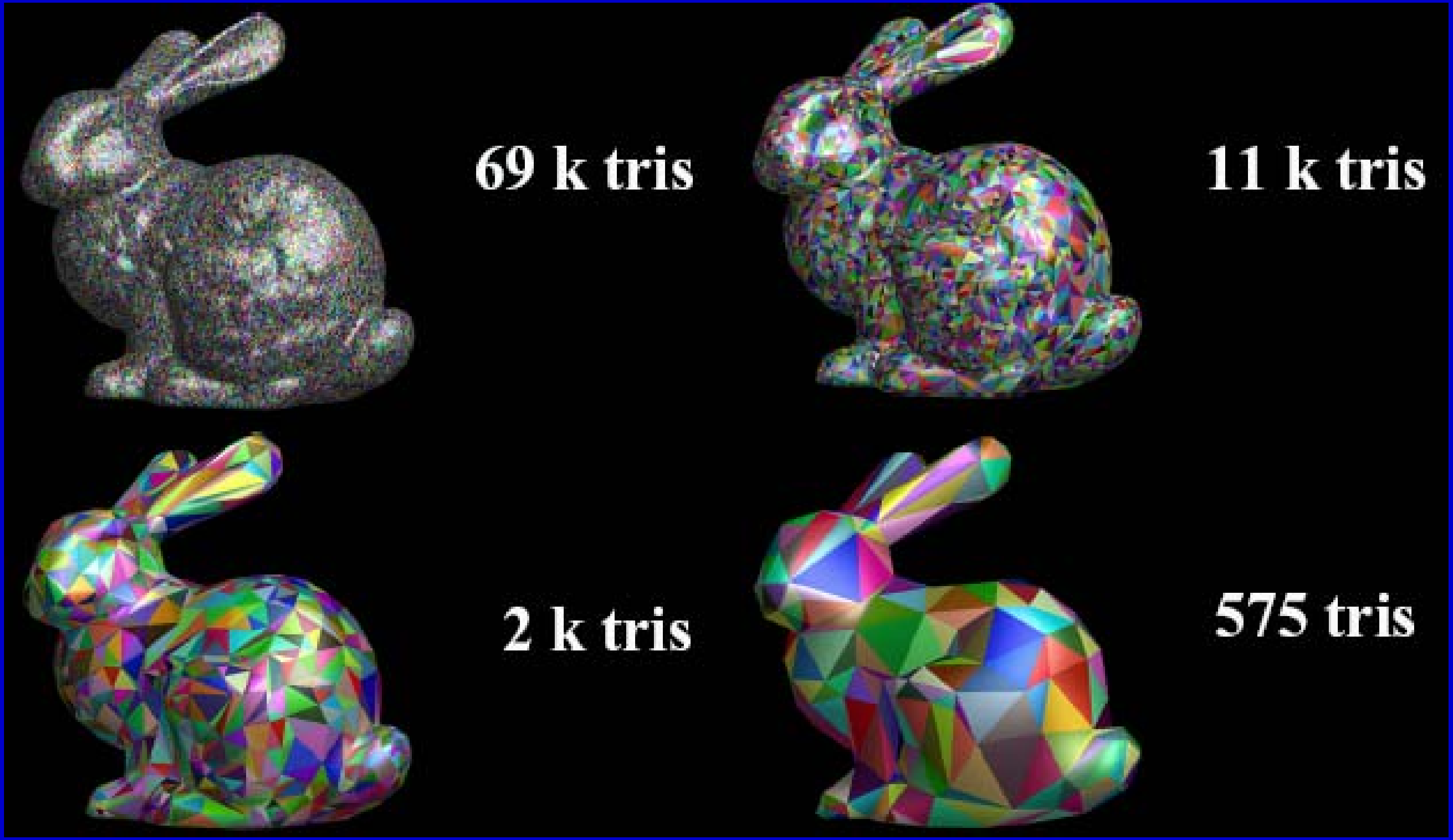
Using of Simplification

Multi-resolution representations

- Static levels of detail
  - -Individual, complete simplified meshes

- Dynamic representations
  - - Tree structure traversed & adapted at runtime

Static Levels of Details



Static Levels of Details

Pre-process

- Generate set of independent levels of detail

Run-time

- Select level of detail based on distance from viewpoint

Advantages

- Fairly efficient storage (2x original)
- No significant run-time overhead

Disadvantages

- Requires per-object simplification
- Not good for spatially large objects

Dynamic Levels of Details

Pre-process

- Generate tree of simplification operations

Run-time

- Refine/coarsen current model according to viewpoint

Advantages

- Allows finer control of tessellation

Disadvantages

- More run-time computation and complexity
- Difficult for retained-mode graphics

Questions Revisited

1. What are the input restrictions

- Vertex cluster and vertex pair allow general triangle input
- Vertex remove and edge collapse usually apply to manifold meshes

2. How much is primitive count reduced?

- Topology modifying algorithms can often reduce more for complex environments
- Dynamic simplification can reduce more than static for a given error bound

Questions Revisited

3. How good can the results look

- Topology-preserving techniques usually produce better results than object merging
- Attention to attributes as well as geometry important for preserving appearance

4. How much space is used?

- Dynamic approach requires more space at run-time than static

5. How much pre-processing time?

- Vertex-vertex and vertex-plane metrics generally faster than point-surface and surface-surface metrics

References

- Bajaj, Chandrajit and Daniel Schikore. Error-bounded Reduction of Triangle Meshes with Multivariate Data. *SPIE*. vol. 2656. 1996. pp. 34-45.
- Cohen, Jonathan, Dinesh Manocha, and Marc Olano. Simplifying Polygonal Models using Successive Mappings. Proceedings of IEEE Visualization '97. pp. 395-402.
- Cohen, Jonathan, Marc Olano, and Dinesh Manocha. Appearance-Preserving Simplification. Proceedings of ACM SIGGRAPH 98. pp. 115-122.
- Cohen, Jonathan, Amitabh Varshney, Dinesh Manocha, Gregory Turk, Hans Weber, Pankaj Agarwal, Frederick Brooks, and William Wright. Simplification Envelopes. Proceedings of SIGGRAPH 96. pp. 119-128.
- DeFloriani, Leila, Paola Magillo, and Enrico Puppo. Building and Traversing a Surface at Variable Resolution. Proceedings of IEEE Visualization ‘97. pp. 103-110.
- Erikson, Carl and Dinesh Manocha. GAPS: General and Automatic Polygonal Simplification. Proceedings of 1999 ACM Symposium on Interactive 3D Graphics. pp. 79-88.

References

- Garland, Michael and Paul Heckbert. Simplifying Surfaces with Color and Texture using Quadric Error Metrics. Proceedings of IEEE Visualization '98. pp. 263-269, 542.
- Garland, Michael and Paul Heckbert. Surface Simplification using Quadric Error Bounds. Proceedings of SIGGRAPH 97. pp. 209-216.
- Guéziec, André. Surface Simplification with Variable Tolerance. Proceedings of Second Annual International Symposium on Medical Robotics and Computer Assisted Surgery (MRCAS '95). pp. 132-139.
- Hoppe, Hugues. Progressive Meshes. Proceedings of SIGGRAPH 96. pp. 99-108.
- Hoppe, Hugues. View-Dependent Refinement of Progressive Meshes. Proceedings of SIGGRAPH 97. pp. 189-198.
- Hoppe, Hugues, Tony DeRose, Tom Duchamp, John McDonald, and Werner Stuetzle. Mesh Optimization. Proceedings of SIGGRAPH 93. pp. 19-26.
- Hoppe, Hugues H. New Quadric Metric for Simplifying Meshes with Appearance Attributes. Proceedings of IEEE Visualization '99. pp. 59-66.

References

- Klein, Reinhard, Gunther Liebich, and Wolfgang Straßer. Mesh Reduction with Error Control. Proceedings of IEEE Visualization '96.
- Lindstrom, Peter and Greg Turk. Fast and Memory Efficient Polygonal Simplification. Proceedings of IEEE Visualization '98. pp. 279-286, 544.
- Luebke, David and Carl Erikson. View-Dependent Simplification of Arbitrary Polygonal Environments. Proceedings of SIGGRAPH 97. pp. 199-208.
- Ronfard, Remi and Jarek Rossignac. Full-range Approximation of Triangulated Polyhedra. Computer Graphics Forum. vol. 15(3). 1996. pp. 67-76 and 462.
- Rossignac, Jarek and Paul Borrel. Multi-Resolution 3D Approximations for Rendering. Modeling in Computer Graphics. Springer-Verlag1993. pp. 455-465.
- Xia, Julie C., Jihad El-Sana, and Amitabh Varshney. Adaptive Real-Time Level-of-Detail-Based Rendering for Polygonal Models. IEEE Transactions on Visualization and Computer Graphics. vol. 3(2). 1997. pp. 171-183.