Progressive Compression and Transmission of Arbitrary Triangular Meshes

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Motivations

- Archiving with limited storage resource
- Reduce network traffic
- 3D database access
- Quick access for direct manipulation
- Progressive, level-of-detail
Related Work

- Multi-resolution schemes.
- Compression of meshes.
- Hoppe, SIGGRAPH96: progressive meshes.
- Popovic and Hoppe, SIGGRAPH97: simplicial complexes.
- Taubin et al. SIGGRAPH98: progressive forest split: manifold.
- Gueziec et al. VIS99: non-manifold.
- Pajarola and Rossignac, ‘99: batches of refinements.
- Cohen-or et al. VIS99: arbitrary (topology/genus preserving).
Contributions

- Most general: any triangle set!

Our Scheme

Set of triangles: non-manifold, non-consistent

Manifold

Simple
Contributions

- Most general: any triangle set (non-manifold, not a simplicial complex…).
- Fully progressive: up to a single triangle!
Contributions

- Most general: any triangle set (non-manifold, not a simplicial complex...).
- Fully progressive: up to a single triangle.
- Flexible: Topology preserving vs. non-preserving.
Contributions

- Most general: any triangle set (non-manifold, not a simplicial complex...).
- Fully progressive: up to a single triangle.
- Flexible: visual quality vs. Compression and topology preservation.
- Mapping between the surface of each level and geomorph.
Outline of the Talk

- Layering structure
- Encoding the layers:
  - Encoding geometry
  - Encoding connectivity
- Progressive model:
  - Topology preserving decomposition
  - Topology non-preserving decomposition
- Results
- Future work
Layering Structure

Breadth first search from a source vertex(s):
Vertex Layers $\rightarrow$ Edge Classification $\rightarrow$ Triangle Layers

Chords
Transversals

Layer 1
Layer 2
Geometric Primitives

- **Branching vertex** – a vertex which is adjacent to more than, or less than, two vertices in the same layer.
- **Contour** – ordered list of non-branching vertices from the same layer.
- **Triangle strip** – an ordered list of adjacent triangles from one layer between two contours.
Strips…
Bubbles and Fans

“Bubble”

“Fan”
Encoding the Layers

- Encoding geometry:
  - Bounding box
  - Predictive coding of vertex positions using contours in the layers

- Encoding connectivity:
  - Vertex-layer layout
  - Triangle strips and bubbles
  - Triangle fans
Geometry Encoding

- For each layer, first encode the branching vertices alone.
- For each contour in the layer,
  - Directly encode the starting vertex.
  - For each successive vertex:
    - Compute the prediction and correction vectors.
    - Quantize correction vectors.
  - Entropy encode the correction codes.
Prediction Order

0th order representation (explicit vertex coordinates)

1st order representation ($\Delta$-vertex coordinate)

2nd order representation ($\Delta^2$-vector coordinates)
Quantization and Prediction

\[(r, \phi, \theta)\]

\([0,1] \ [0,2\pi] \ [0,\pi]\]

Second-order prediction

Error Propagation

Predict from coded position
Not from original position!
Encoding of Triangle Strips...

Parent contour

Parent contour

Child contour
Bubble Encoding

Bubble encoding:

Parent contour

Child contour

102, (0,3,1), (1,3,2)
Encoding of Triangle Strips

Strip encoding: 010010110...
Actual Coding of Connectivity

- Encoding triangle strips and bubbles
- Encoding triangle fans
- Group 4 bits as a symbol
- Use Huffman coding
Incremental Transmission and Display

Layered Progressive Decomposition?

- Remove whole layers?
- Remove vertices inside layers?

Artifacts:
Alternating Decomposition

- *Intra-layer* decomposition (vertices within individual contours are decimated)

- *Inter-layer* decomposition (decimate whole contours)
Intra-layer Decomposition

- Remove every other vertex beside the start and end
- Leave at least three vertices in the contour
Intra-layer Decomposition

- Remove every other vertex beside the start and end
- Leave at least three vertices in the contour
Intra-layer Decomposition

- Remove every other vertex beside the start and end
- Leave at least three vertices in the contour
Intra-layer Geometry Encoding

- Reconstruction: quadratic prediction + correction

computed

stored
Intra-layer Connectivity Encoding

Retriangulation is done connecting both sides to avoid long triangles.
D1 and D2 are used in reconstruction for locating the boundary of the decimated vertex.
Inter-layer Decomposition

- The two adjacent contours do not include branching points
- The gap is triangulatable
- The error does not exceed the tolerance
Inter-layer Decomposition

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Inter-layer Decomposition

- The two adjacent contours do not include branching points
- The gap is triangulatable
- The error does not exceed the tolerance
Inter-layer Geometry Encoding

- Second order prediction encoding
Inter-layer Connectivity Encoding

2-3-2-1-4-0
Reconstruction…

2-3-2-1-4-0
Reconstruction...

2-3-2-1-4-0
Reconstruction...

2-3-2-1-4-0
Reconstruction...

2-3-2-1-4-0
Reconstruction…

2-3-2-1-4-0
Reconstruction…

2-3-2-1-4-0
Reconstruction…
Topology Preserving Decomposition
Topology Non-preserving Decomposition

- Triangle contraction
- Priority queue to determine the contraction order
- Applies to non manifold features
- Details in the paper…
Topology Non-preserving Decomposition
Results: Progressive Connectivity

Topology changing reconstruction (4.78 bytes per triangle)

Layering based reconstruction (3.32 bytes per triangle)
Horse
Crocodile
## Statistics

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<thead>
<tr>
<th>Model</th>
<th>Triangles</th>
<th>Bits/triangle</th>
<th>Triangle Area</th>
<th>Total Bits</th>
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</table>
Summary

- Layered decomposition:
  - Topology preserving: intra-layer and inter-layer geometry and connectivity encoding.
  - Topology non-preserving: triangle contraction encoding.

- Results:
  - Average of between 5~6 bits per triangle (connectivity).
  - Total size of around 30% of the original models.

- Fully progressive compression method.
- Applies to any set of triangles.
- Flexible (in terms of topology).
- Supports mapping and geomorph.
Future Work

- Optimization of starting positions of the layering structure.
- Using many starting points or contours.
- Optimization of intra and inter level simplifications in terms of errors imposed.
- Higher order geometry predictions.