Progressive Compression and Transmission of Arbitrary Triangular Meshes

Chandrajit Bajaj, Valerio Pascucci, Guozhong Zhuang,

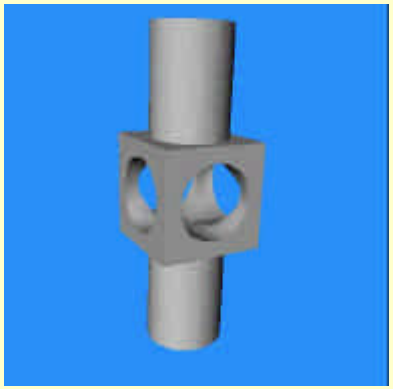
Center For Computational Visualization

Computer Sciences & TICAM

University Of Texas

Austin, TX 78712

Motivations



- Archiving with limited storage resource
- Reduce network traffic
- 3D database access
- Quick access for direct manipulation

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- Progressive, level-of-detail

Related Work

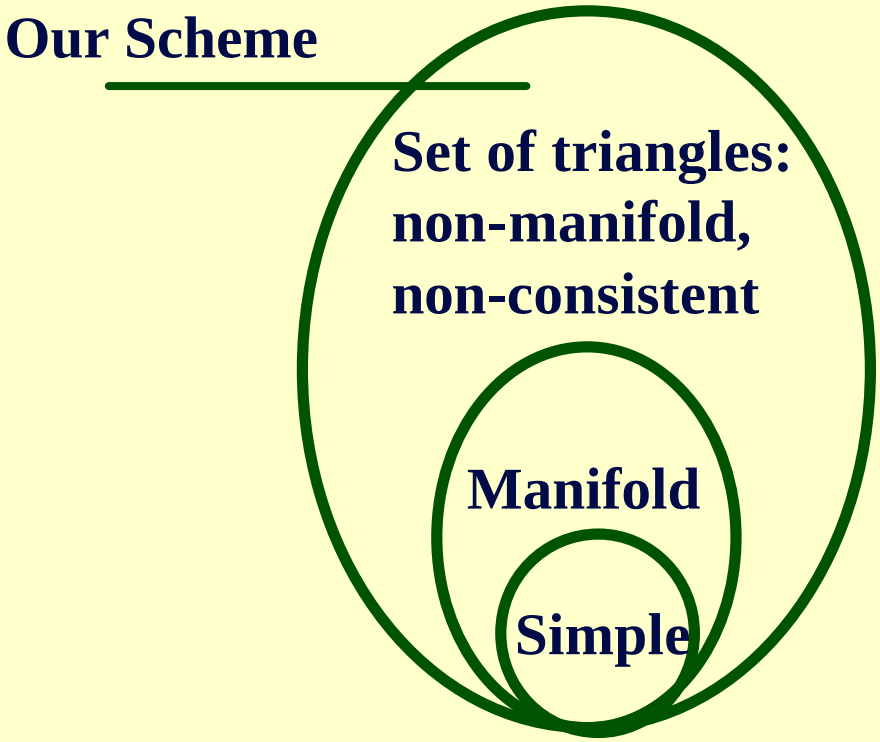
- Multi-resolution schemes.

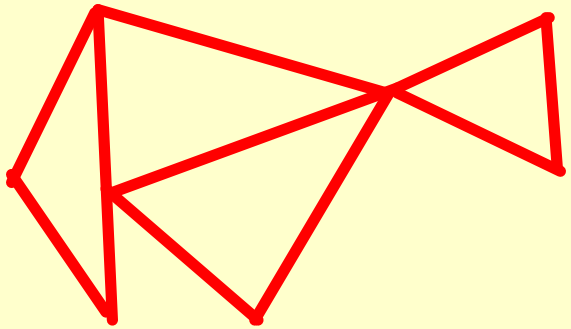
- Compression of meshes.

- 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

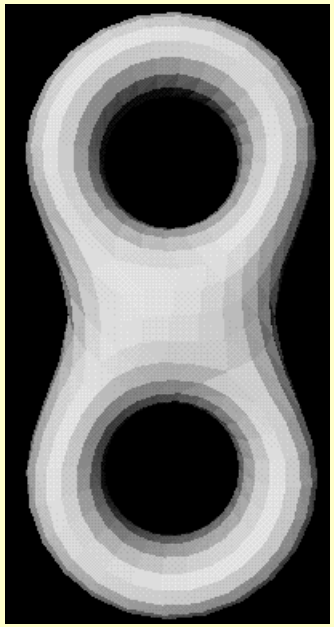
- Most general: any triangle set!

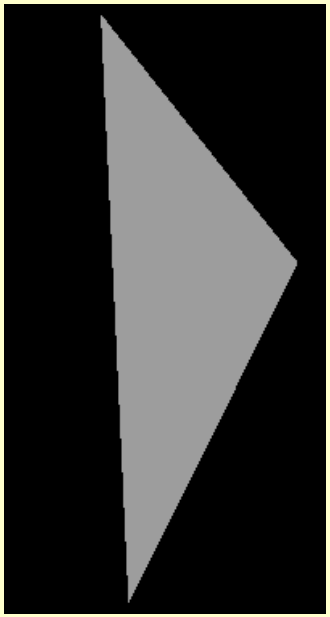




Contributions

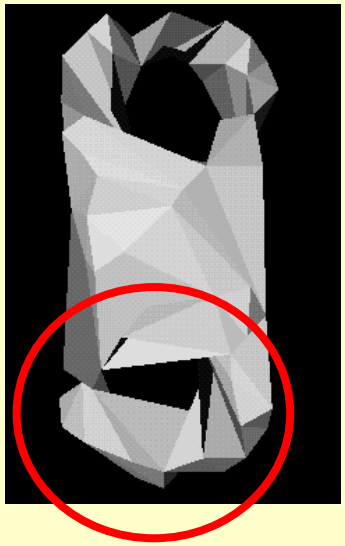
- Most general: any triangle set (non-manifold, not a simplicial complex…).
- Fully progressive: up to a single triangle!

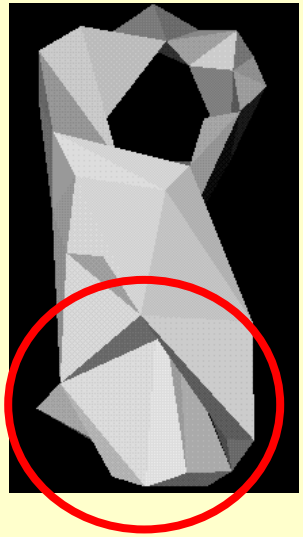




Contributions

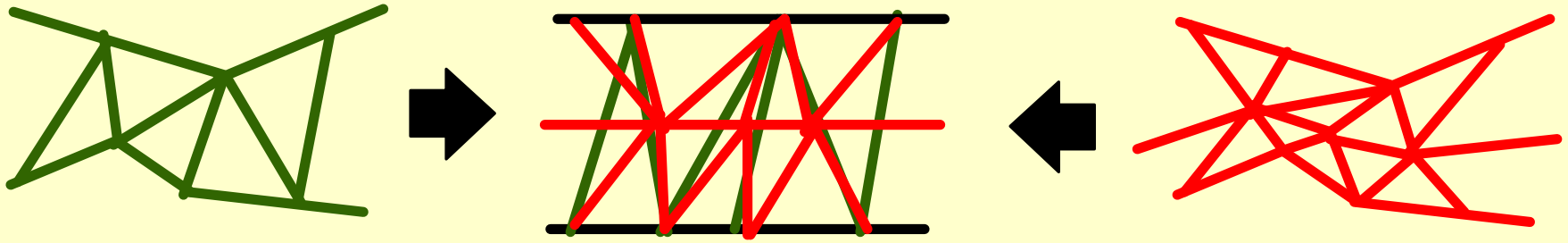
- Most general: any triangle set (non-manifold, not a simplicial complex…).
- Fully progressive: up to a single triangle.
- Flexible: Topology preserving vs. non-preserving.





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.

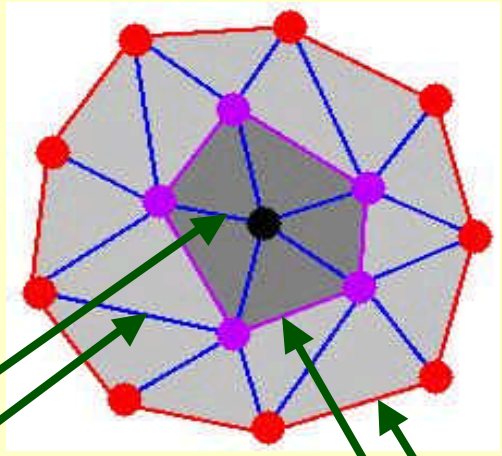


Outline of the Talk

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

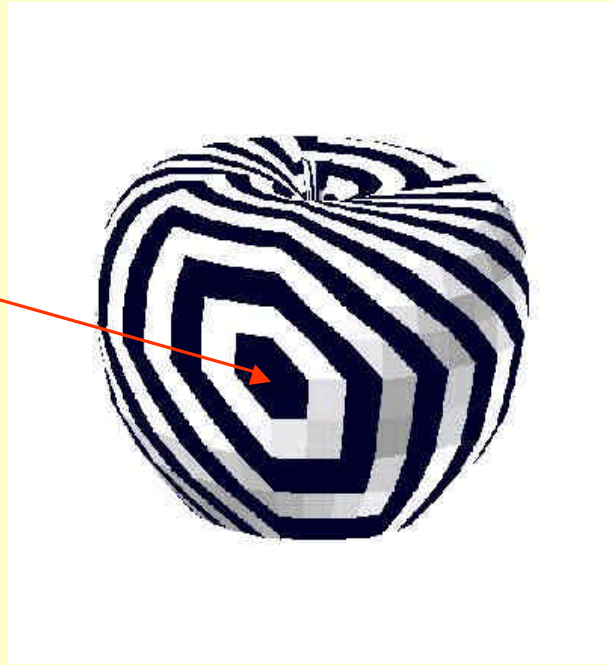
Layering Structure

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



Chords

Transversals

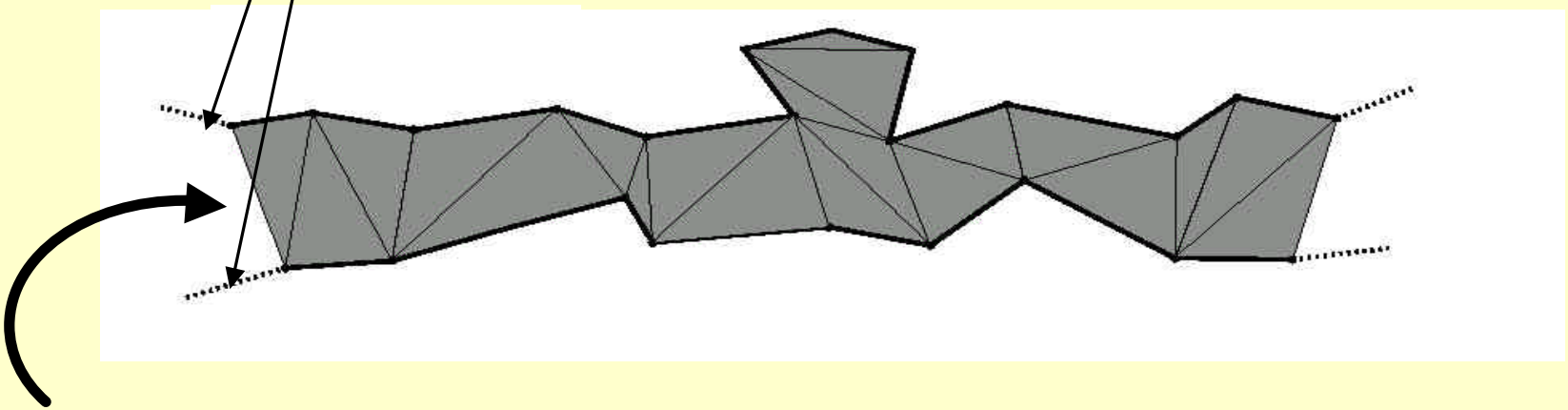


Layer 1

Layer 2

Geometric Primitives

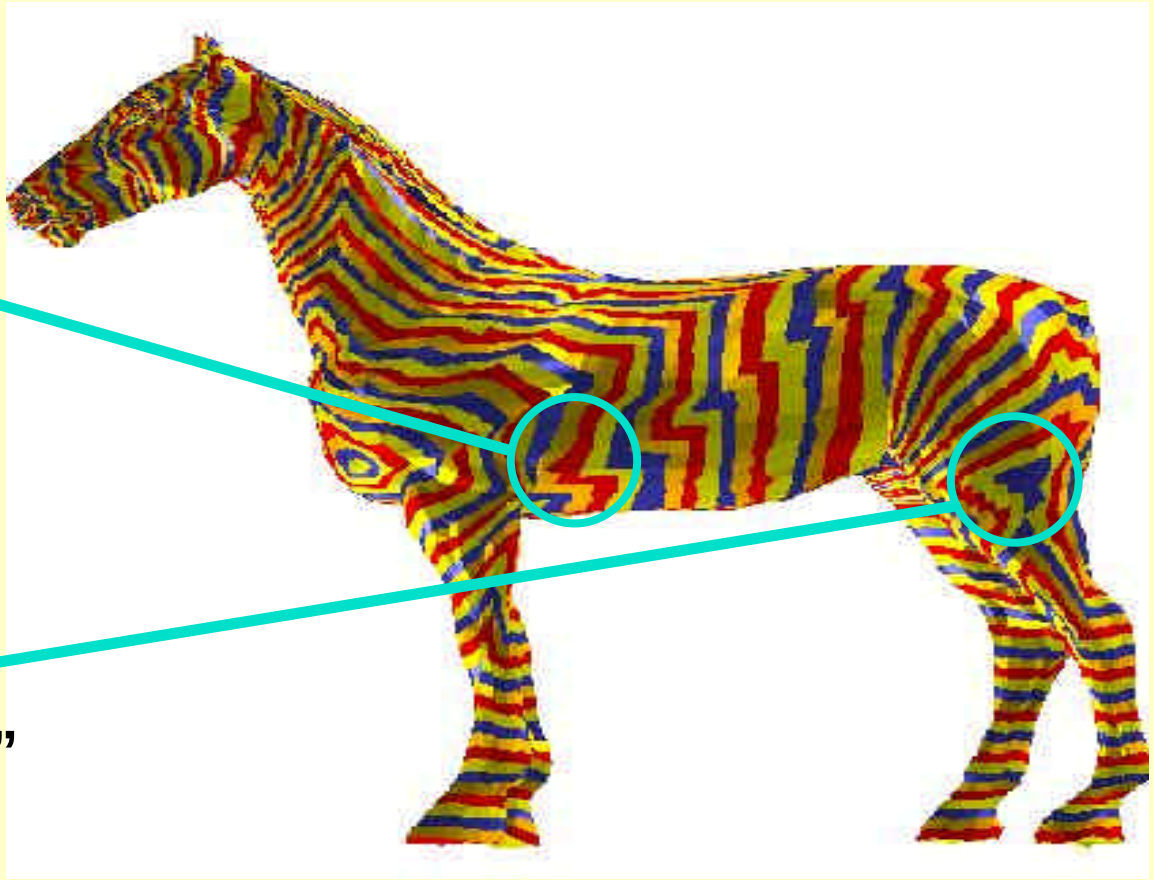
- ***Branching vertex*** **– a vertex which is adjacent to more than, or less than, two vertices in the same layer.**
- ***Contour*** **– ordered list of non-branching vertices from the same layer.**



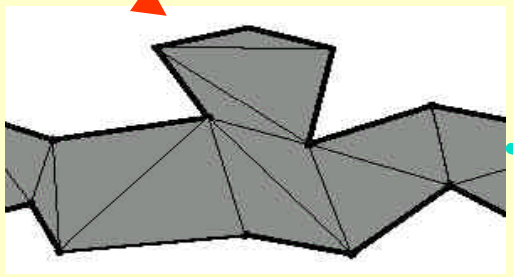
- ***Triangle strip*** **– an ordered list of adjacent triangles from one layer between two contours.**

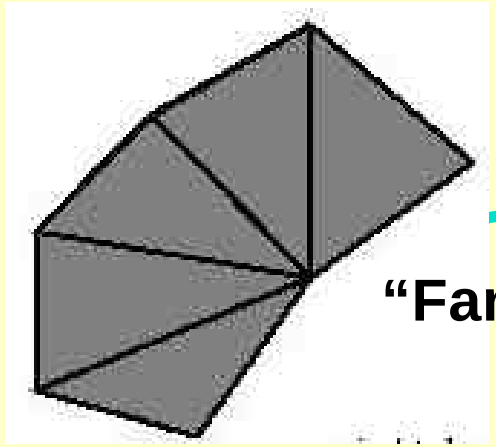
Strips…

Bubbles and Fans



“Bubble”





“Fan”

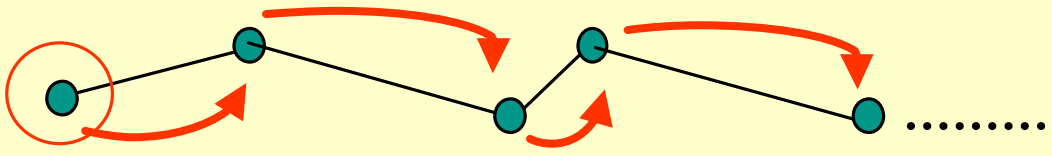
Encoding the Layers

- 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

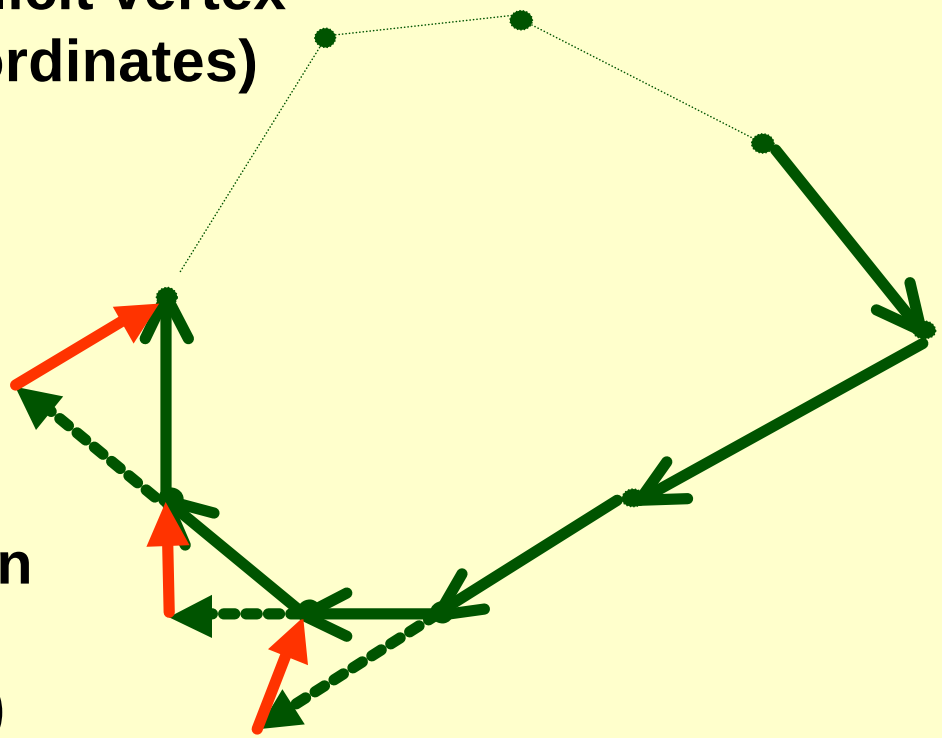
Geometry Encoding

- 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

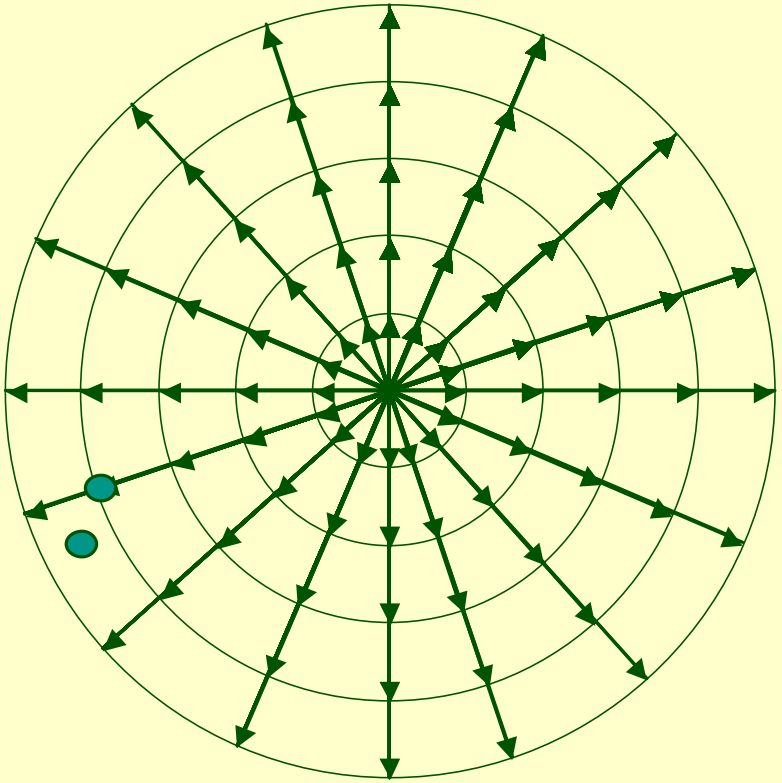
0^{th} order representation (explicit vertex coordinates)



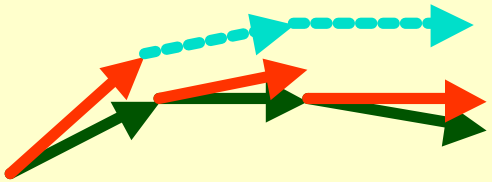
1^{st} order representation (D - vertex coordinate)

2^{nd} order representation (D^2-vector coordinates)

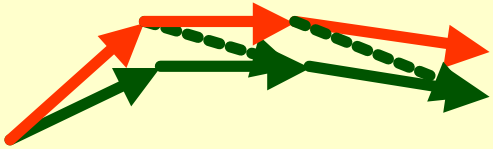
Quantization and Prediction



Second-order prediction

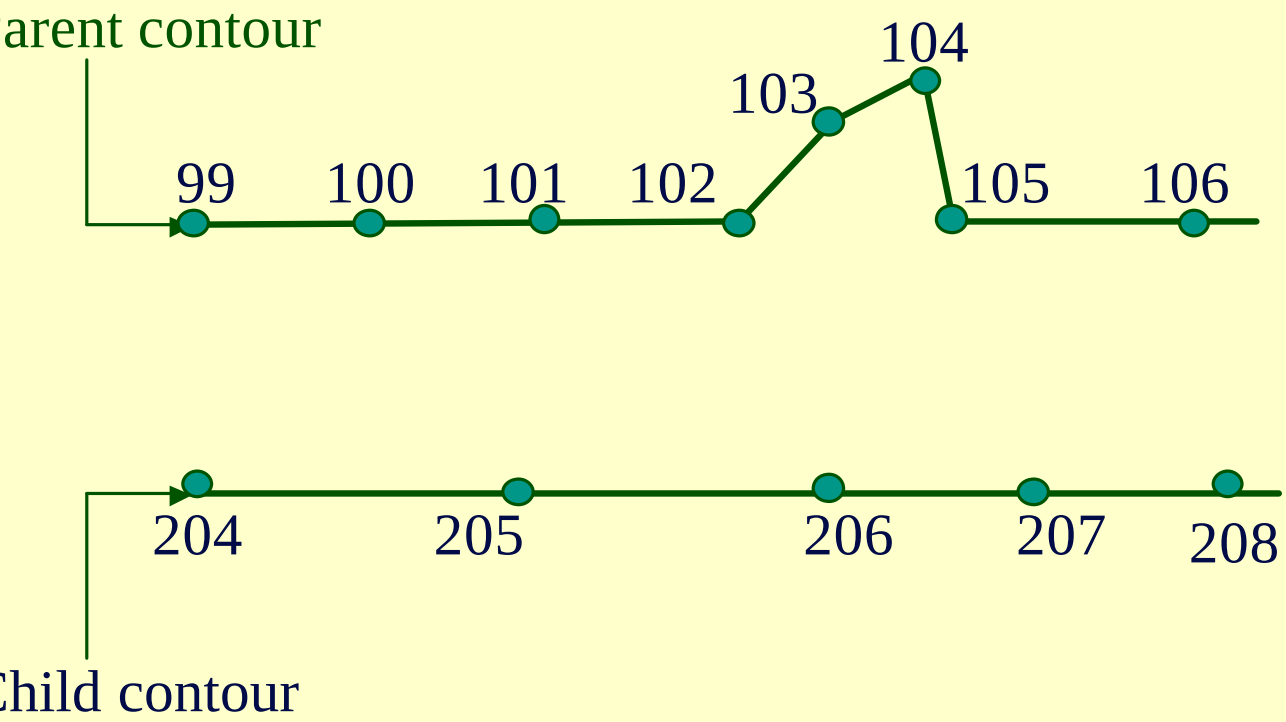


Error Propagation

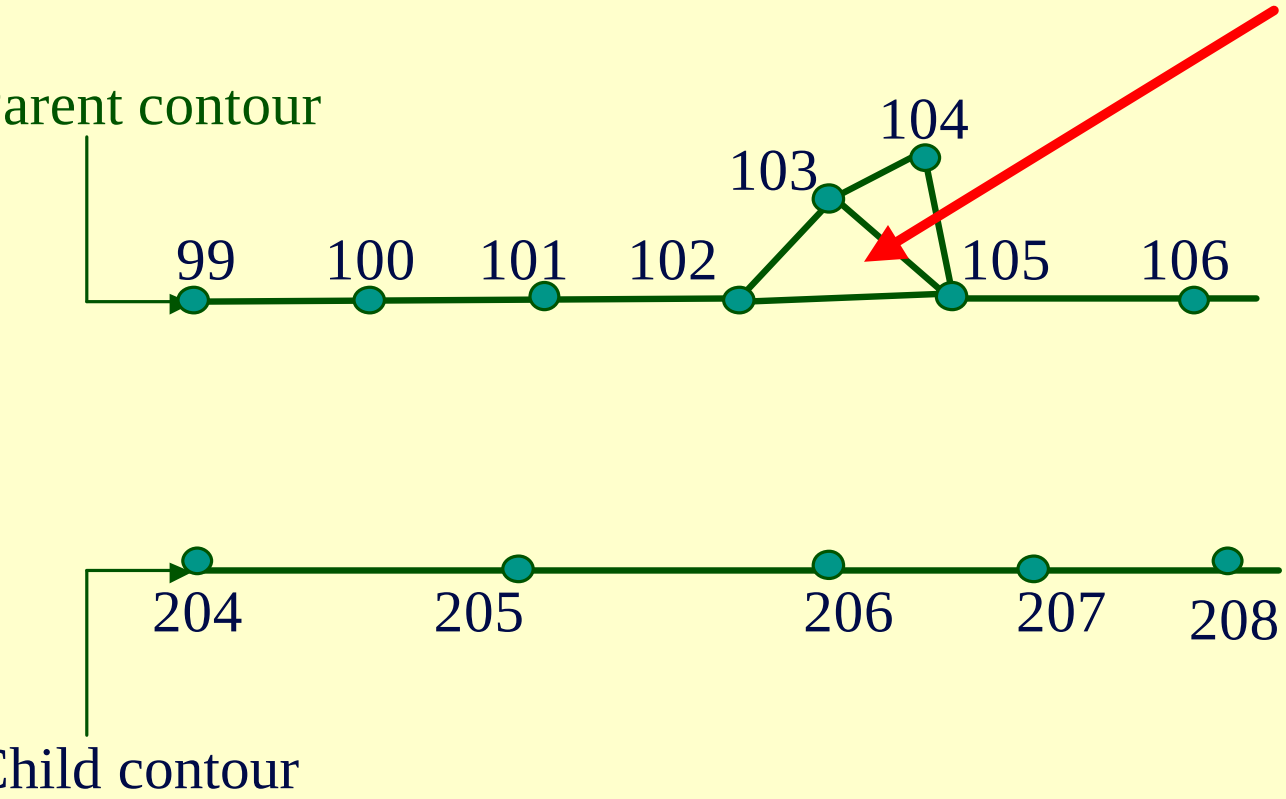


Predict from coded position
Not from original position!

Encoding of Triangle Strips…



Bubble Encoding



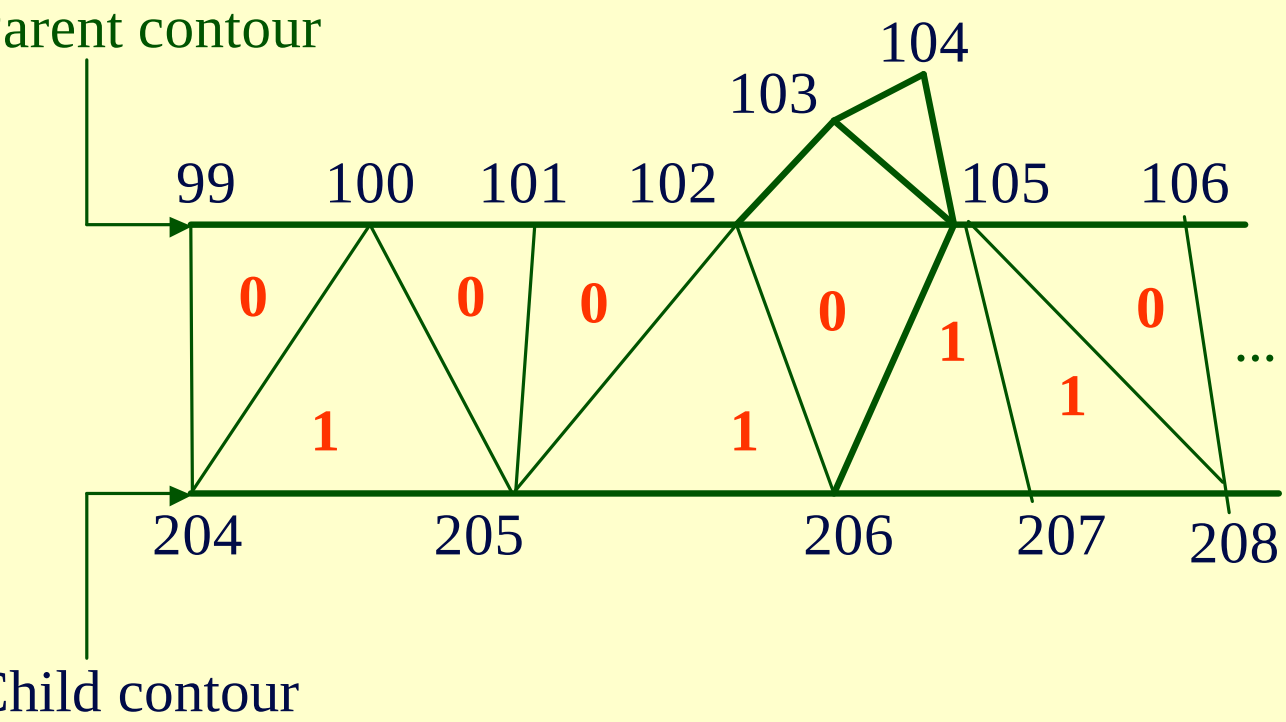
Bubble encoding:

local	relative
102	0
103	1
104	2
105	3

102 , (0,3,1) , (1,3,2)

Encoding of Triangle Strips

Strip encoding: 010010110...

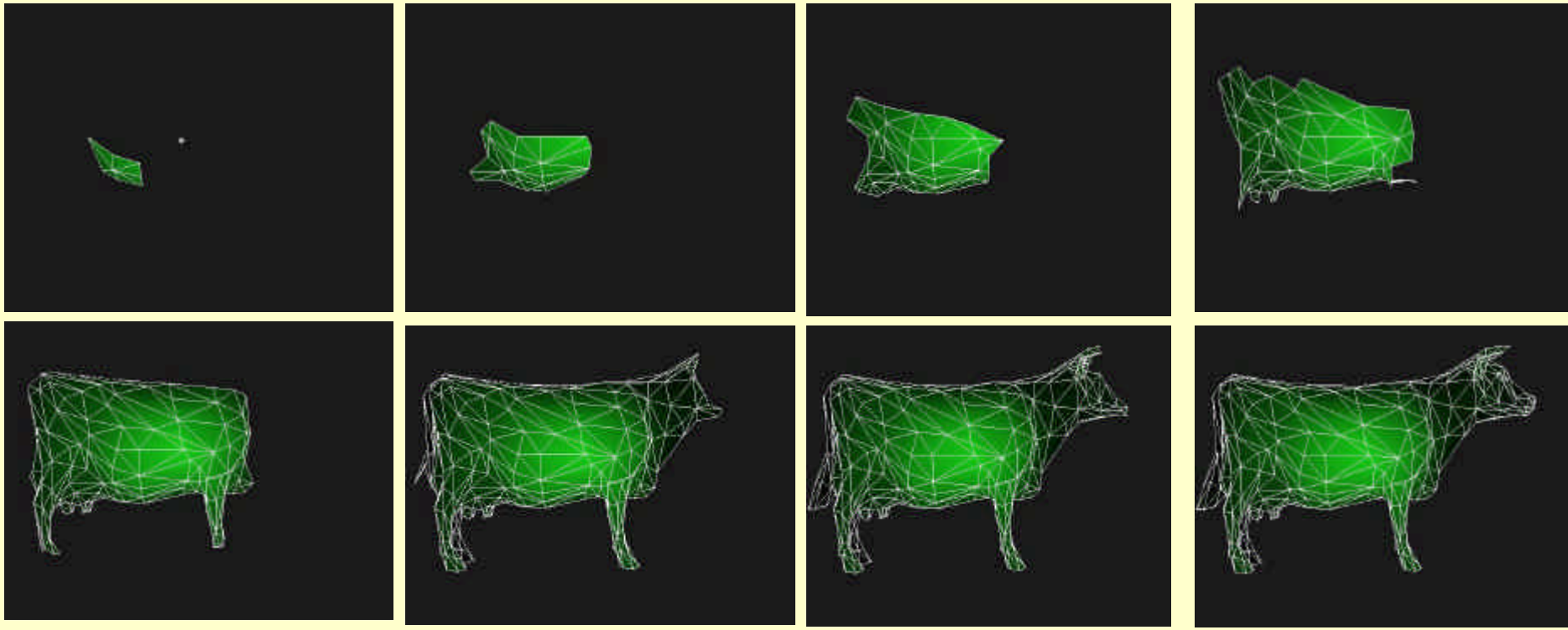


Actual Coding of Connectivity

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

Incremental Transmission and Display

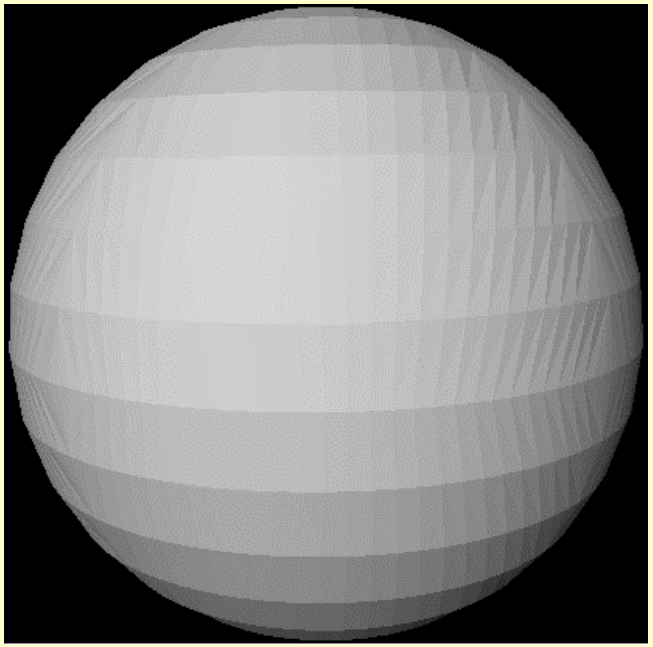
Single Resolution Compression of Arbitrary Triangular Meshes with Properties, Computational Geometry Theory and Application (in press)

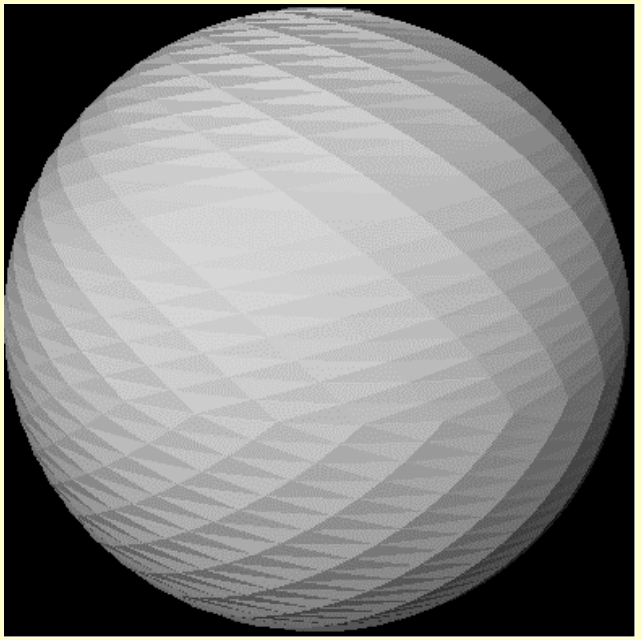


Layered Progressive Decomposition?

- Remove whole layers?
- Remove vertices inside layers?

- Artifacts:





Alternating Decomposition

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

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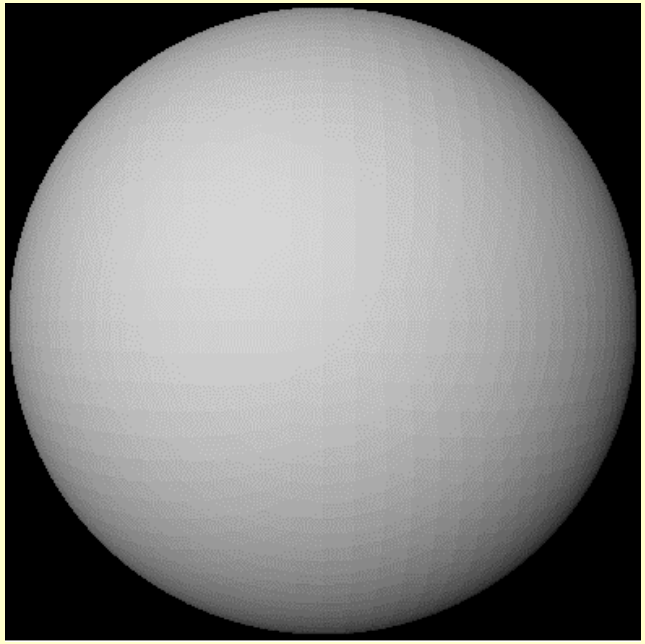
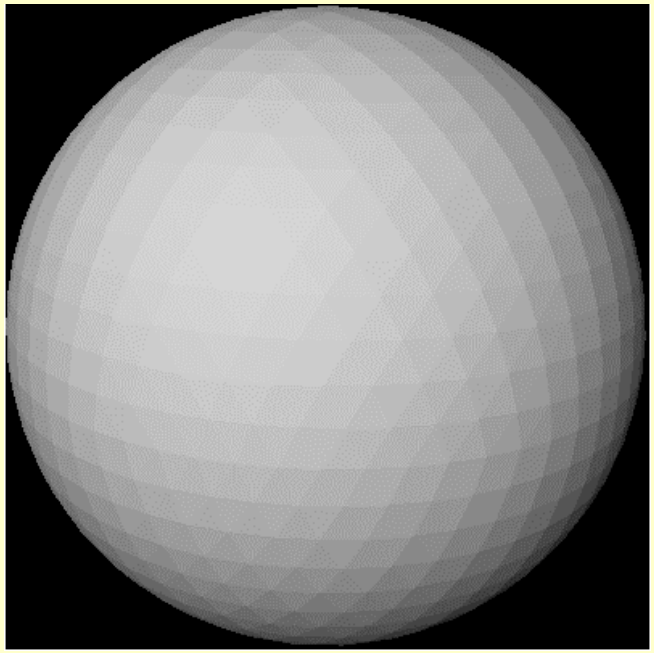
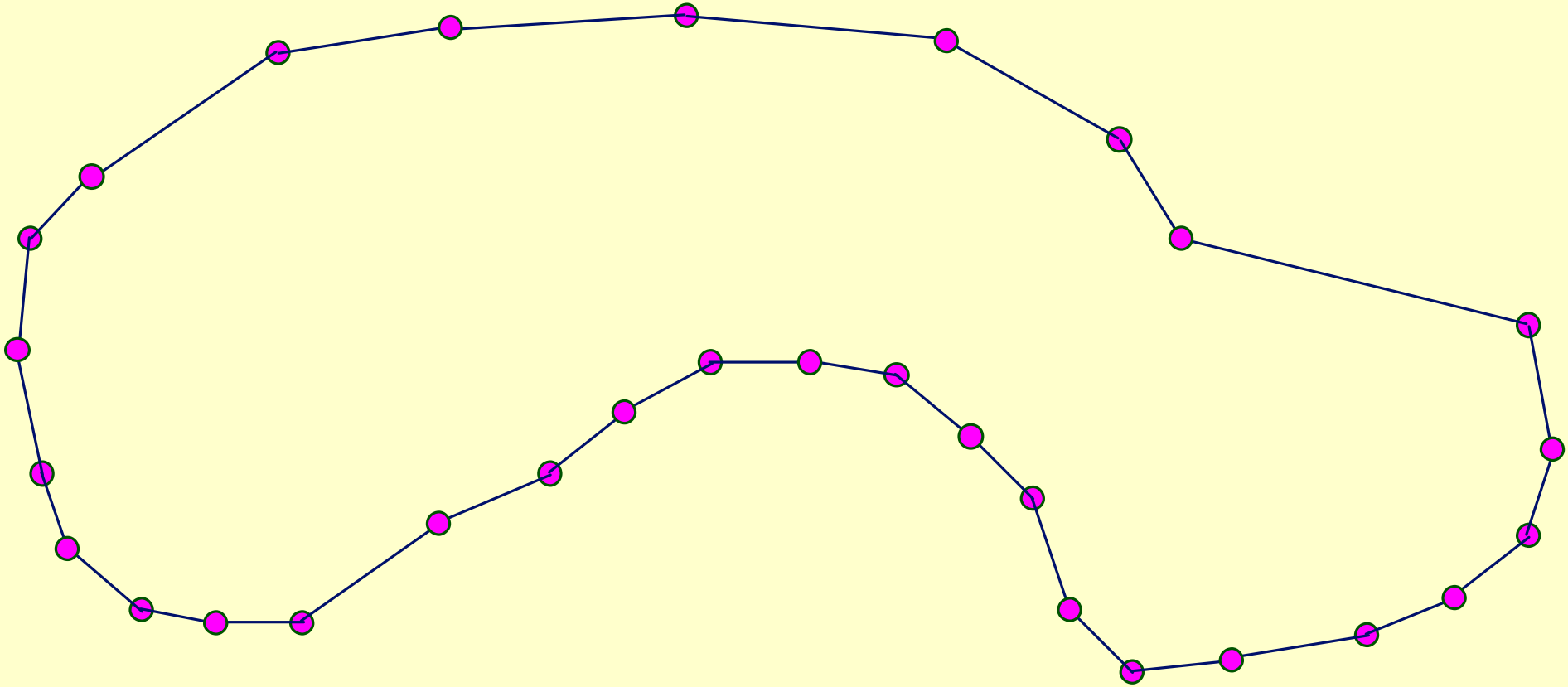
- ***Inter-layer*** **decomposition (decimate whole contours)**





Intra-layer Decomposition

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



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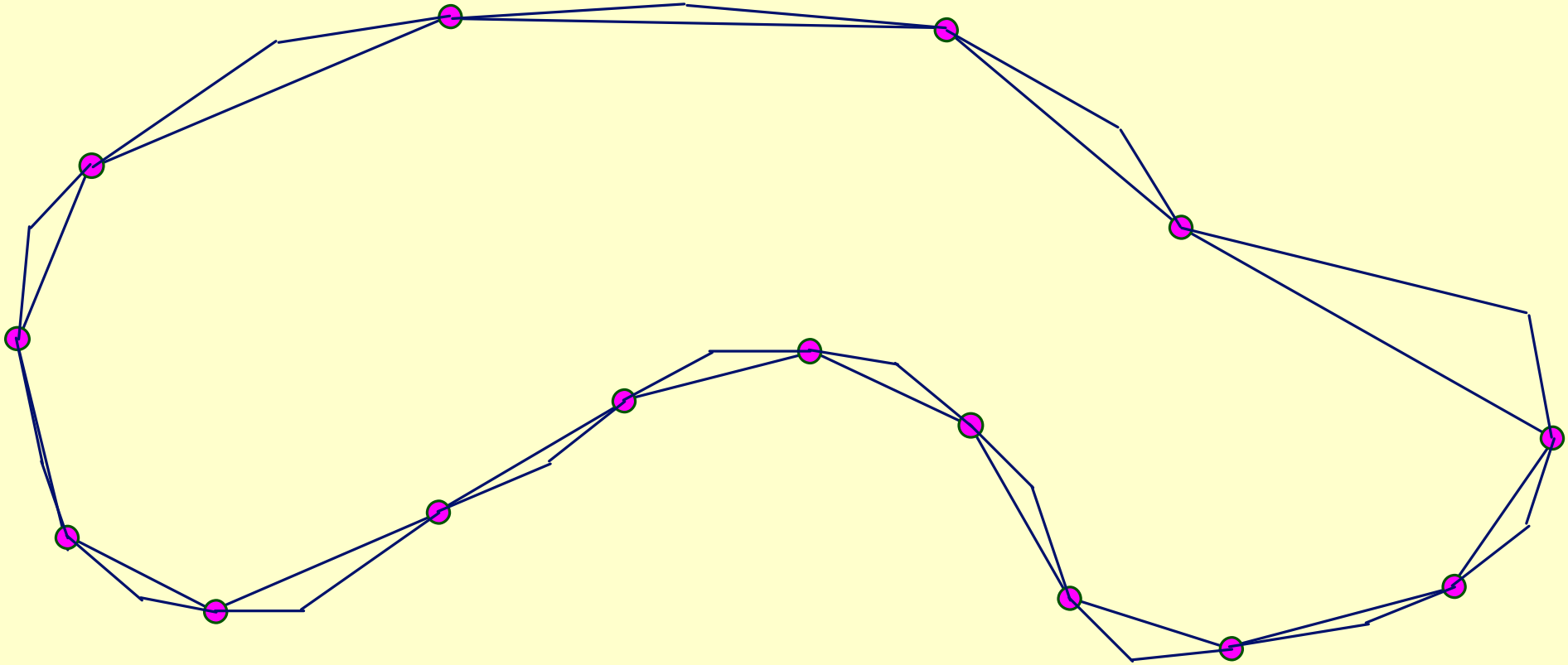

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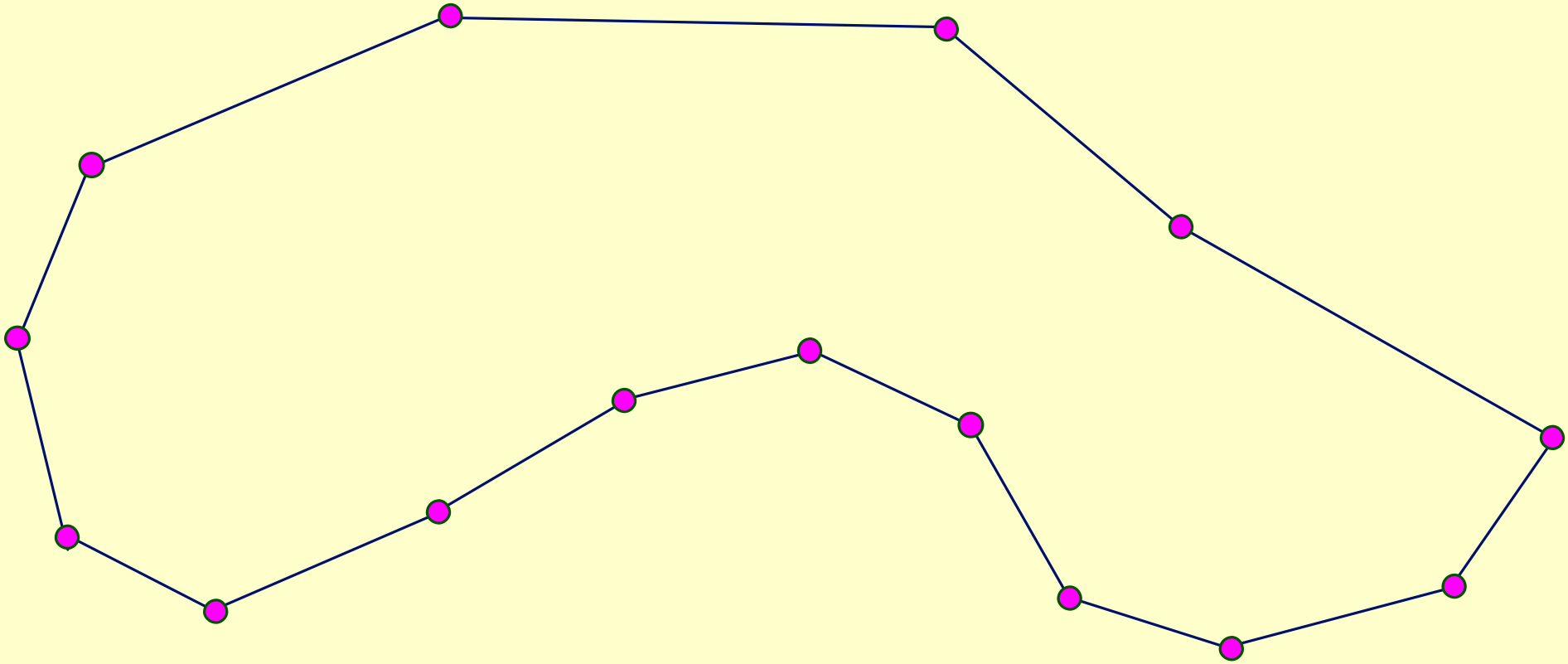
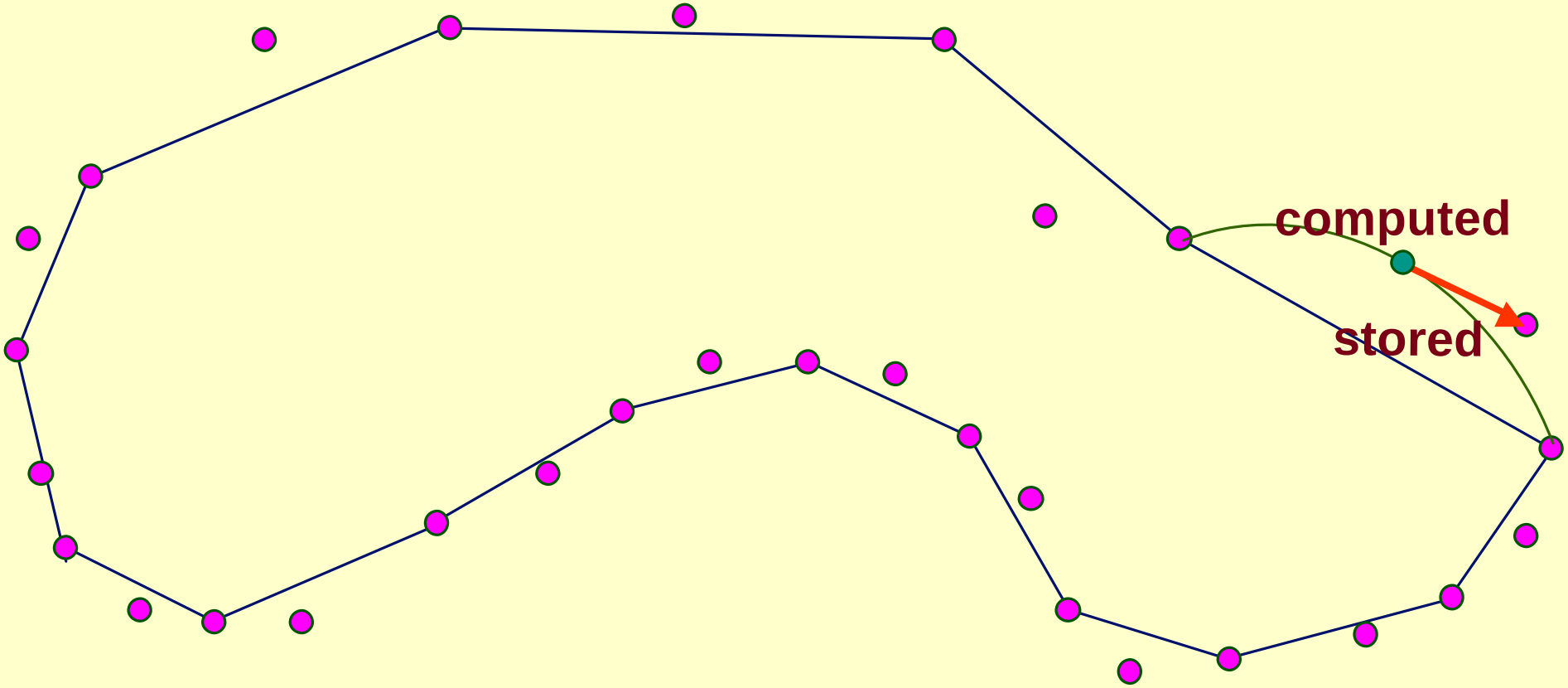
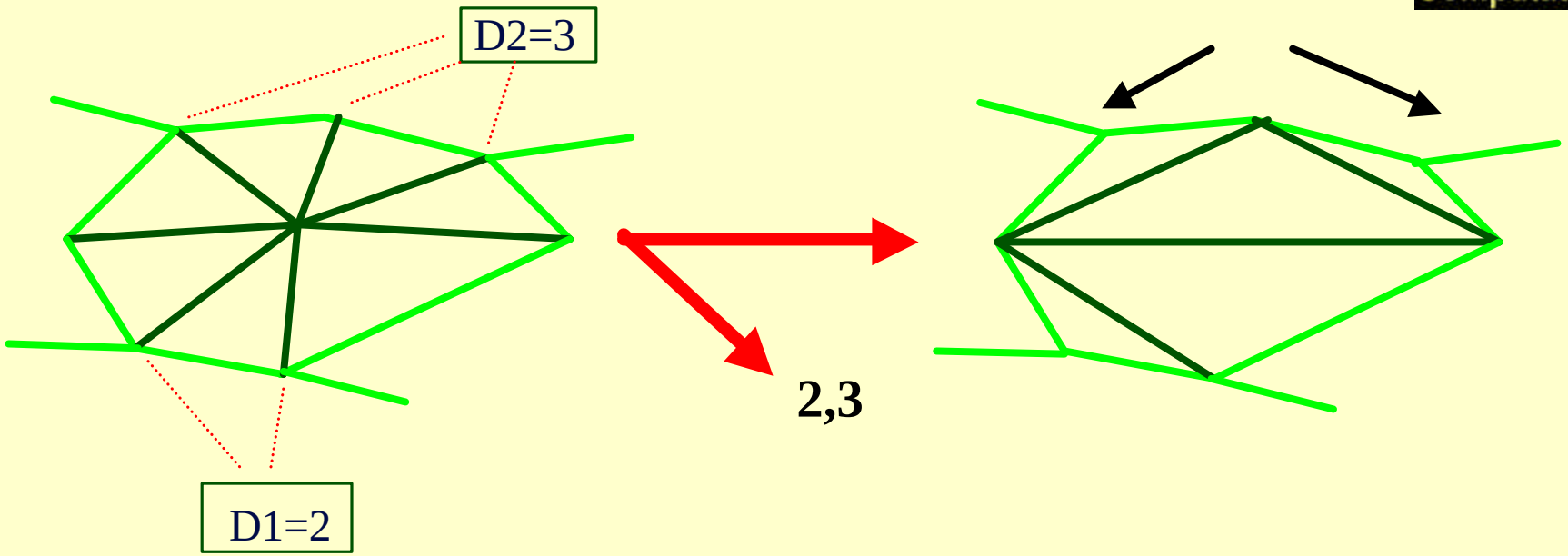


Intra-layer Geometry Encoding

- **Reconstruction : quadratic prediction + correction**

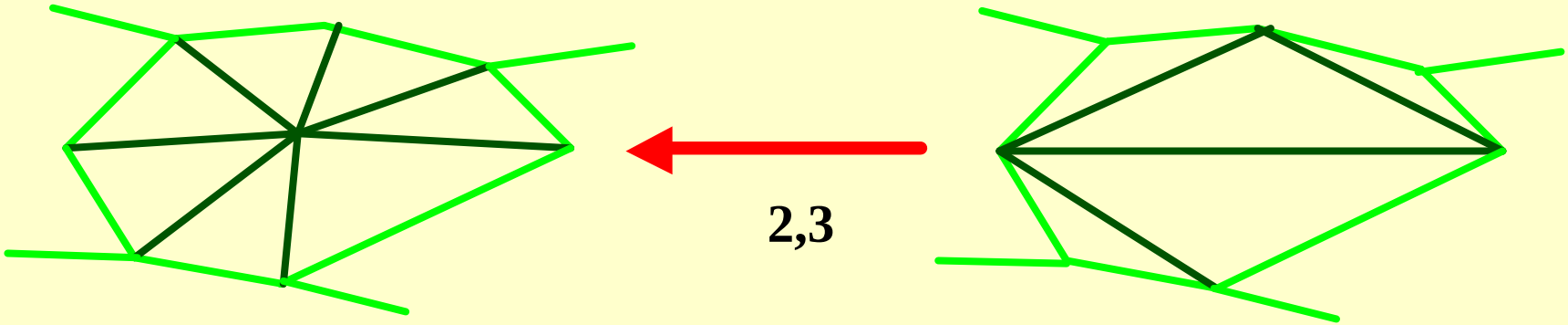


Intra-layer Connectivity Encoding



Retriangulation is done connecting both sides to avoid long triangles

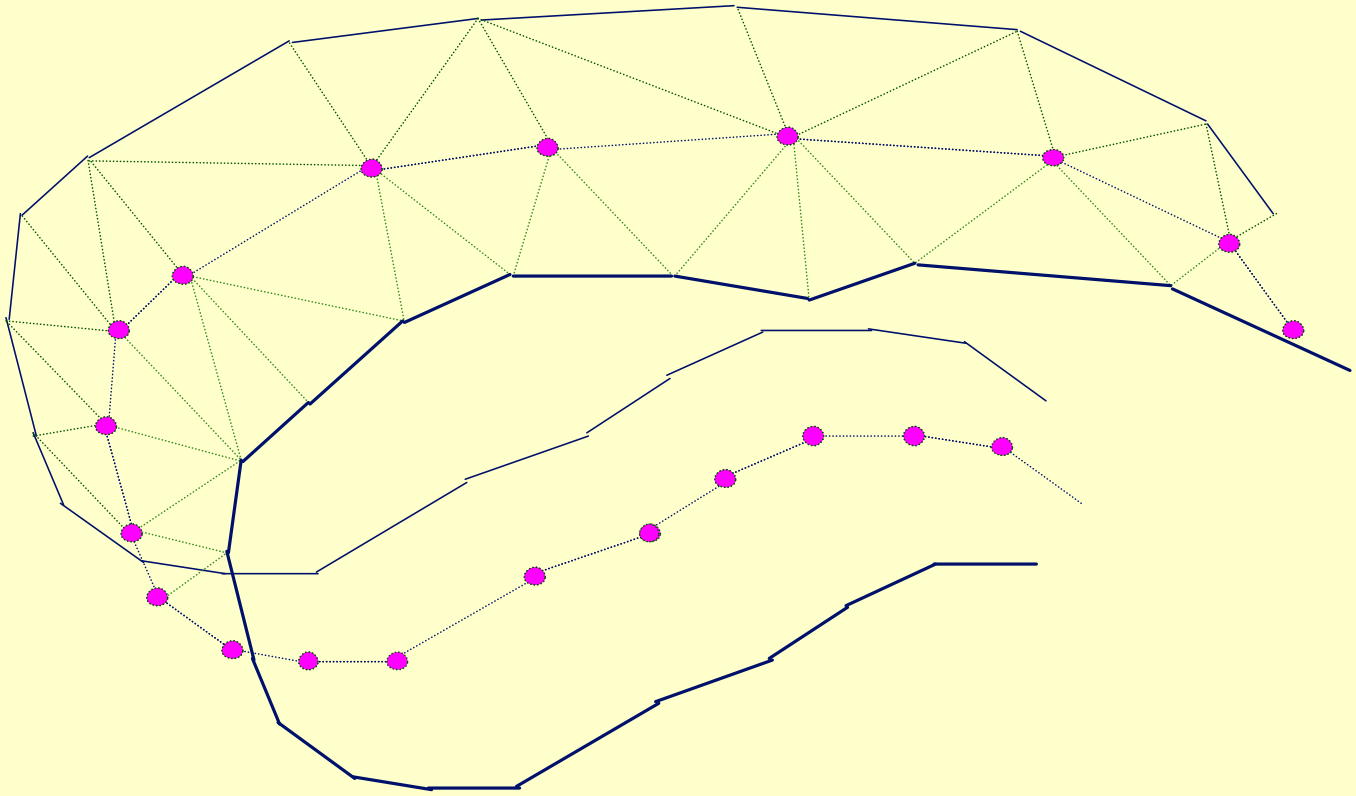
Reconstruction



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



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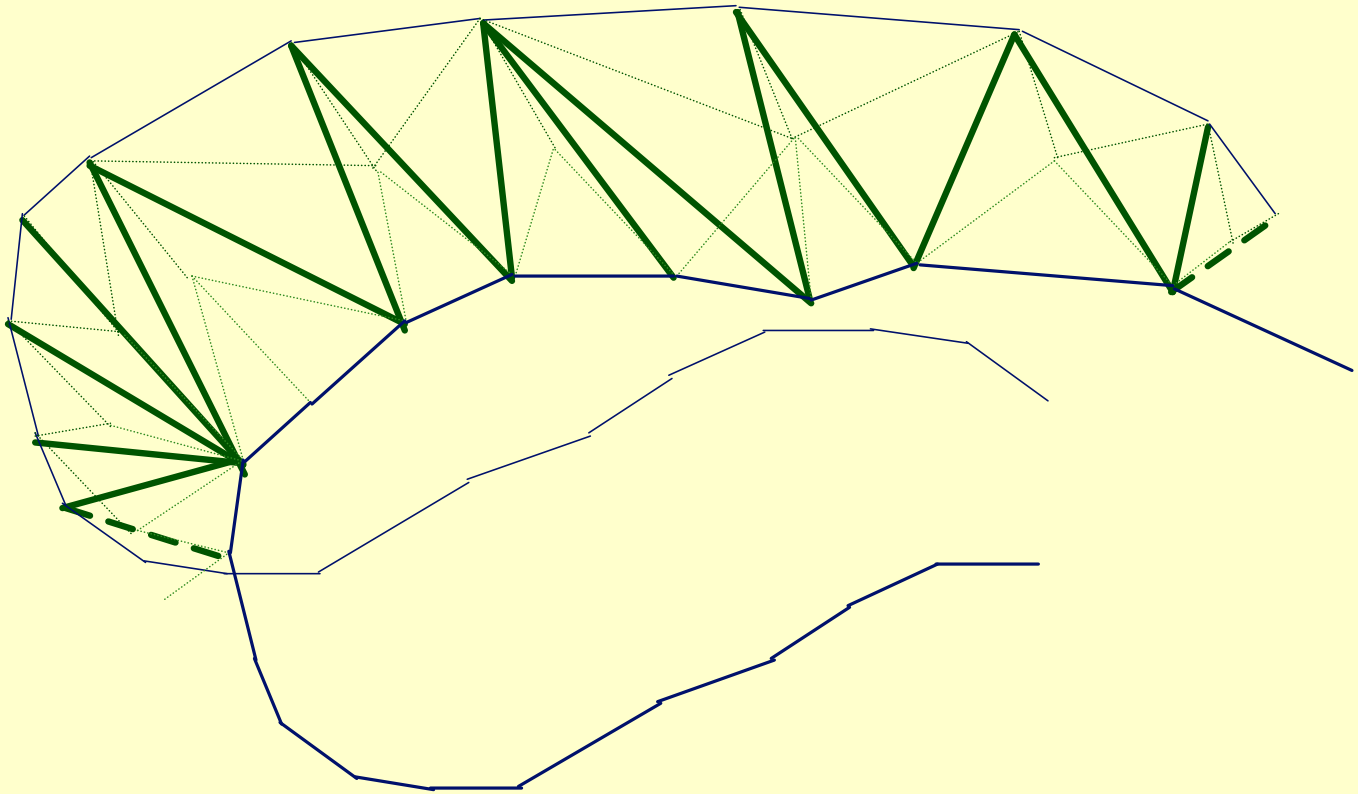

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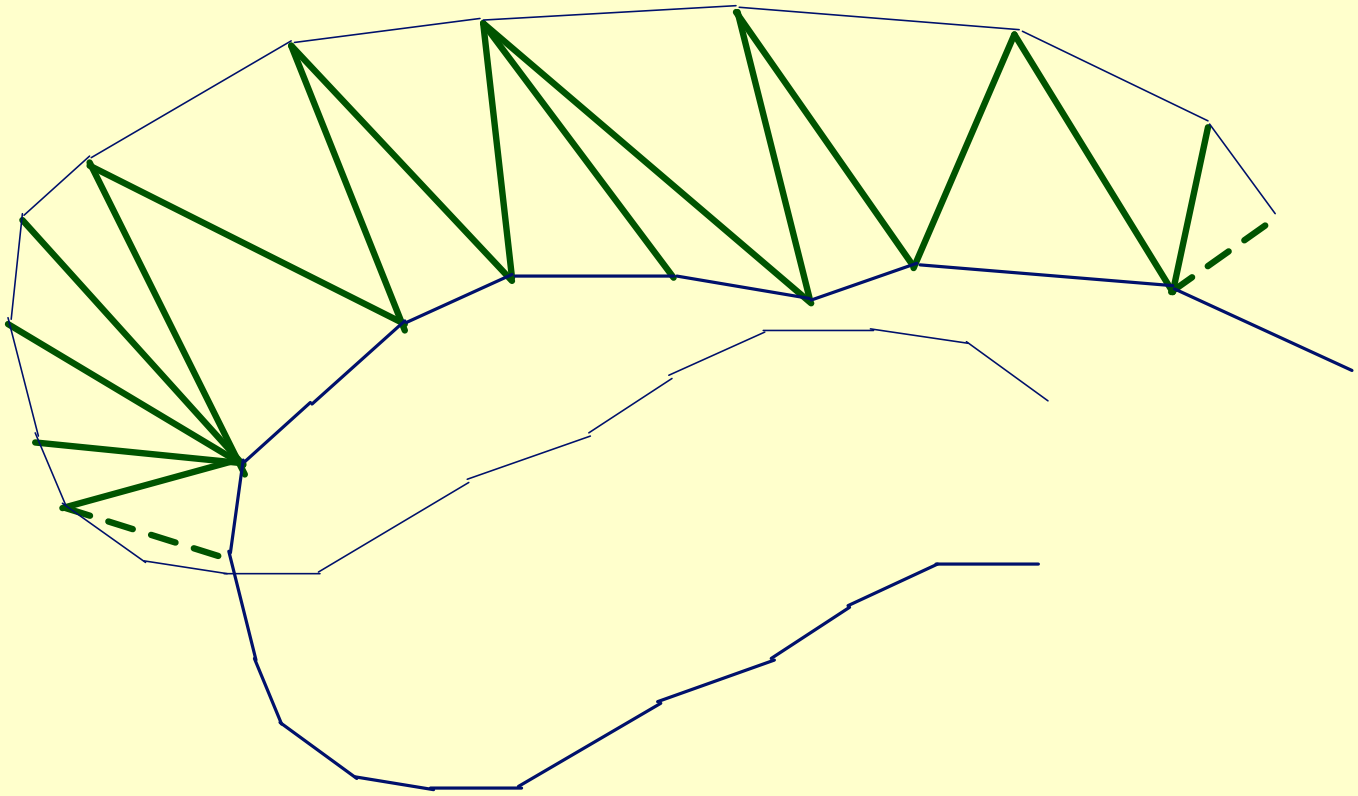
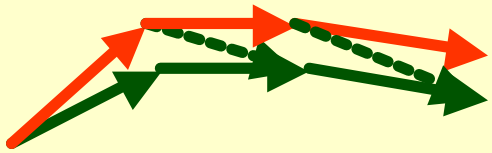
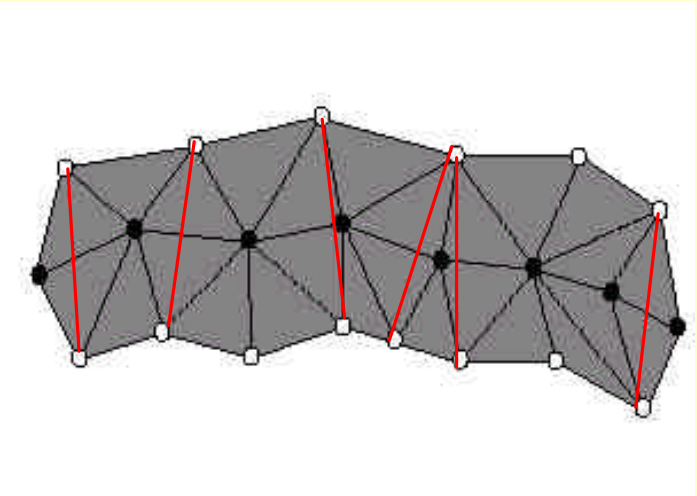


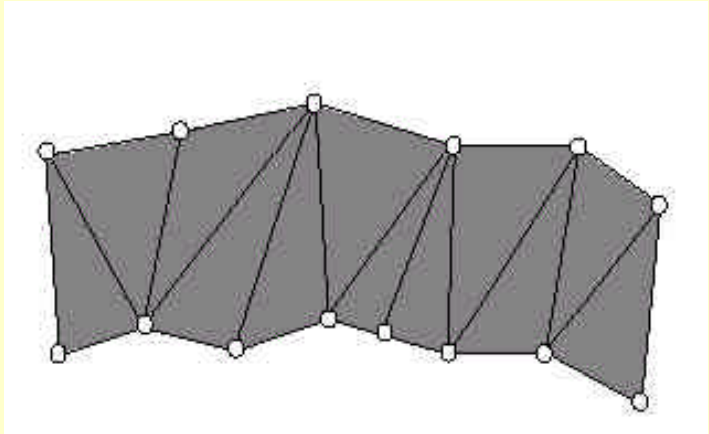
Inter-layer Geometry Encoding

- Second order prediction encoding



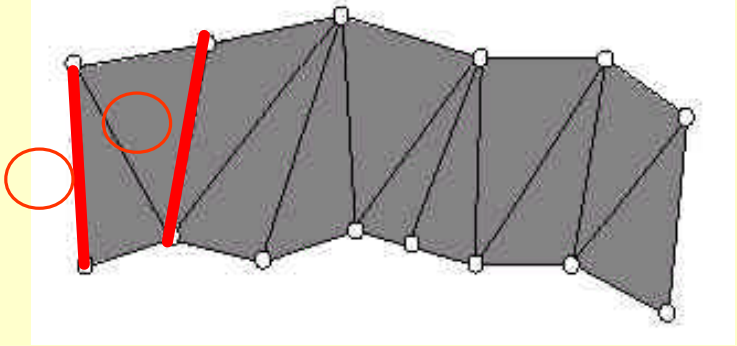
Inter-layer Connectivity Encoding





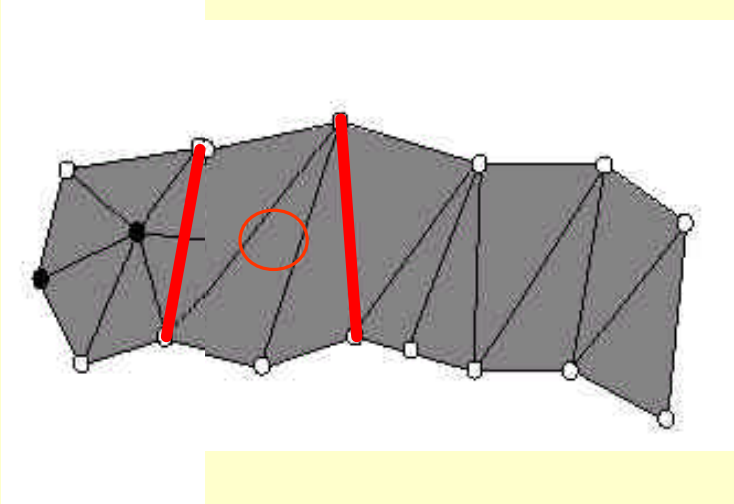
2-3-2-1-4-0

Reconstruction…



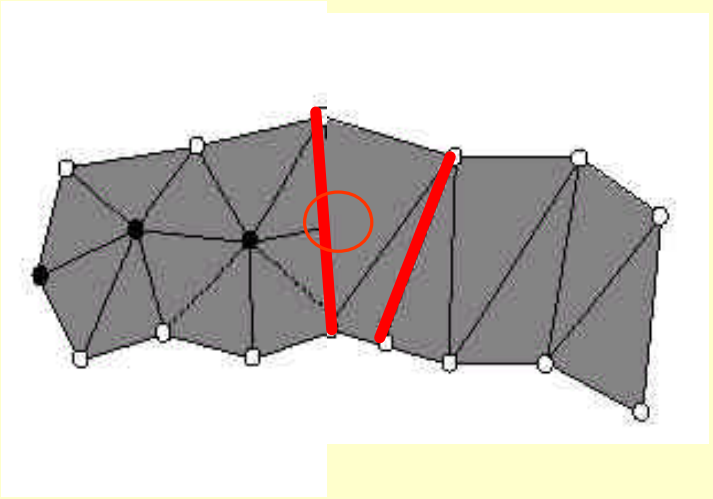
2-3-2-1-4-0

Reconstruction…



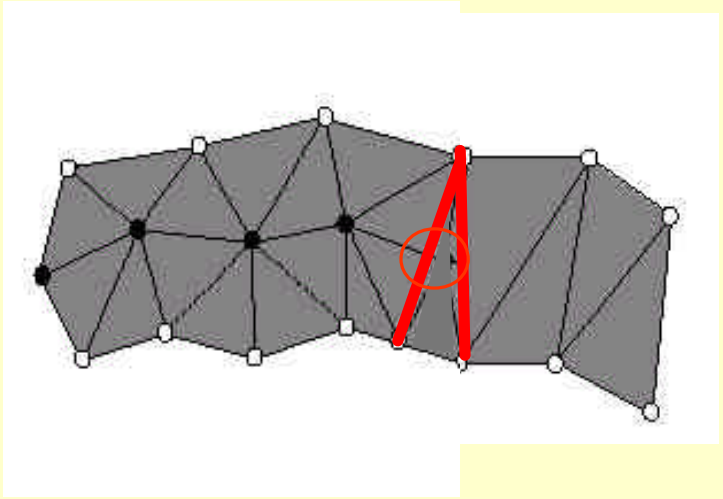
2-3-2-1-4-0

Reconstruction…



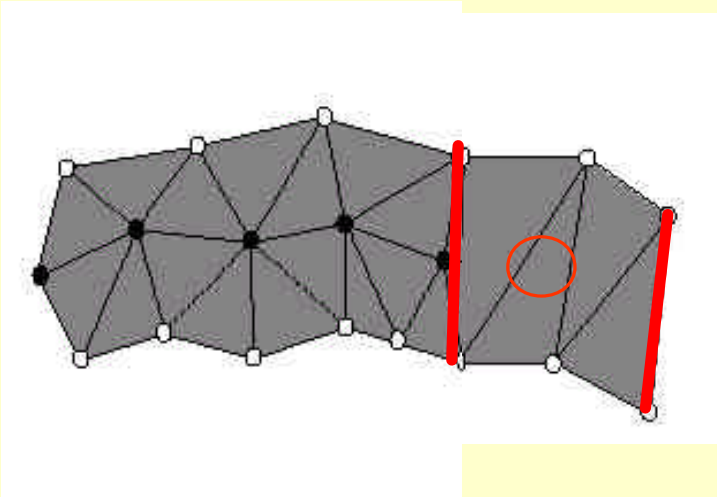
2-3-2-1-4-0

Reconstruction…



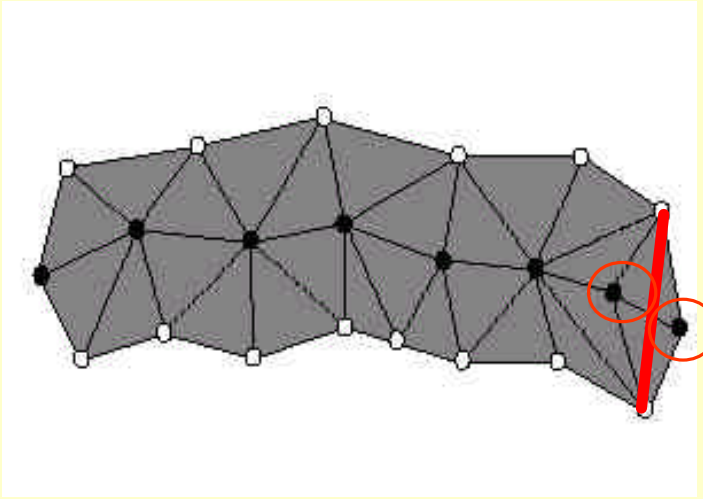
2-3-2-1-4-0

Reconstruction…



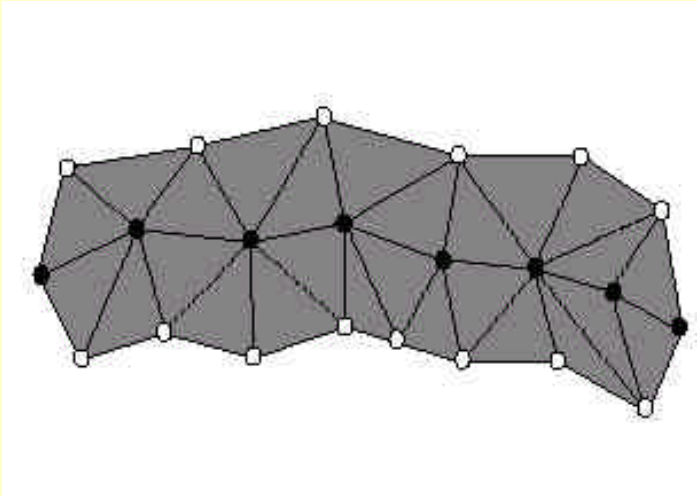
2-3-2-1-4-0

Reconstruction…

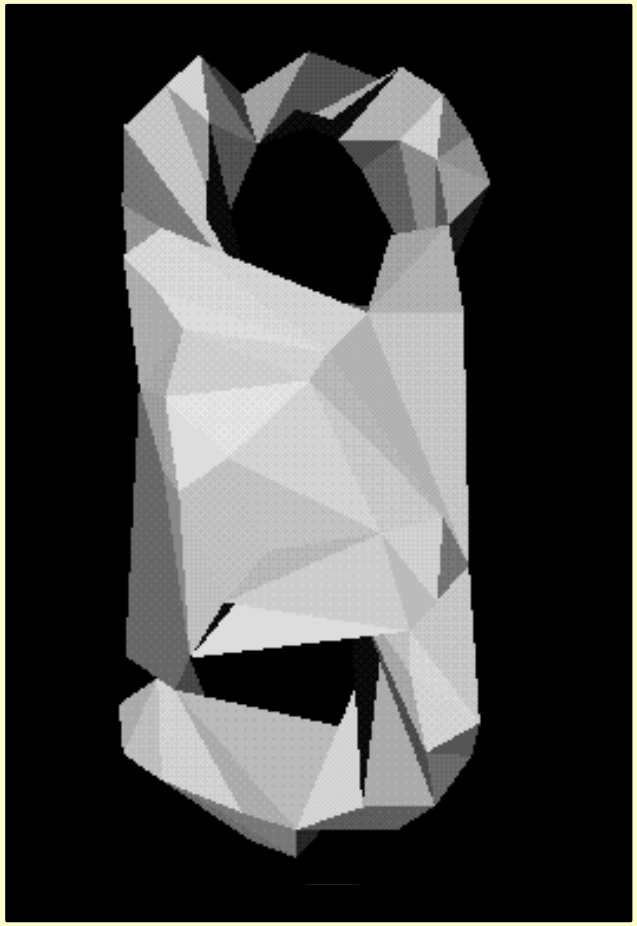


2-3-2-1-4-0

Reconstruction…

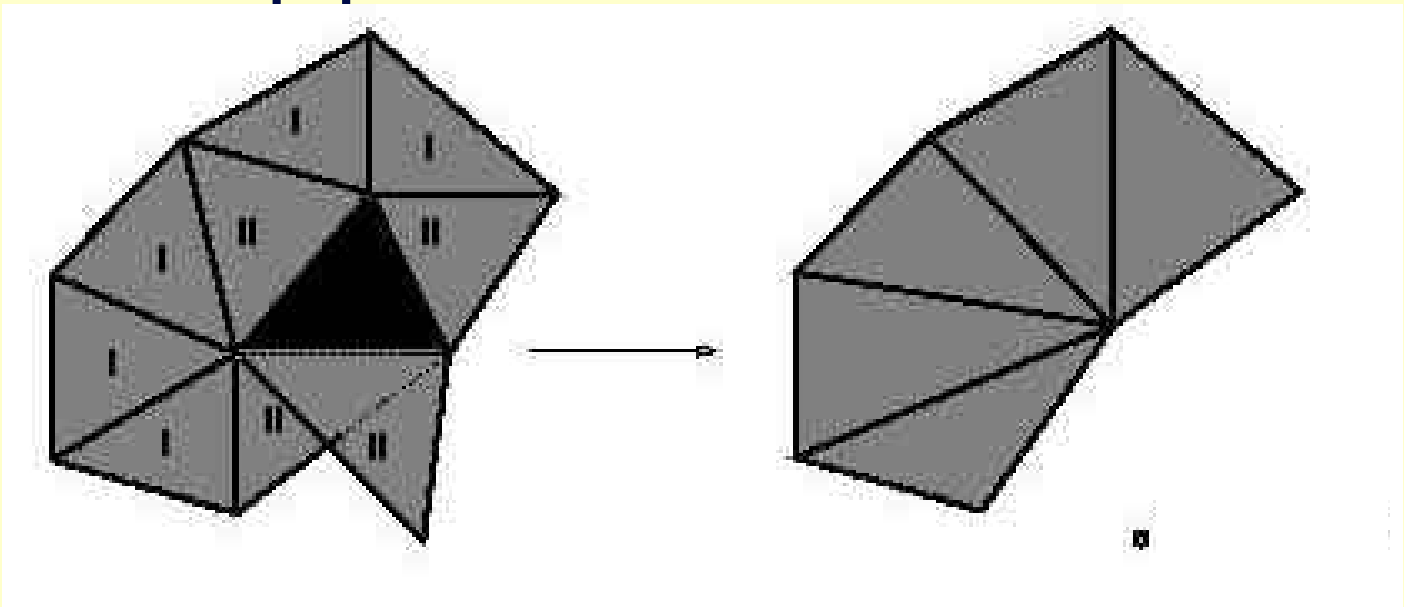


Topology Preserving Decomposition

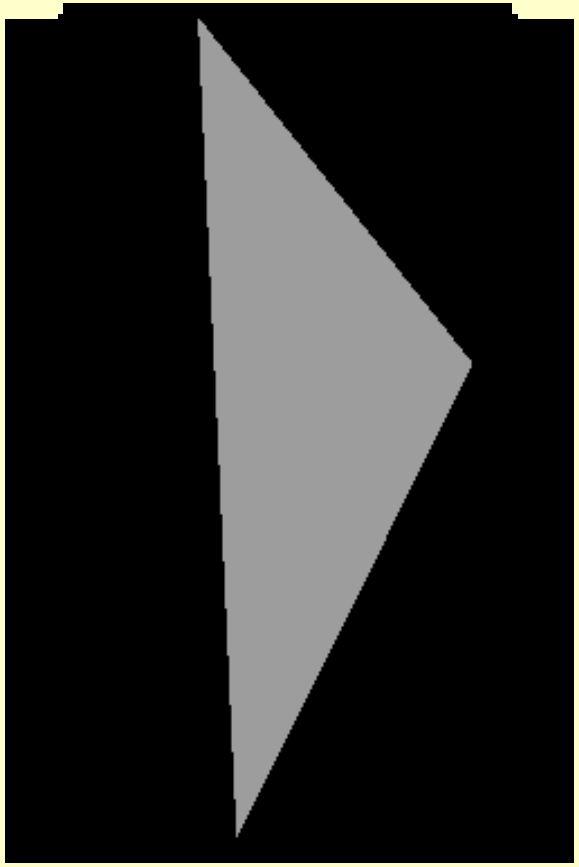


Topology Non-preserving Decomposition

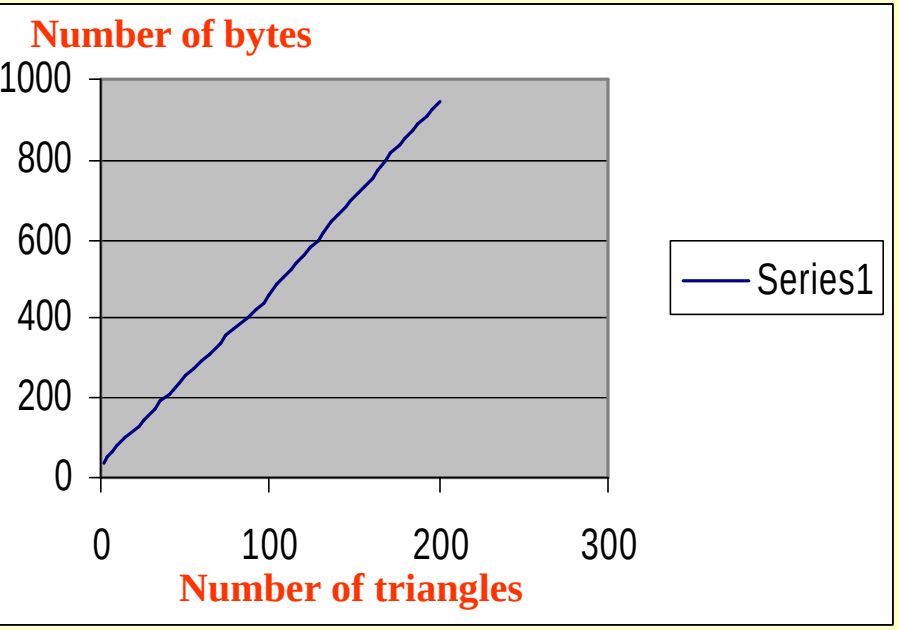
- Triangle contraction
- Priority queue to determine the contraction order
- Applies to non manifold features
- Details in the paper…



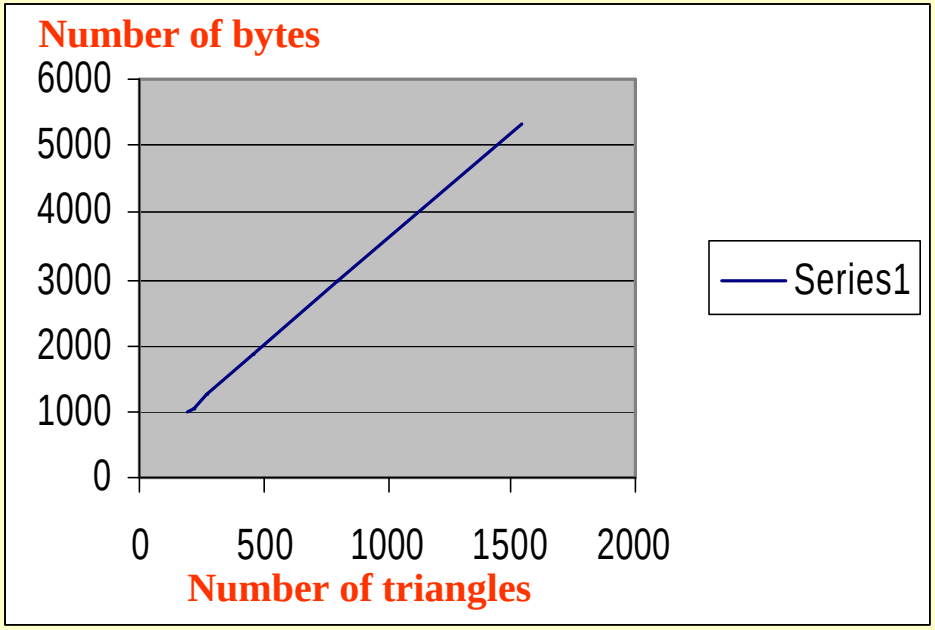
Topology Non-preserving Decomposition



Results: Progressive Connectivity

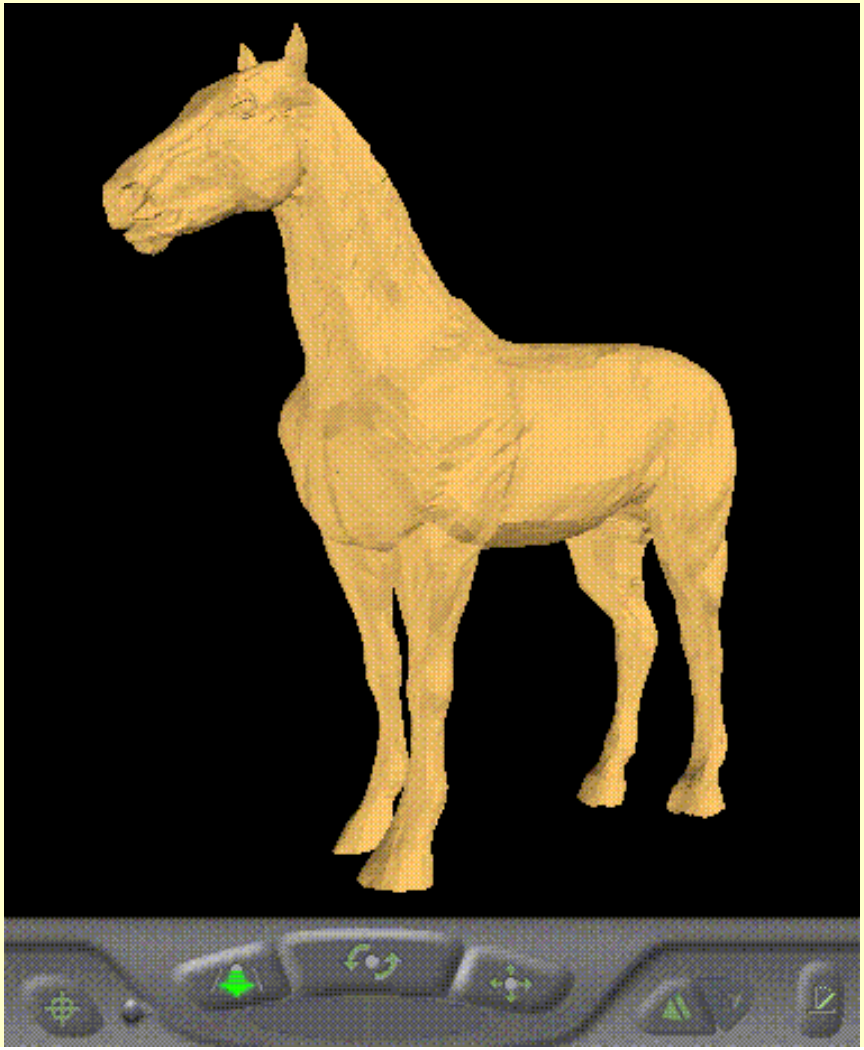


Topology changing reconstruction
(4.78 bytes per triangle)

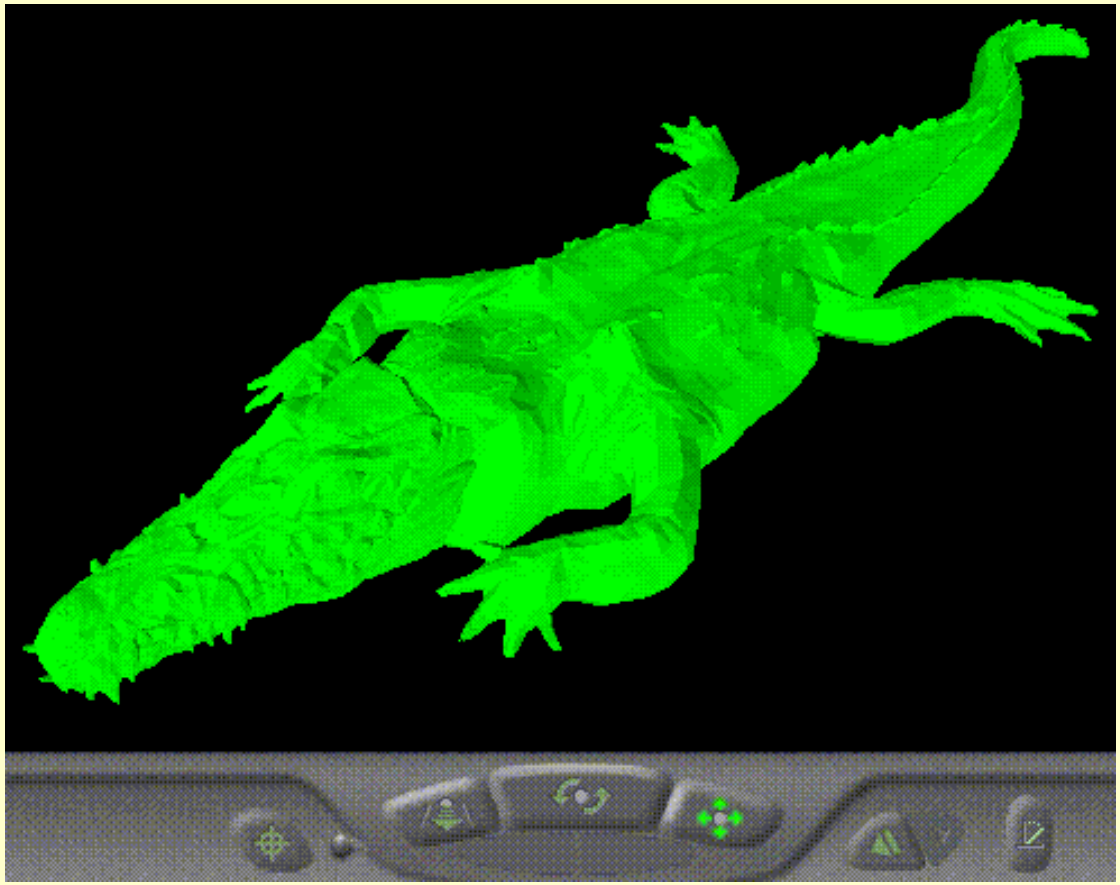


Layering based reconstruction
(3.32 bytes per triangle)

Horse



Crocodile



Statistics

Crocodile				
Triangles	300	8589	16784	34,404
bits/triangle	20	9.50	5.6	4.9
Bunny				
Triangles	150	1228	4012	10,009
bits/triangle	19.3	15.7	8.5	5.2
Horse				
Triangles	870	5496	9754	22,258
bits/triangle	18.3	8.3	6.9	5.5

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.