Progressive Meshes

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Progressive Meshes

- Motivations
- Progressive Triangular Meshes
  - Connectivity
  - Geometry
- Progressive Tetrahedral Meshes (Progressive Simplicial Complex)

Complex Meshes

43,000 faces

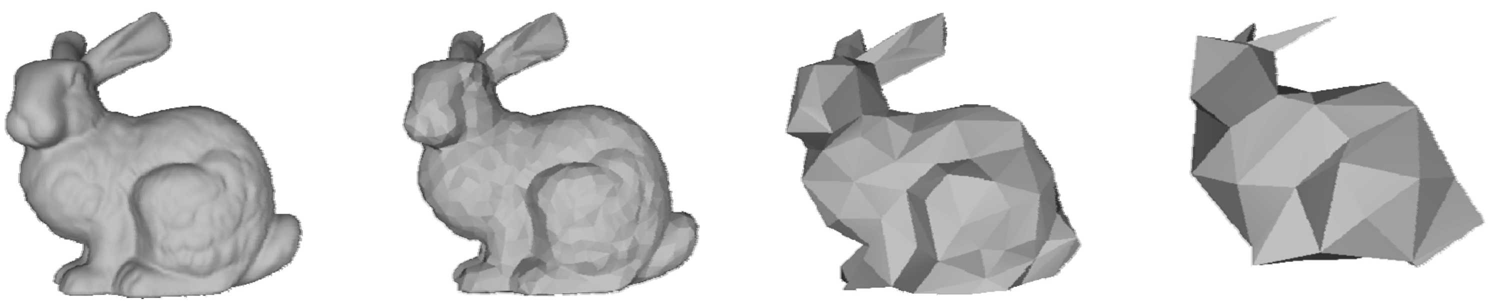
lots of faces!

<u>Challenges:</u>

- Expensive to store, transmit, render, and edit

Level of Detail

- Decreasing the complexity of a 3D object representation
  - as it moves away from the viewer
  - or based on other metrics (object importance, eye-space position…)
- Applied on geometry, texture, material…

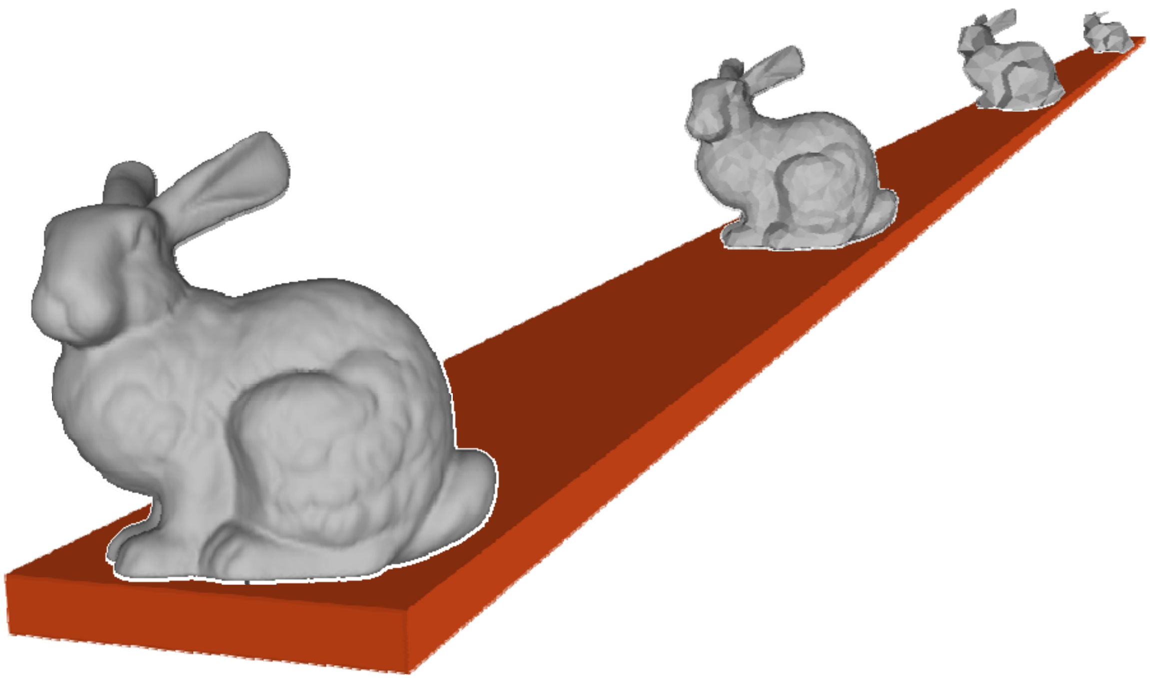


69,451 polys 2,502 polys 251 polys 76 polys

Courtesy Stanford 3D Scanning Repository

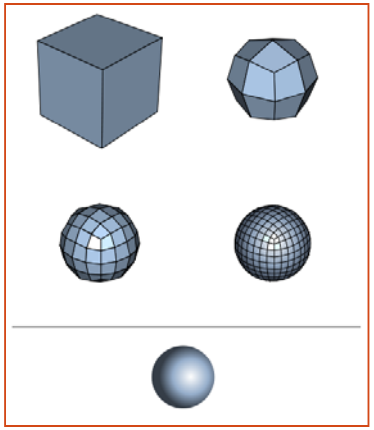
Level of Detail

- Distant objects use coarser LODs:

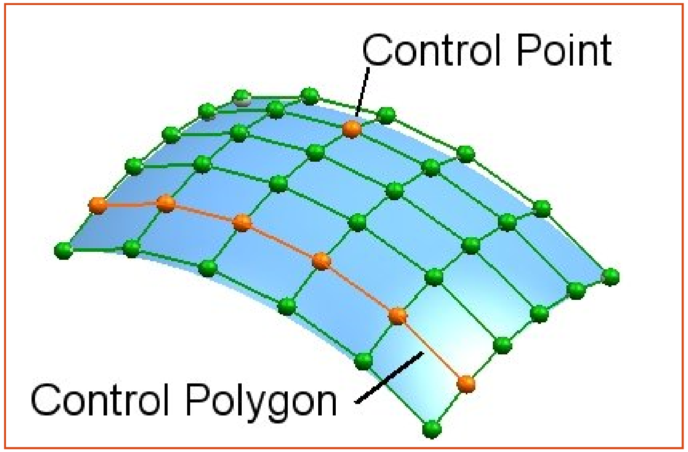


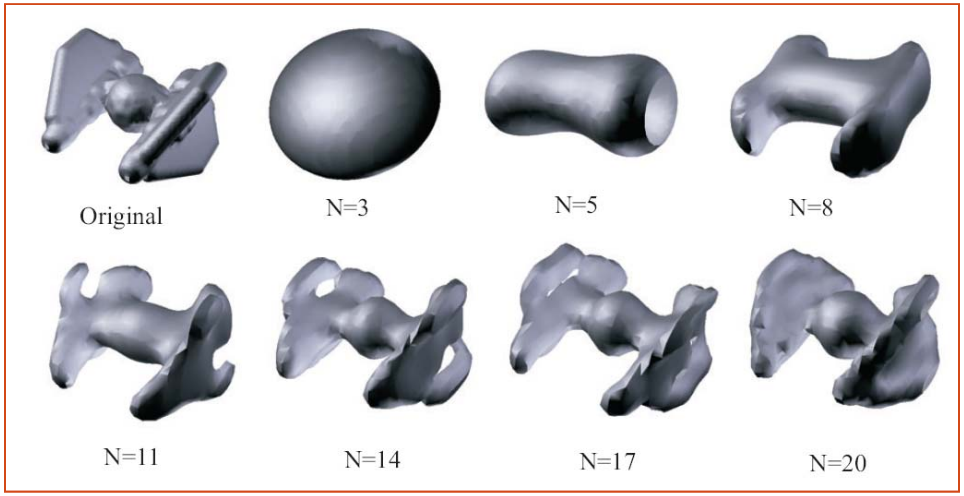
Multiresolutional Modeling, Processing and Analysis

A webpage about Multiresolutional modeling by Michael Garland:
http://www.cs.cmu.edu/afs/cs/user/garland/www/multires/index.html



- Subdivision Surface
- Spline
- Wavelet
- …



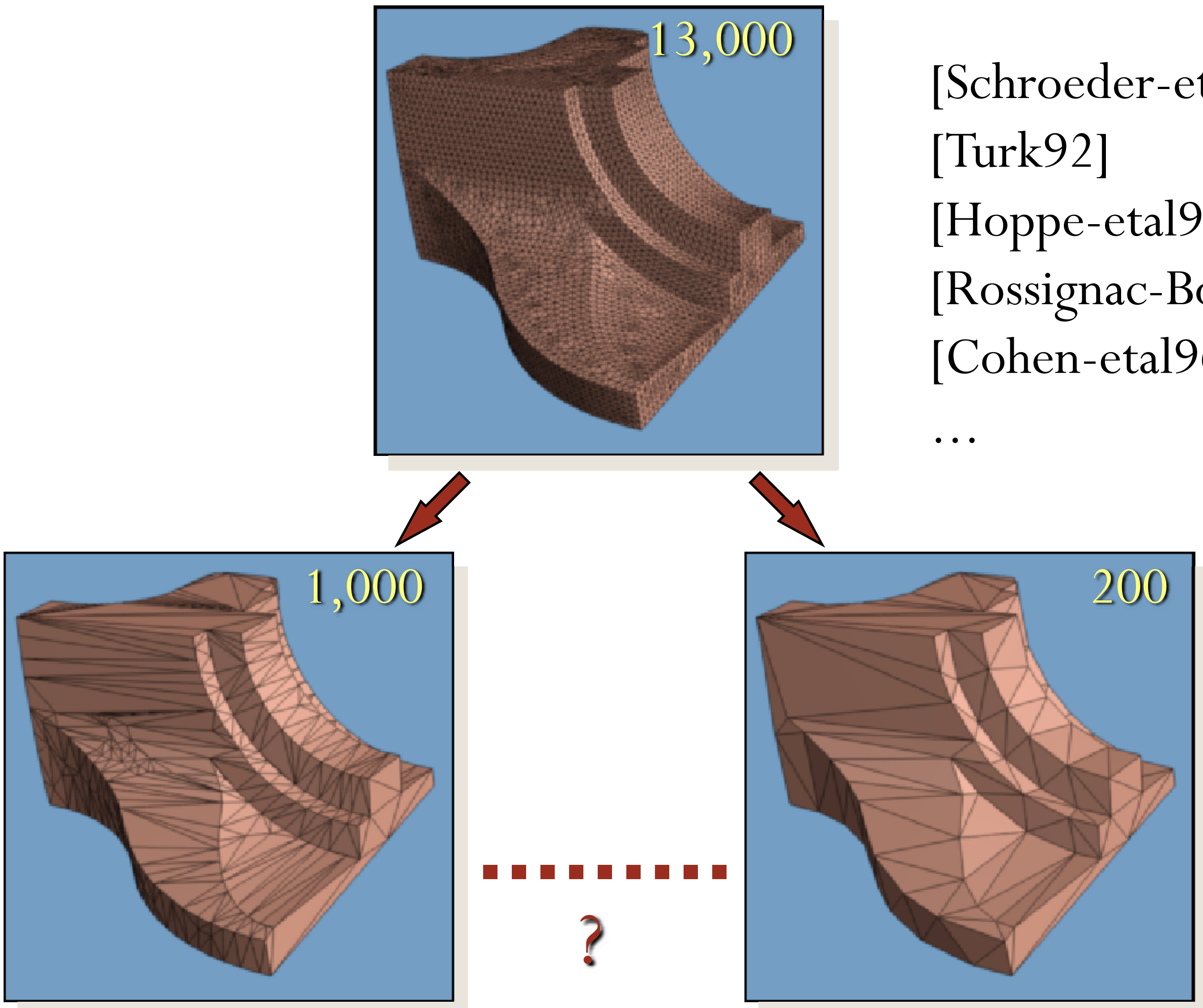


Motivations

- Applications of multiresolution techniques : Compression, Progressive transmission and display, Level-of-detail Control, Multiresolution editing…

- A mesh simplification procedure for general input meshes
  - Preserve various properties (colors, normals, …)
  - Lossless
  - Continuous-resolution
  - Efficient (time and space)
  - Progressive transmission

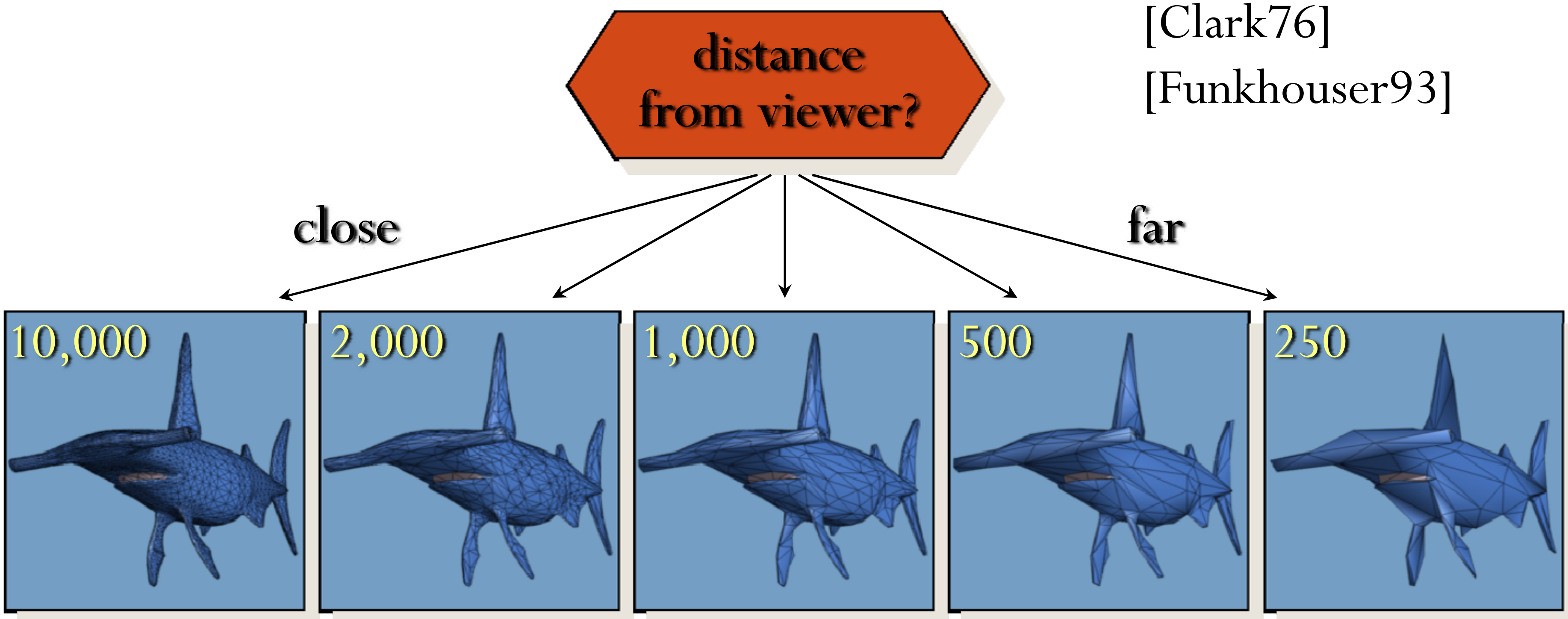
Mesh Simplification



[Schroeder-etal92]
[Turk92]
[Hoppe-etal93]
[Rossignac-Borrel93]
[Cohen-etal96]
…

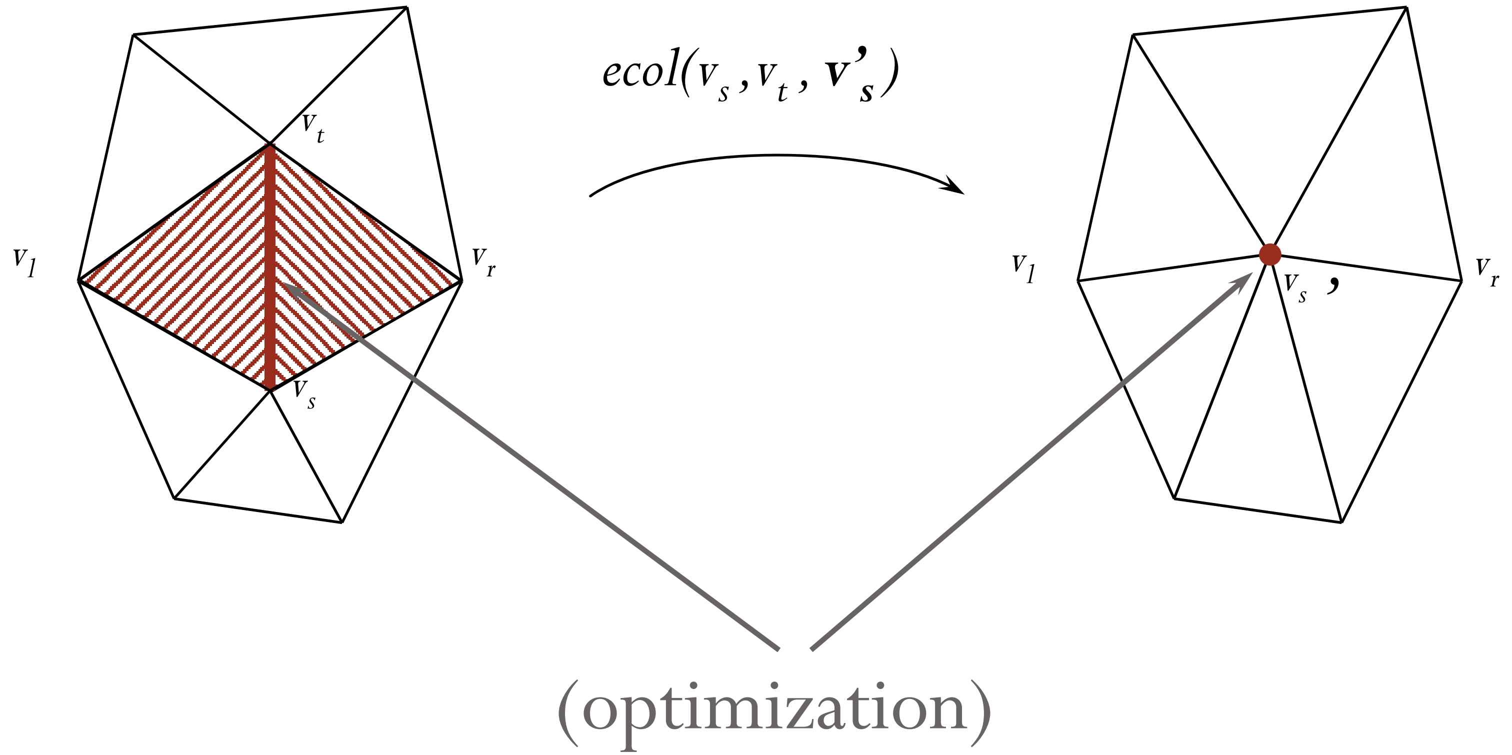
Level-of-detail (LOD)

[Clark76]
[Funkhouser93]



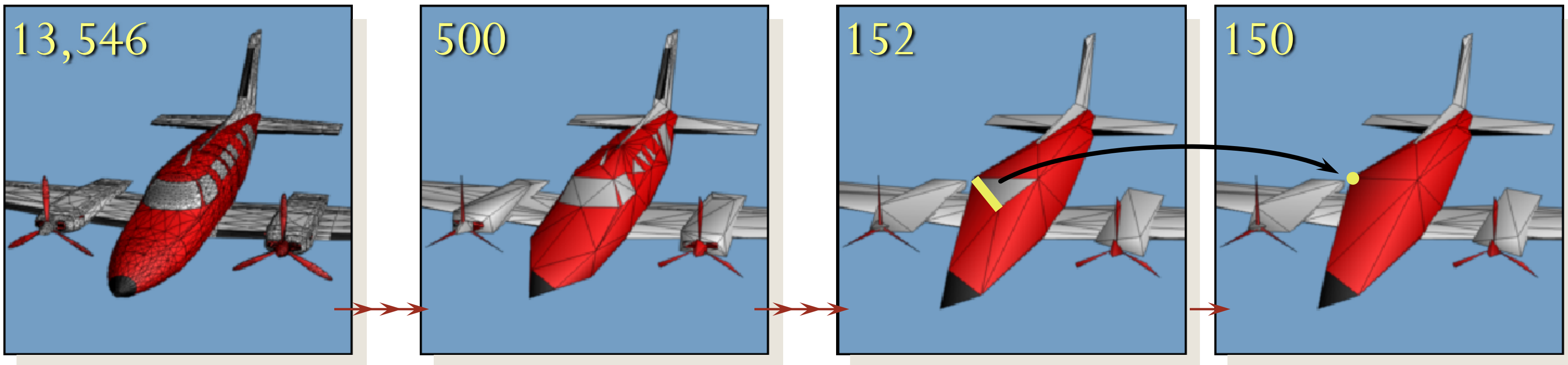
Mesh simplification procedure

- Idea: apply sequence of edge collapses:



Can be easily implemented using Half-Edge Data Structure!

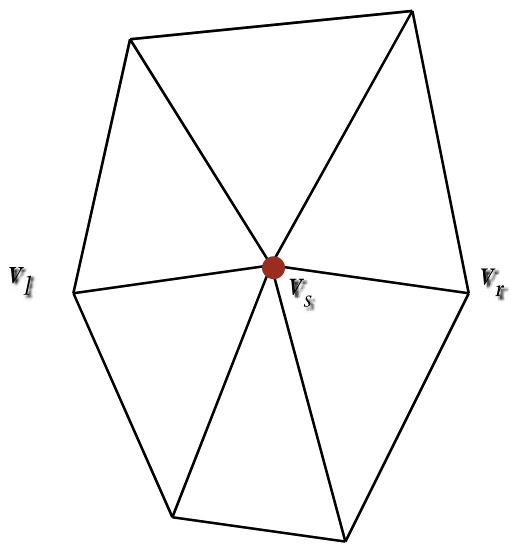
Simplification process



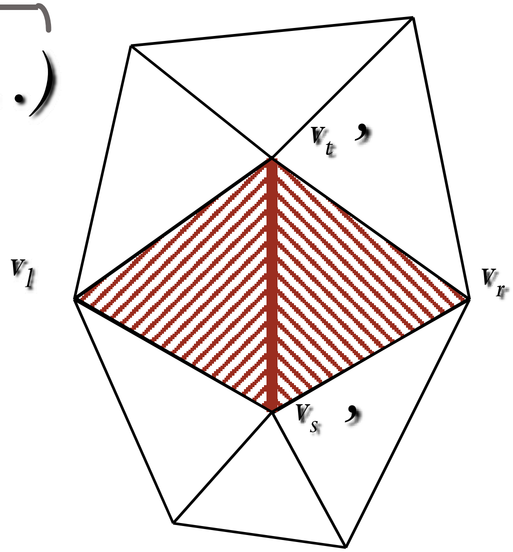
$$\hat{M}=M^{n} \xrightarrow[ecol_{n-1}]{} \;\rightarrow\rightarrow\rightarrow\; M^{175} \;\rightarrow\rightarrow\rightarrow \xrightarrow[ecol_{i}]{} M^{1} \xrightarrow[ecol_{0}]{} M^{0}$$

Invertible

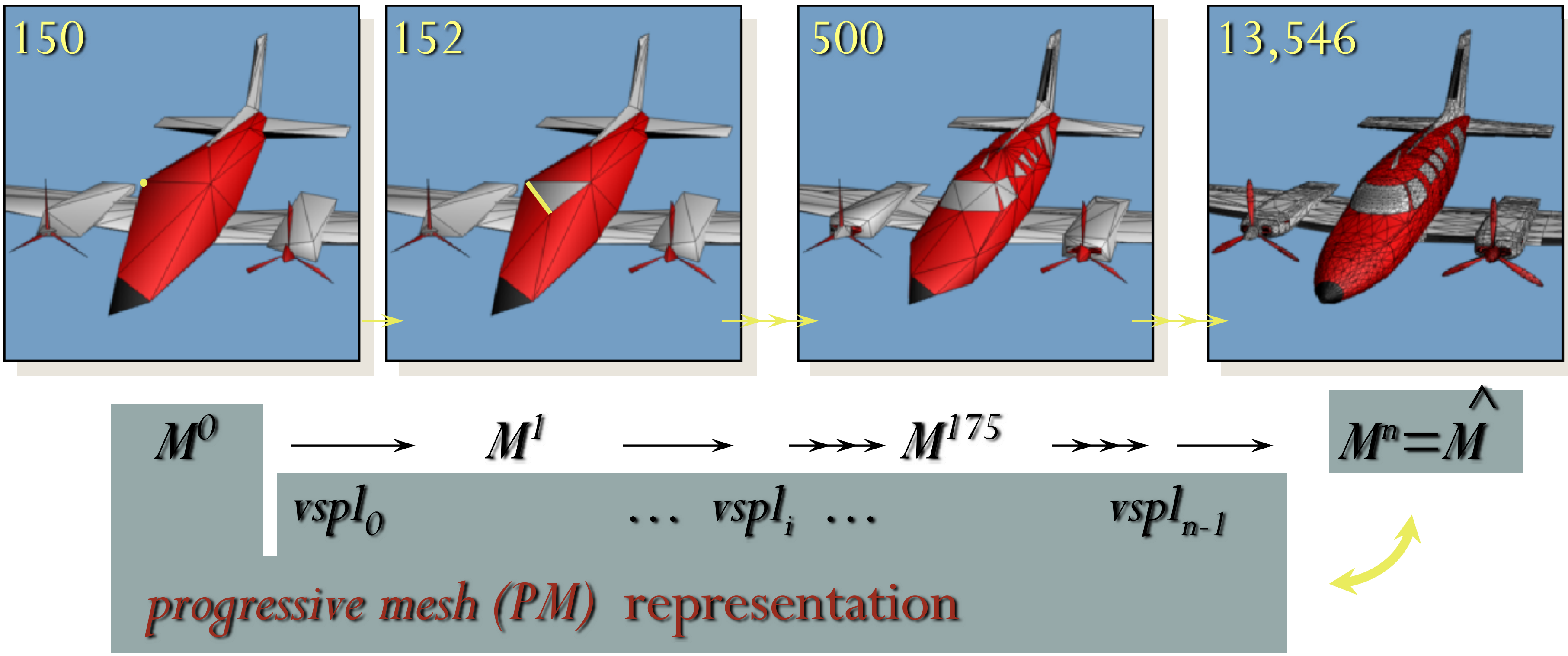
Vertex split transformation:



$$vspl(v_s, v_l, v_r, \overbrace{v'_s, v'_t, \ldots}^{attributes})$$

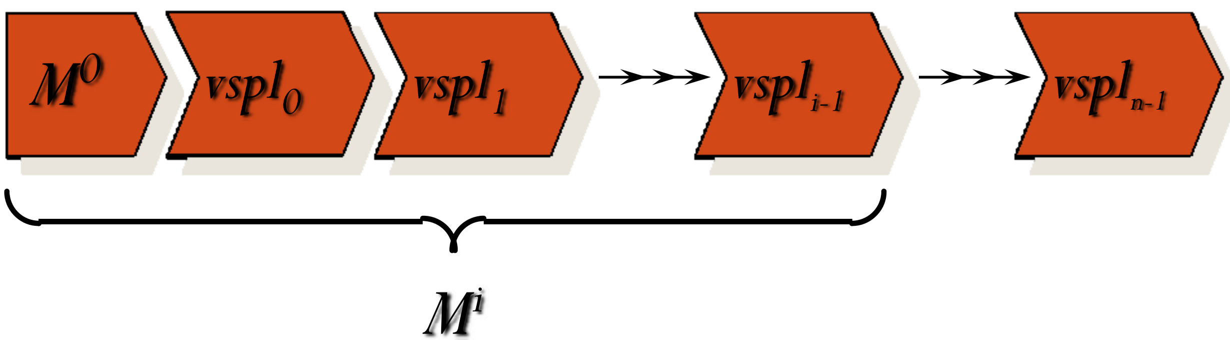


Reconstruction process

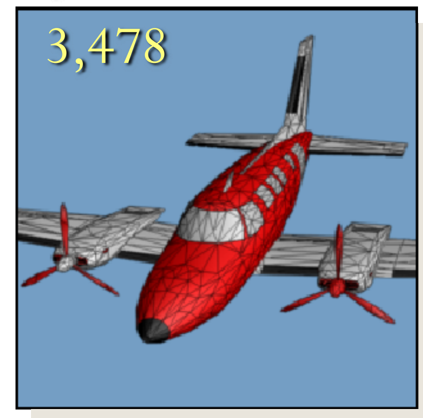


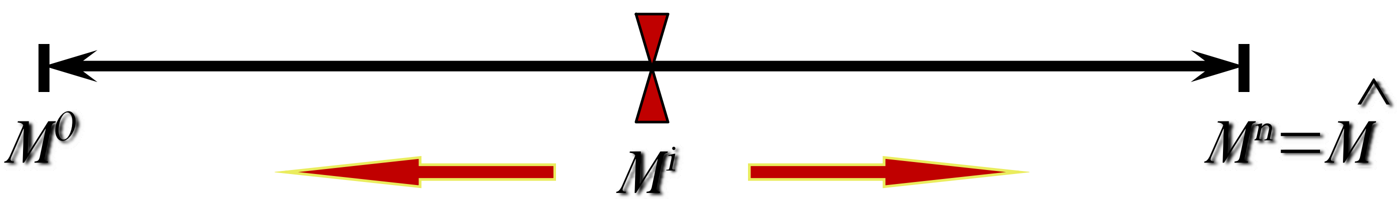
Continuous-resolution LOD

From PM, extract M^i of any desired complexity.



3,478 faces?





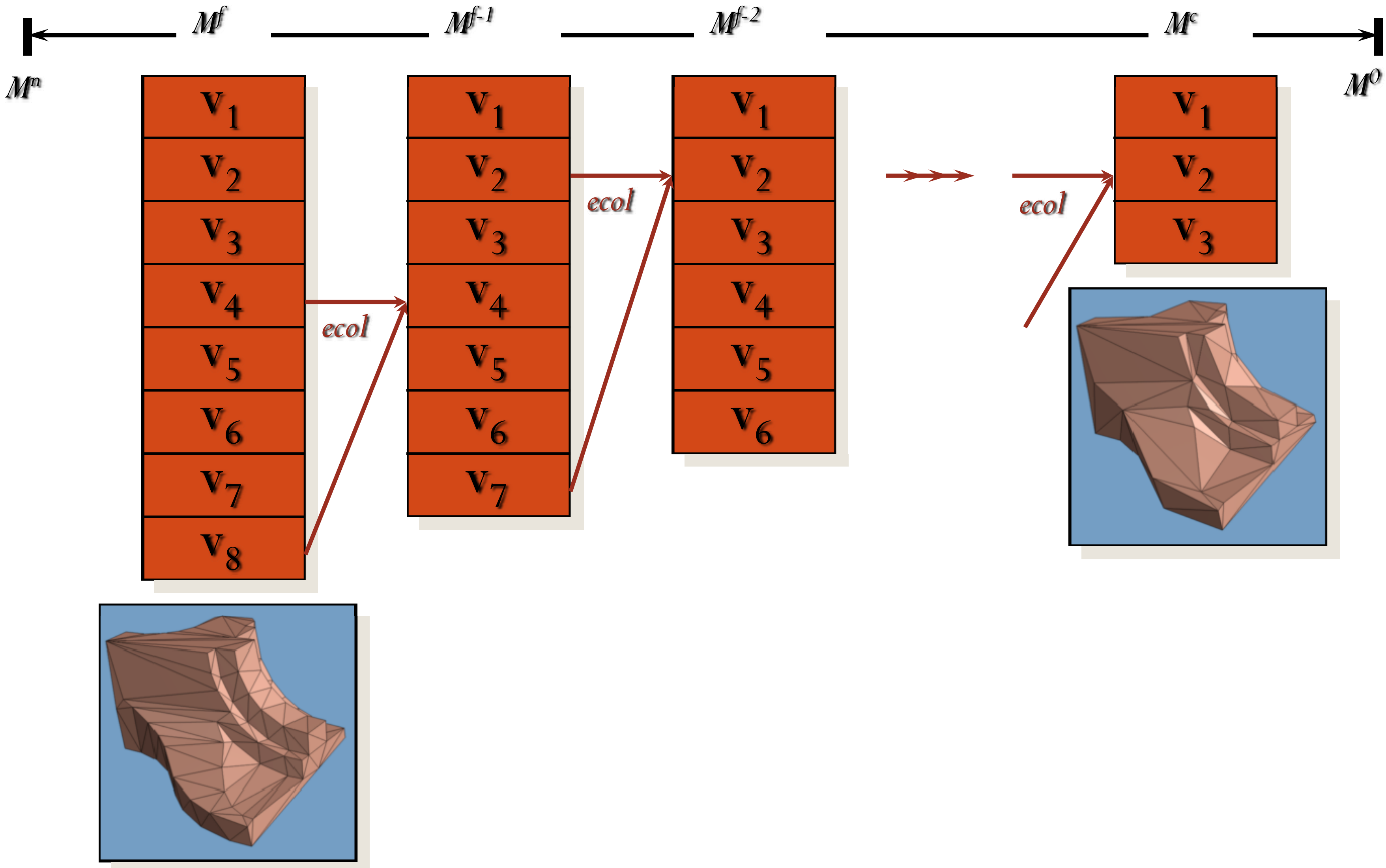
200K faces/sec!

100K faces/sec!

Video

(166 MHz Pentium)

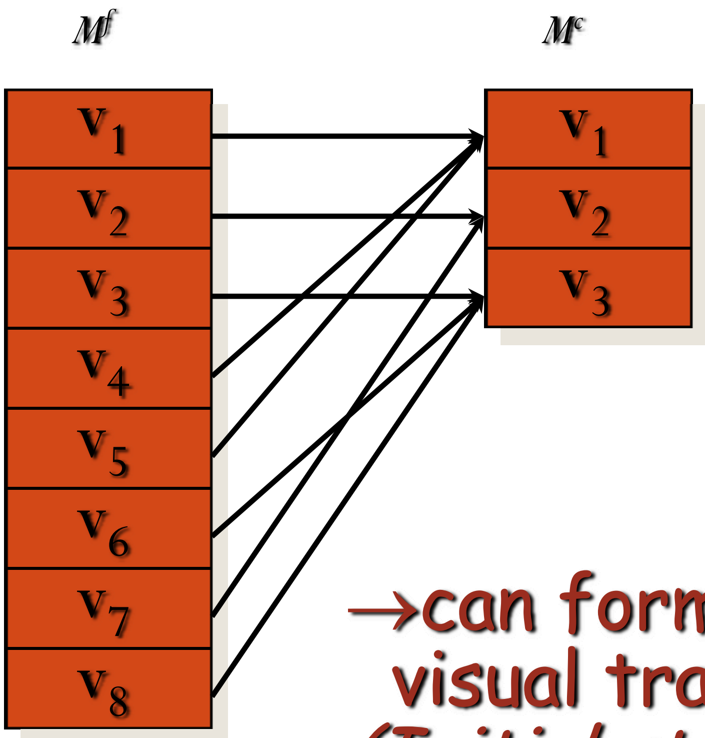
Property: Vertex correspondence

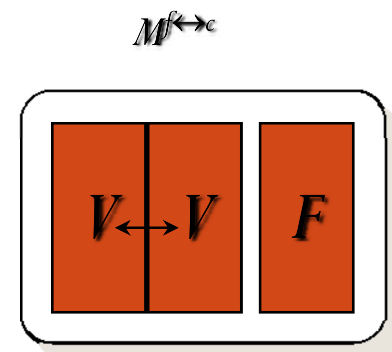


Application: Smooth transitions

Correspondence is a surjection:

Video





→can form a smooth visual transition: *geomorph*

(Initial status: topologically M^f, geometrically $M^{f\text{->}c}$)

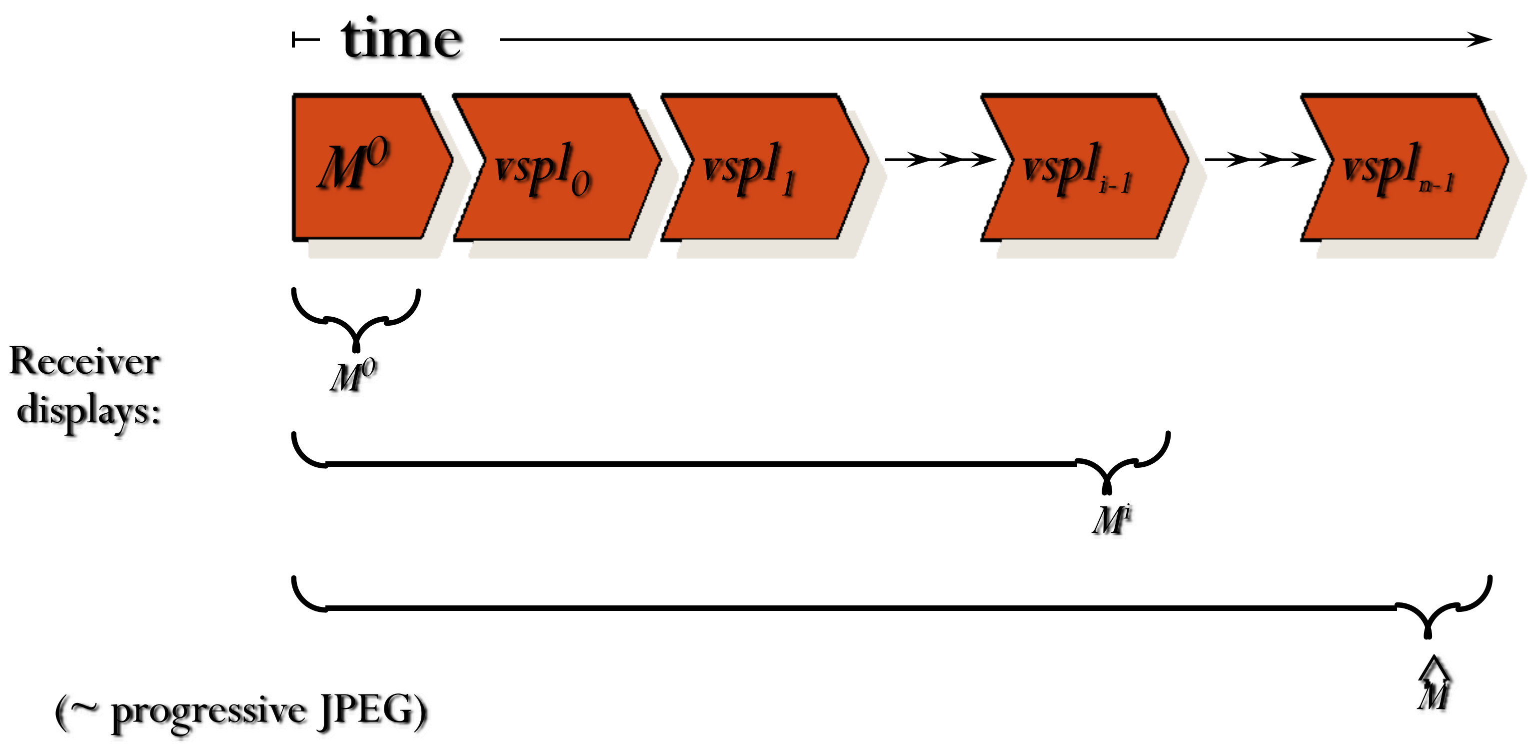
Morphing by Linear Interpolation

- Source mesh $M1=\{V1, \dots, Vn\}$
- Target mesh $M2=\{U1, \dots, Un\}$
- The interpolated mesh :

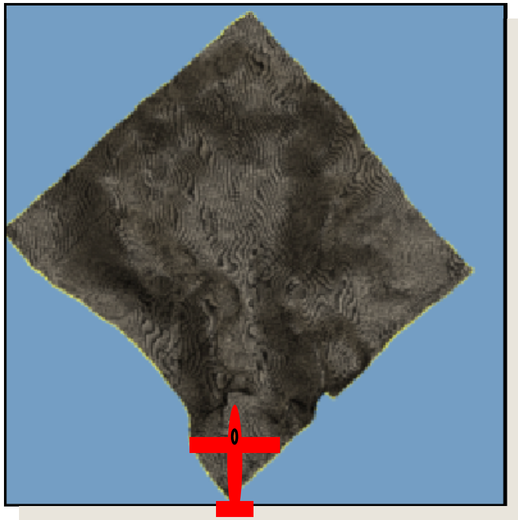
$$M(t) = \{V1*(1-t)+U1*t, \dots, Vn*(1-t)+Un*t\}$$

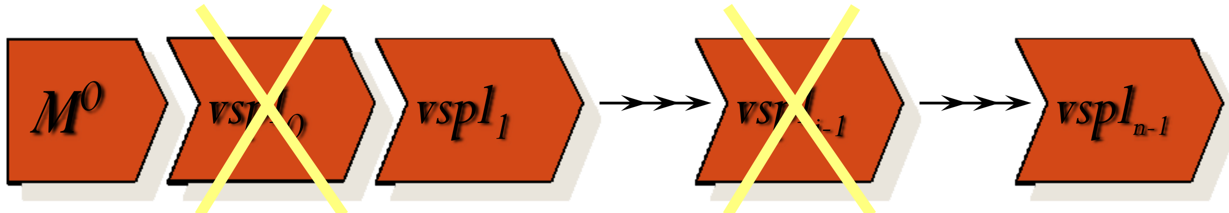
Application: Progressive transmission

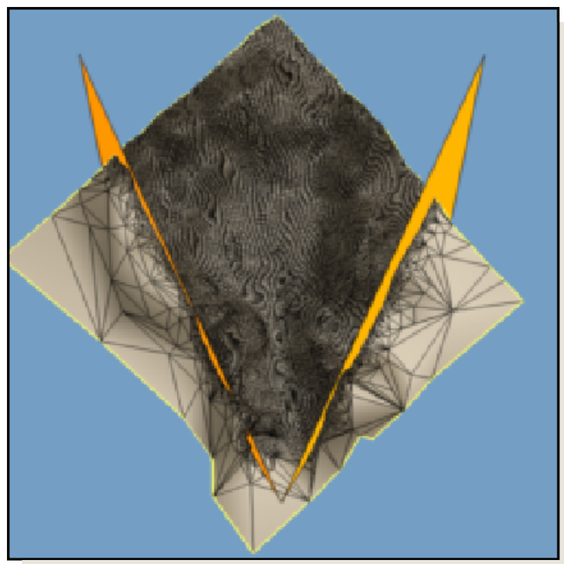
Transmit records progressively:

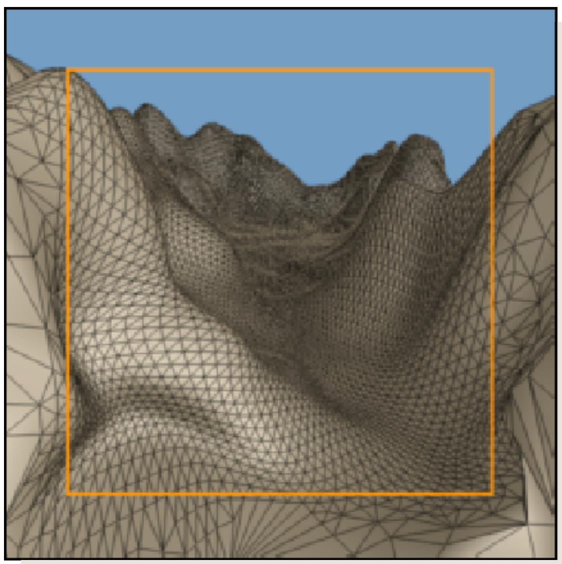


Application: Selective refinement





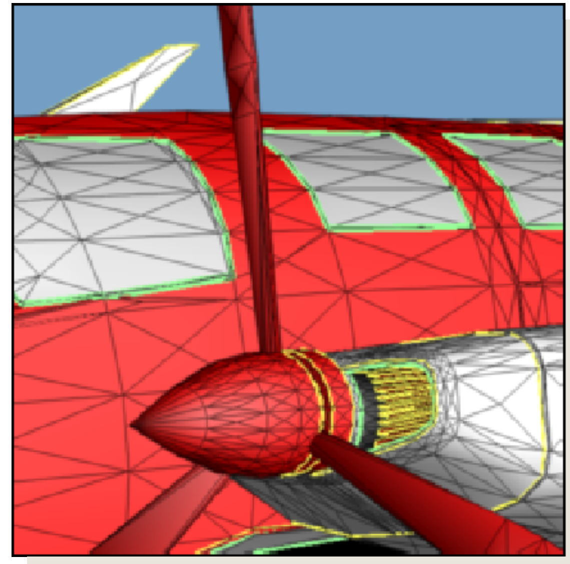




(e.g. view frustum)

How to select edge collapses?

- Preserve *appearance*:
  - geometric shape
  - scalar fields (e.g. color)
  - discontinuity curves



$$E = \cancel{\int}(e_{shape} + e_{scalars})dA + \cancel{\int}(e_{disc})dL$$

$$\sum_{\text{points}} \qquad\qquad\qquad\qquad \sum_{\text{points}}$$

Selecting edge collapses

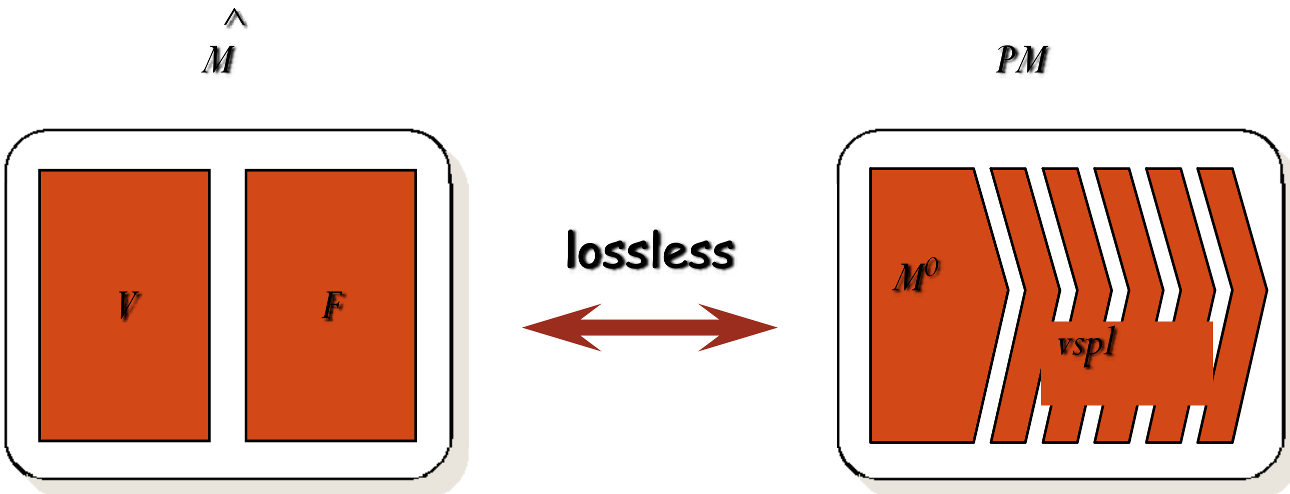
- Greedy algorithm: always collapse edge resulting in smallest ΔE

Simplification rates: ~ 30 faces/sec

[Hoppe Siggraph 96]

- off-line process
- could use simpler heuristics

Summary



- single resolution

- continuous-resolution
- smooth LOD
- space-efficient
- progressive

Videos

Summary

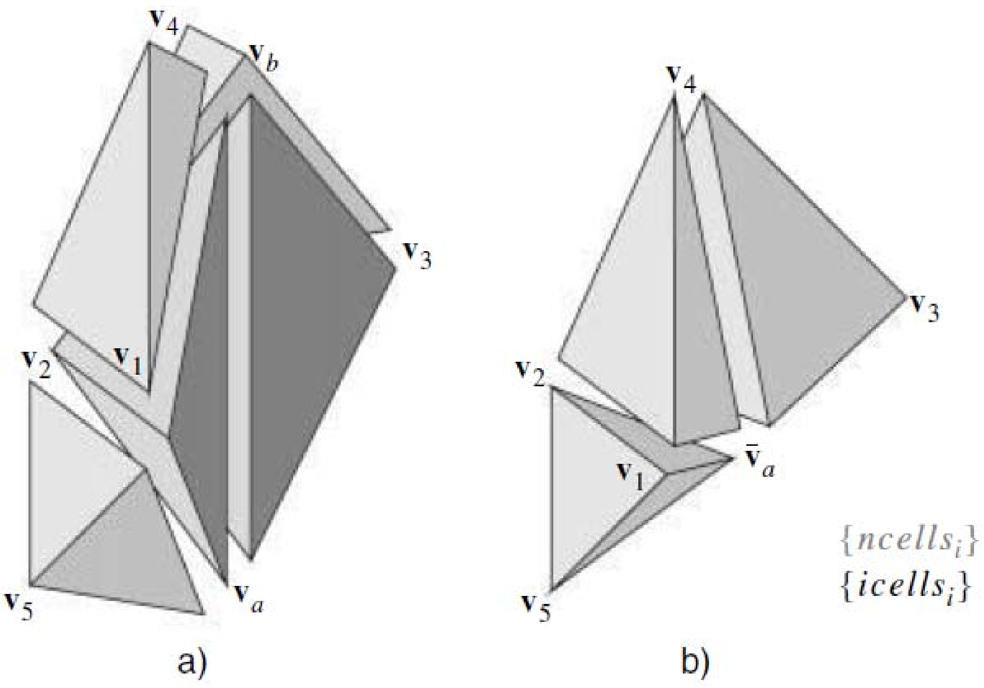
- Three issues that deserve more consideration:
  1. Correctness Detection
  2. Collapsing Edge Selection
  3. New Vertex Position
     1) Ideally: given n vertices → best approximation
     2) Practically: local optimization

Summary

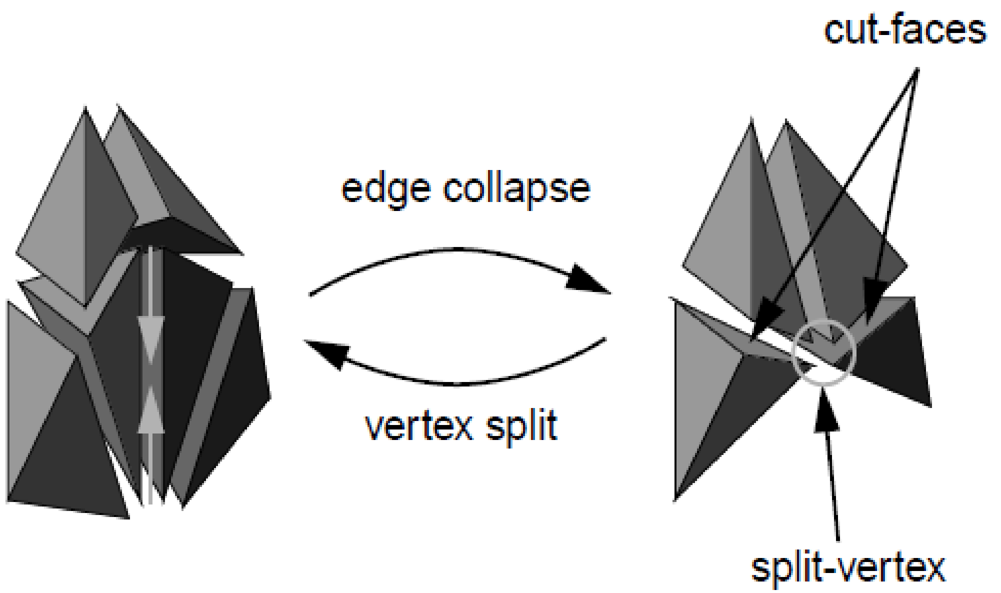
- Bottom line:
  - You got the concept and idea
  - And with the half-edge data structure, you can make this whole thing work
    - [Topologically Correctness] Shrink a complicated triangle mesh to a simple one, without changing Euler number
    - [Geometrically Roughly Right] Keep using the averaged spatial position
- Consider its generalization to 3D…

Progressive Tetrahedral Meshes

Edge Collapse

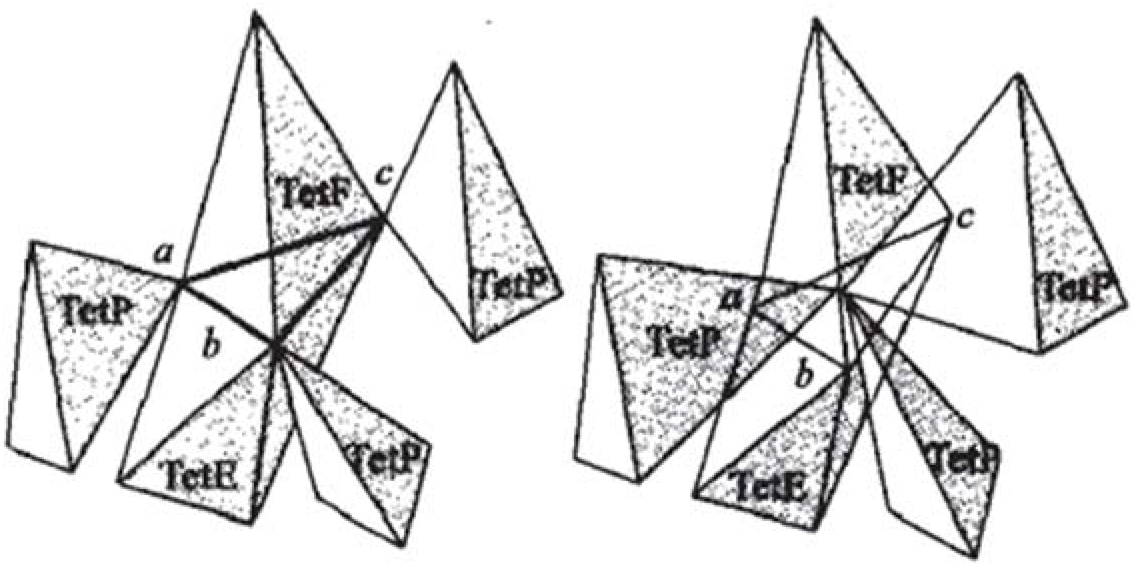


Progressive Tetrahedral Meshes



Progressive Tetrahedral Meshes

Is "Edge Collapse" the only way?



Progressive Tetrahedral Meshes

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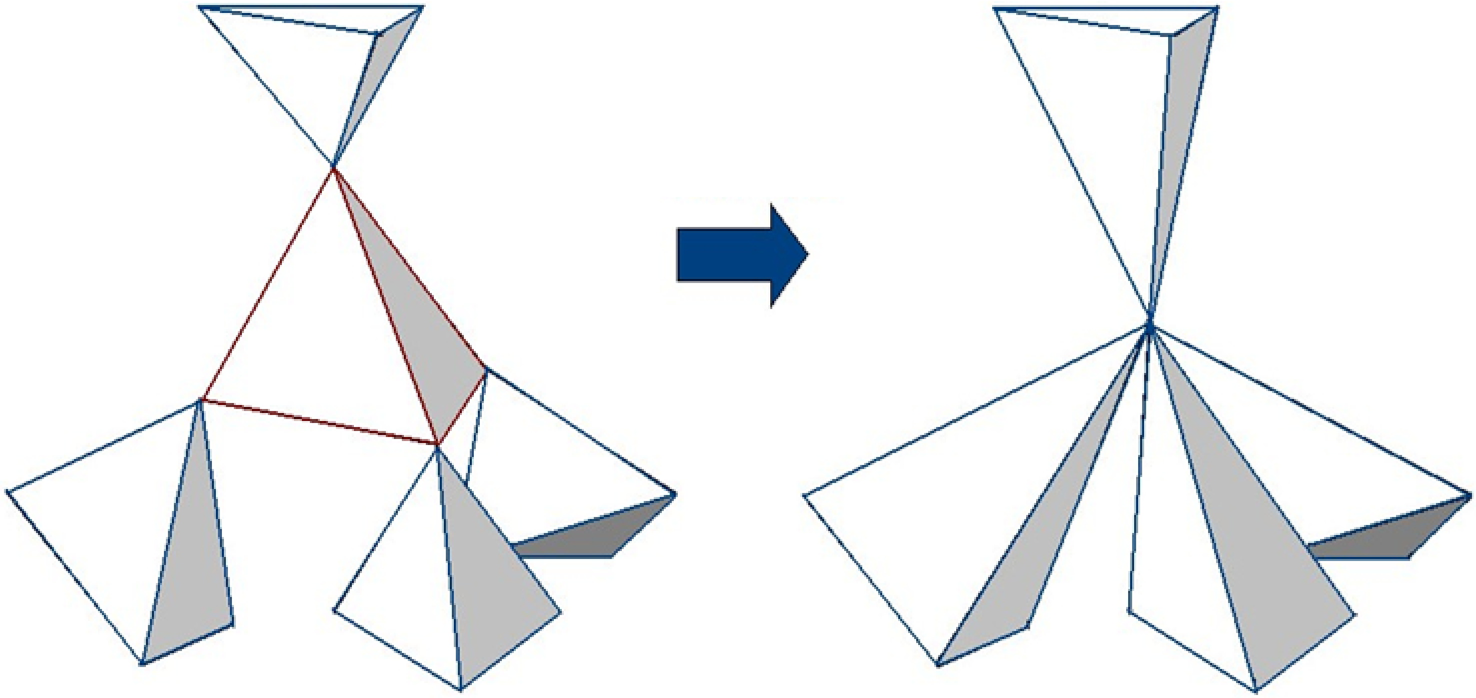
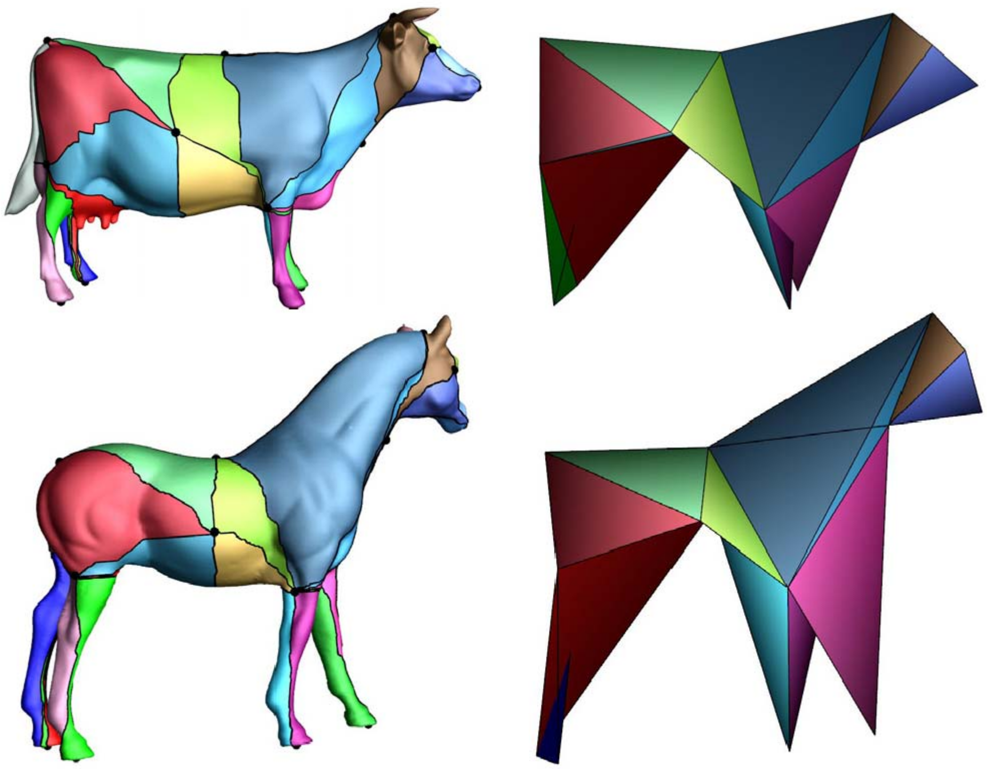


Some applications

Inter-surface mapping and morphing



Some applications

Dynamic Collision Detection Video

And many more in visualization, vision, and CAGD…