Simplification envelopes

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Outline

- Introduction
- Background
- Concepts and assumptions
- Envelope computation
- Simplification
- Other features

Introduction

- User specified error bound ε
- Framework
  - Local algorithm
  - Global algorithm
- Geometry preserving
- Prevention of self-intersection
- Offset surfaces (envelopes)
- Hierarchy of LOD

Hierarchy of LOD

Introduction

- We create TWO envelopes around a 3D Mesh, an inner envelope & an outer envelope
- Conceptually this is similar to the Russian Matroshka doll that can have a smaller doll inside & a bigger doll outside.

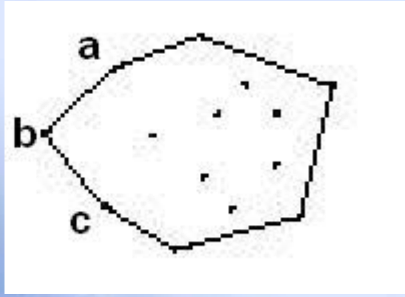
Background

- Two categories
  - Minimize number of vertices
  - Minimize the error

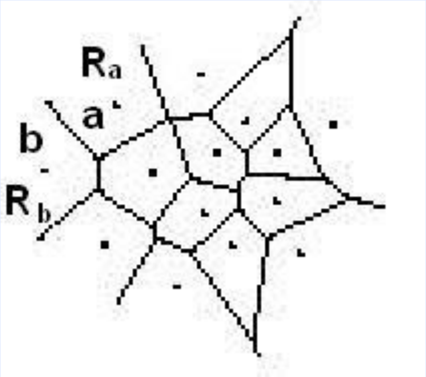
Concepts

- Convex hull
- Voronoi diagram
- Delaunay triangulation

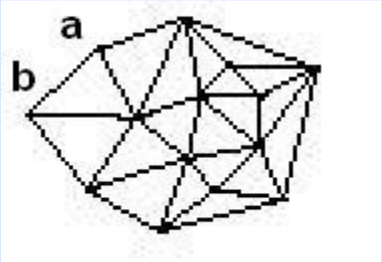
Point set P



Convex hull



Voronoi diagram



Delaunay triangulation

Terminology and assumptions

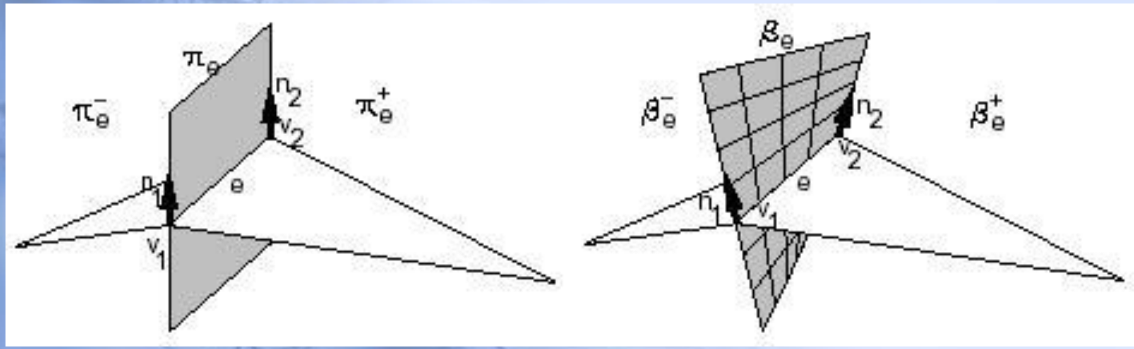
- P: polygonal model
- A: approximation of P
- ε -approximations
- Assumptions
  - Triangles
  - Well-behaved model
  - Manifold (or bordered manifold)
  - Single normal

Envelope computation I

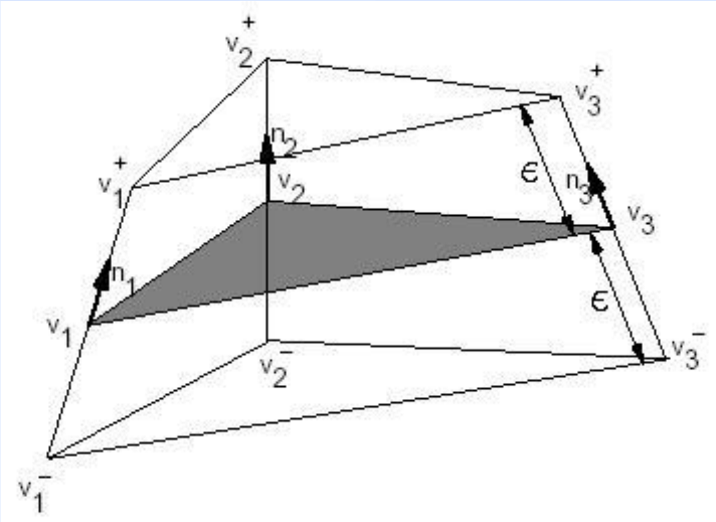
- Fundamental triangles
- Edge half-spaces
- Fundamental prism

$$c(v_i^{\pm}) = c(v_i) \pm \varepsilon n(v_i)$$

$$n(v_i^{\pm}) = n(v_i)$$



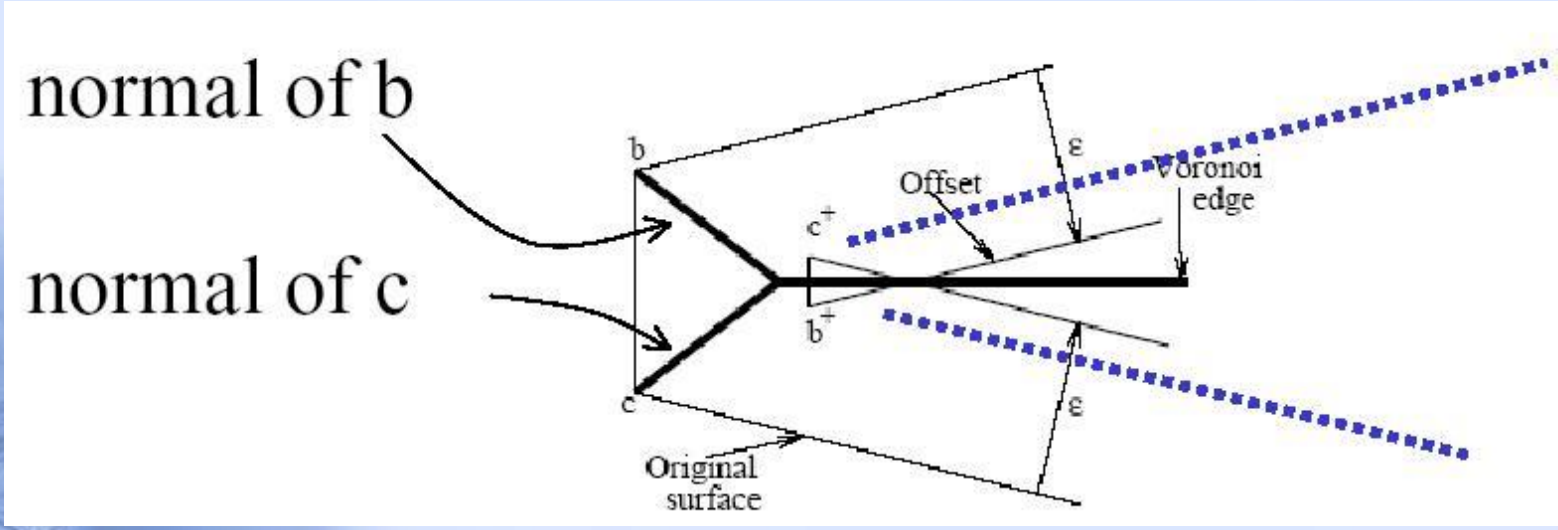
Edge half-spaces



The fundamental prism

Envelope computation II

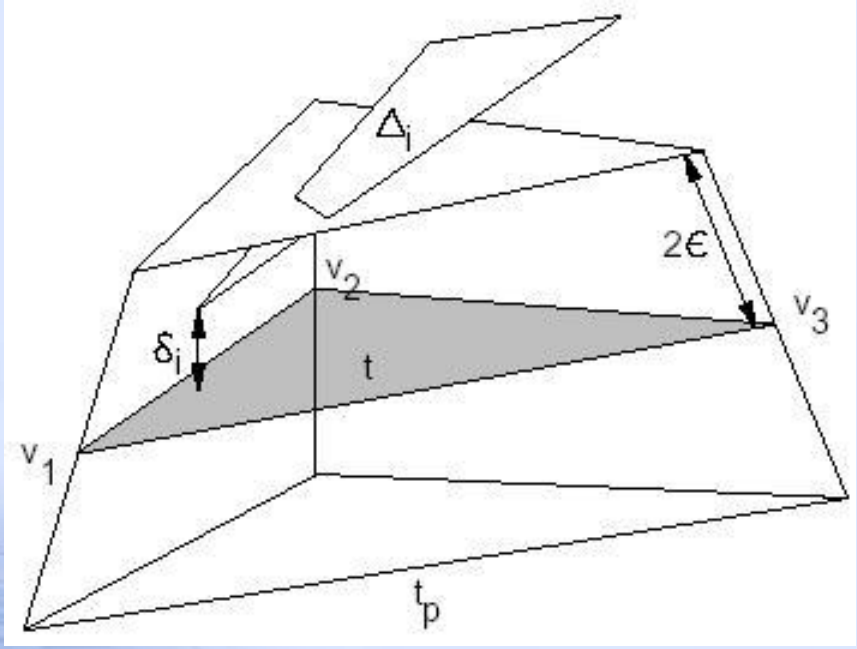
- Voronoi regions



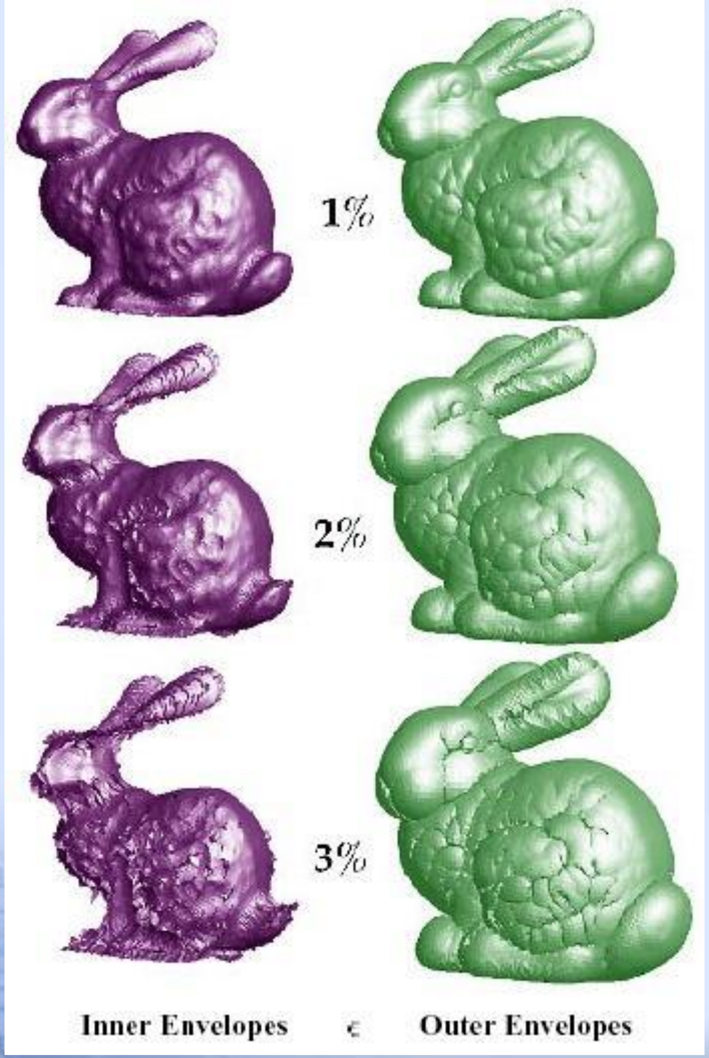
Offset surfaces, Courtesy of Irene

Analytical ε computation

$$\varepsilon_{new} = \frac{1}{2}\min_i \delta_i$$

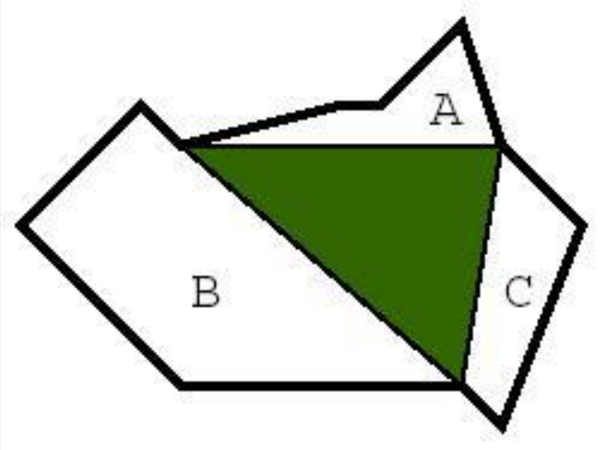


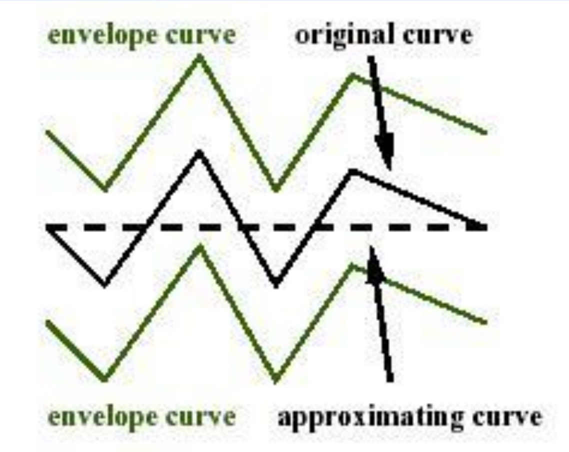
Numerical ε computation



Generation of approximation

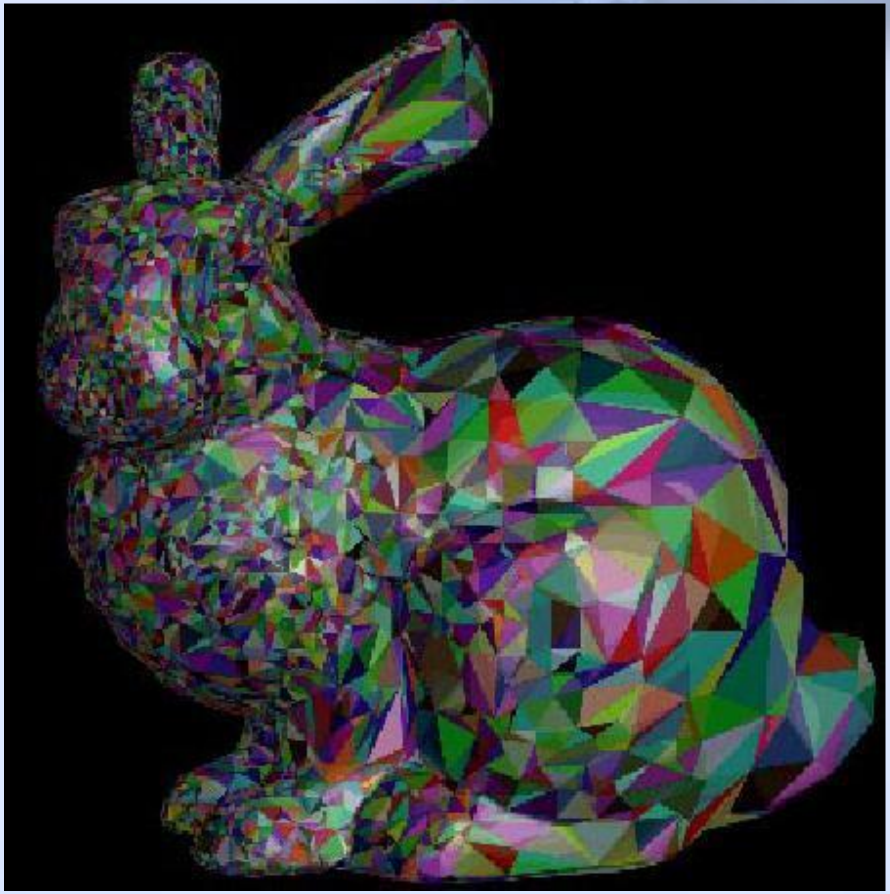
- Hole creation
- Hole filling
- Candidate triangle
- Local algorithm
- Global algorithm
  - Cover
  - Overlap



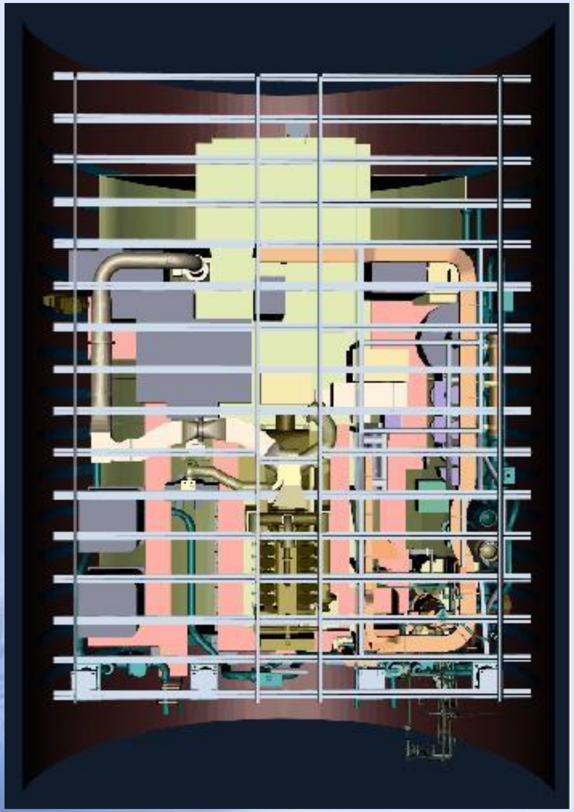


Additional features

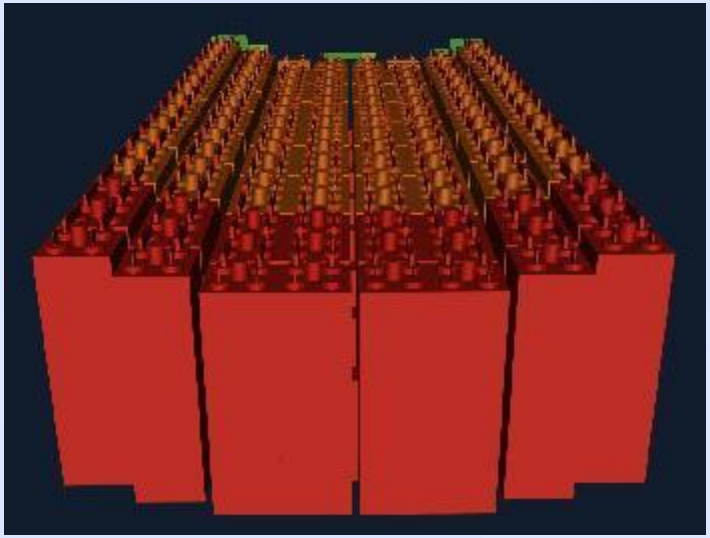
- Preserve sharp edges
- Adaptive approximation
- Manifold Bordered surfaces



Results

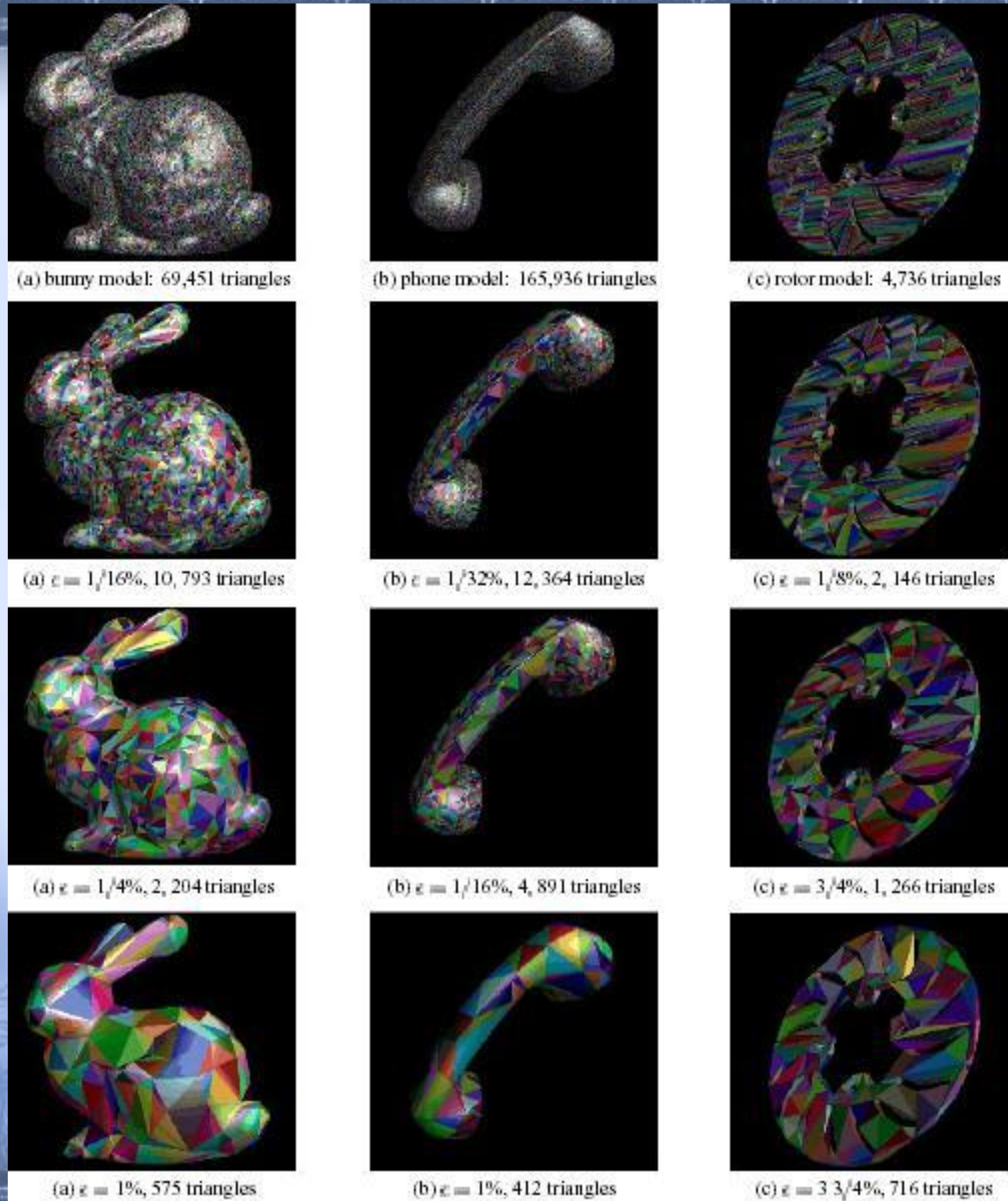


AMR model, 3,000 objects, 500,000 triangles. Simplified 2,600 objects, 430,000 triangles.



Batteries model, 87,000 triangles.

Simplified 45,000 triangles.


(a) bunny model: 69,451 triangles
(b) phone model: 165,936 triangles
(c) rotor model: 4,736 triangles
(a) ε = 1/16%, 10, 793 triangles
(b) ε = 1/32%, 12, 364 triangles
(c) ε = 1/8%, 2, 146 triangles
(a) ε = 1/4%, 2, 204 triangles
(b) ε = 1/16%, 4, 891 triangles
(c) ε = 3/4%, 1, 266 triangles
(a) ε = 1%, 575 triangles
(b) ε = 1%, 412 triangles
(c) ε = 3 3/4%, 716 triangles

Performance

Bunny			Phone			Rotor			AMR		
ϵ %	# Polys	Time	ϵ %	# Polys	Time	ϵ %	# Polys	Time	ϵ %	# Polys	Time
0	69,451	N/A	0	165,936	N/A	0	4,735	N/A	0	436,402	N/A
1/64	44,621	9	1/64	43,537	31	1/8	2,146	3	1	195,446	171
1/32	23,581	10	1/32	12,364	35	1/4	1,514	2	3	143,728	61
1/16	10,793	11	1/16	4,891	38	3/4	1,266	2	7	110,090	61
1/8	4,838	11	1/8	2,201	32	1 3/4	850	1	15	87,476	68
1/4	2,204	11	1/4	1,032	35	3 3/4	716	1	31	75,434	84
1/2	1,004	11	1/2	544	33	7 3/4	688	1			
1	575	11	1	412	30	15 3/4	674	1			

Simplification performance and run times in minutes

On Hewlett-Packard 735/125

Pros and cons

- Advantage
  - High fidelity
- Disadvantages
  - Cannot simplify models drastically
  - ε

Comparison

What matters me most	Recommendation
Geometric accuracy	SE
Performance	QEM
Drastic simplification	QEM
Progressive transmission	PM

References

- [1] J. Cohen et al., “Simplification Envelopes,” Computer Graphics (Proc. Siggraph 96), vol. 30, ACM Press, New York, 1996, pp. 119-128.
- [2] Irene Cheng, “3D Model Simplification & Efficient Transmission,” CMPUT 604 class presentation.
- [3] A. Varshney. “Hierarchical geometric approximations”. Ph.D. Thesis TR-050-1994, Department of Computer Science, University of North Carolina, Chapel Hill, NC 27599-3175, 1994.
- [4] David P. Lueke, “A Developer's Survey of Polygonal Simplification Algorithms”, IEEE CG&A, May/June, 2001
- [5] H. Hoppe, “Progressive Meshes,” Computer Graphics (Proc. Siggraph 96), vol. 30, ACM Press, New York, 1996, pp. 99-108.
- [6] M. Garland and P. Heckbert, “Simplification Using Quadric Error Metrics,” Computer Graphics (Proc. Siggraph 97), vol. 31, ACM Press, New York, 1997, pp. 209-216.