Multiresolution Meshes

COS 526

Tom Funkhouser, 2010

Slides by Guskov, Sweldens, Garland, Hoppe, and Southern

The Problem of Detail

Slide by Garland

Graphics systems are awash in model data

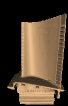
- very detailed CAD databases
- high-precision surface scans

Available resources are constrained

- CPU, space, graphics speed, network bandwidth

We need economical models

- want the minimum level of detail (LOD) required



Georgia Tech

Newport News

Stanford

A Non-Economical Model

Slide by Garland

Stanford

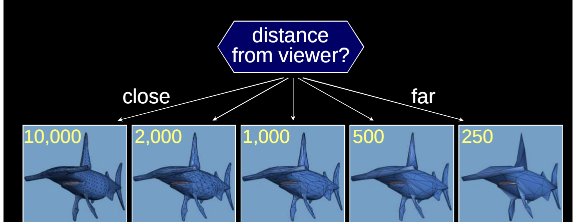
Levels of Detail

Triangles
: 41,855
27,970
20,922
12,939
8,385
4,766

courtesy of Division and Viewpoint

Levels of Detail

Slide by Hoppe



Levels of Detail

Pre-process

- Generate discrete set of independent levels of detail

Run-time

- Select level of detail according to viewpoint

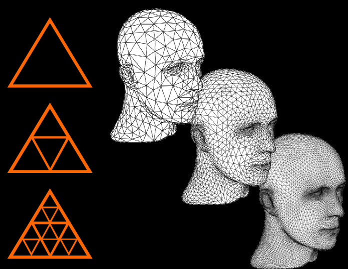
Advantages

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

Disadvantages

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

Multiresolution Meshes

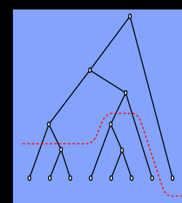


[Hoppe]

Multiresolution Meshes

Encode simplification operations in tree

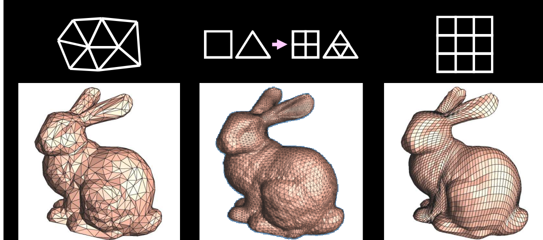
- Subtrees are independent of one another
- Cut through tree defines a mesh
- Move cut up/down to simplify/refine



Xia96, Hoppe97, Luebke97

Multiresolution Meshes

Slide by Hoppe



Irregular *Semi-regular* *Completely regular*

Outline

Completely regular meshes ←
- Geometry image

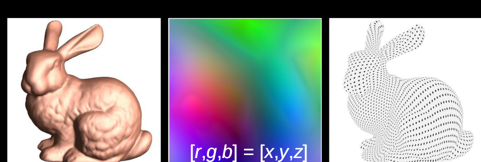
Semi-regular meshes
- Normal mesh

Irregular meshes
- Progressive mesh

Completely Regular Mesh

Slide by Hoppe

Regular sampling of parameter domain



Geometry Image

Outline

Completely regular meshes
- Geometry image

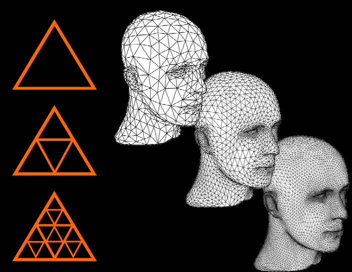
Semi-regular meshes ←
- Normal mesh

Irregular meshes
- Progressive mesh

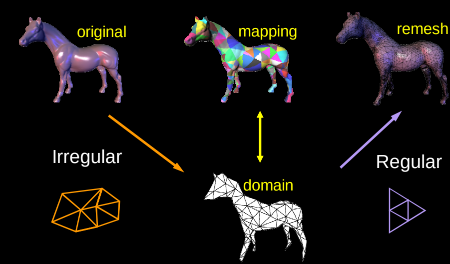
Semi-Regular Mesh

Slide by Sweldens

Arbitrary base mesh + refinement via subdivision



Multiresolution Analysis



[Guskov *et al.*]

Multiresolution Analysis

step 1: construct a simple domain mesh K

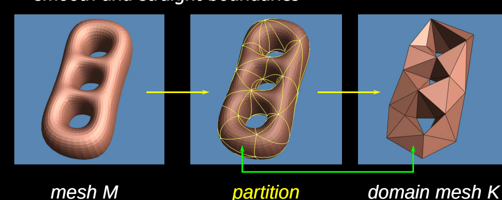
step 2: construct a parametrization r of M over K

step 3: remesh

Multiresolution Analysis

Step 1: construct simple base domain

- topological type of *K* = topological type of *M*
- small number of triangular regions
- smooth and straight boundaries

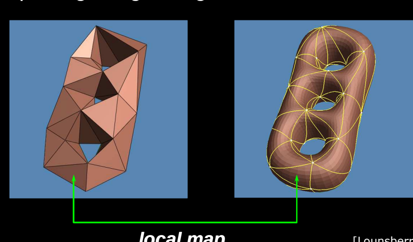


[Lounsberry *et al.*]

Multiresolution Analysis

Step 2: construct parameterization

- Map each face of domain mesh to corresponding triangular region

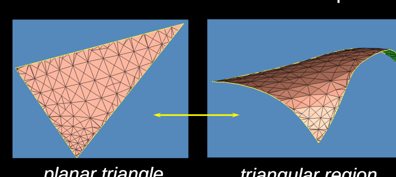


[Lounsberry *et al.*]

Multiresolution Analysis

Step 2: construct parameterization

- Map each face of domain mesh to corresponding triangular region
- Local maps must agree on boundaries and introduce small distortions harmonic maps

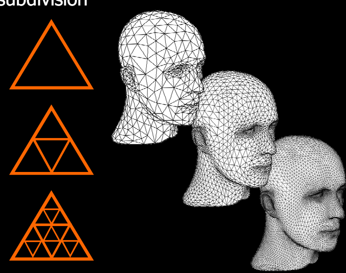


[Lounsberry *et al.*]

Multiresolution Analysis

Step 3: remesh

- Regular subdivision



[Hoppe]

Multiresolution Representation

Wavelet representation

base shape M^0

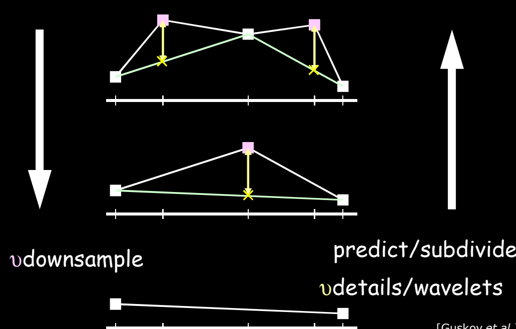
+

sum of local correction terms

(wavelet terms)

[Lounsberry *et al.*]

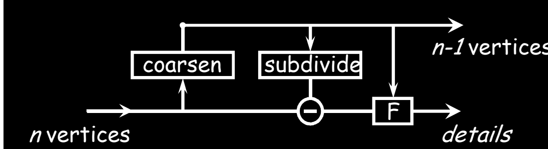
Multiresolution Representation



[Guskov *et al.*]

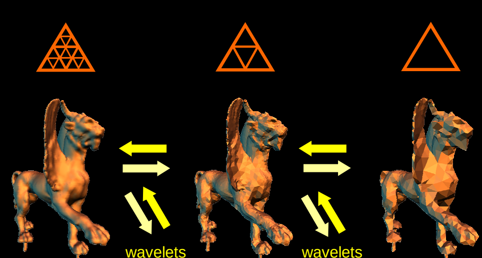
Multiresolution Representation

Burt-Adelson pyramid



[Guskov *et al.*]

Wavelet Computation



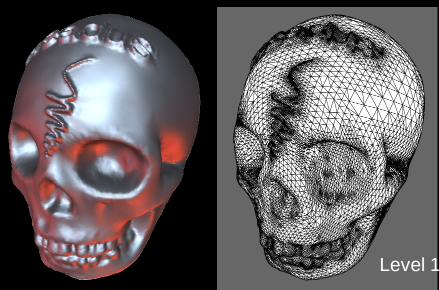
[Guskov *et al.*]

Multiresolution Meshes

Applications:

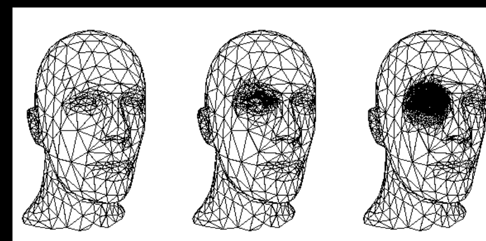
- Adaptive remeshing
- Compression
- Filtering
- Editing
- Morphing

Adaptive Remeshing



[Guskov *et al.*]

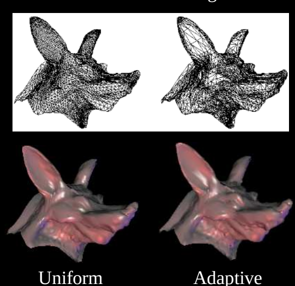
Adaptive Remeshing



[Zorin *et al.*]

Adaptive Remeshing

Both 11K triangles



[Zorin *et al.*]

Multiresolution Meshes

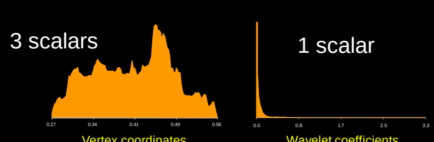
Applications:

- Adaptive remeshing
  Compression
- Filtering
- Editing
- Morphing

Mesh Compression

Effect of wavelet transform

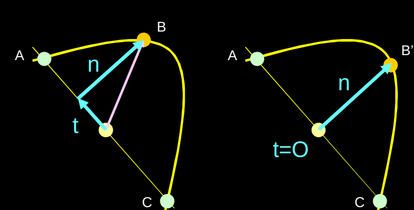
- changes distribution of coefficients
  - almost all coefficients close to zero



[Guskov *et al.*]

Mesh Compression

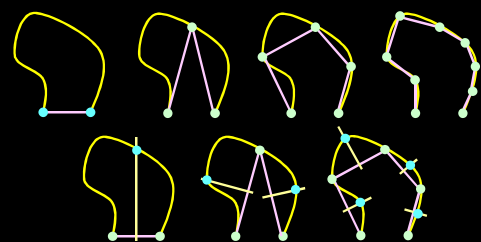
Two scalar displacement (t,n)   One scalar (normal mesh)



[Guskov *et al.*]

Mesh Compression

Normal mesh

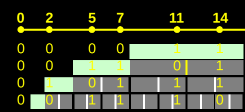


[Guskov *et al.*]

Mesh Compression

Progressive compression:

- encode largest coefficients first
  - encode only most significant bits
  - subsequent bits in later iterations



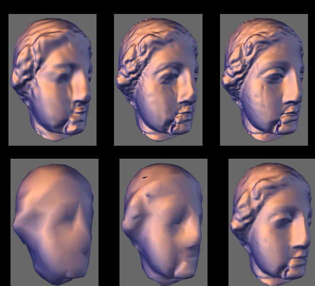
[Guskov *et al.*]

Mesh Compression

Fixed file size

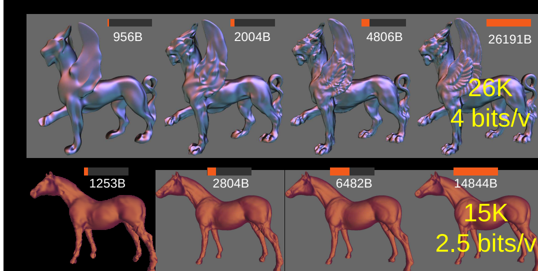
Normal Meshes:

CPM:



[Guskov *et al.*]

Mesh Compression



[Guskov *et al.*]

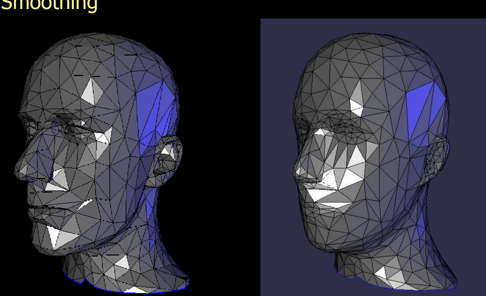
Multiresolution Meshes

Applications:

- Adaptive remeshing
- Compression
- Filtering
- Editing
- Morphing

Multiresolution Mesh Processing

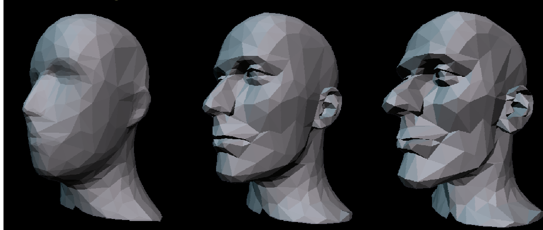
Smoothing



[Guskov *et al.*]

Multiresolution Mesh Processing

Enhancing



smoothed + 2 * (original - smoothed) = enhanced

[Guskov *et al.*]

Multiresolution Mesh Processing

Filtering

[Guskov *et al.*]

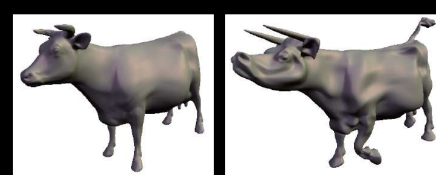
Multiresolution Meshes

Applications:

- Adaptive remeshing
- Compression
- Filtering
- Editing
- Morphing

Multiresolution Mesh Editing

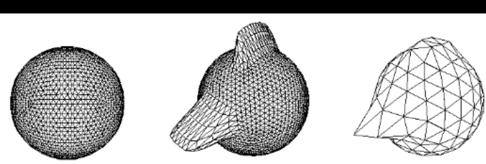
Goal: edit surface with operations at various resolutions



[Guskov *et al.*]

Multiresolution Mesh Editing

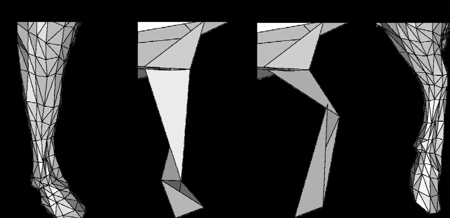
When edit at fine resolution,
update higher levels of multiresolution hierarchy



Input at level 3 | Edit on level 3 | Effect of edit on level 2

[Zorin *et al.*]

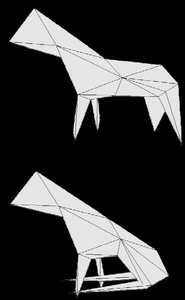
Multiresolution Mesh Editing



original | coarse | edit coarse | edit fine

[Guskov *et al.*]

Multiresolution Mesh Editing



[Guskov *et al.*]

Multiresolution Mesh Editing

[Zorin *et al.*]

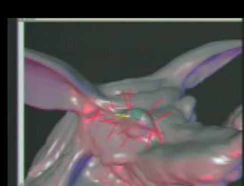
Multiresolution Mesh Editing

[Zorin *et al.*]

Multiresolution Mesh Editing

[Zorin *et al.*]

Multiresolution Mesh Editing



[Zorin *et al.*]

Multiresolution Mesh Editing

Edit & Enhance

[Guskov *et al.*]

Multiresolution Meshes

Applications:

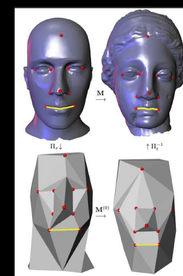
- Adaptive remeshing
- Compression
- Filtering
- Editing

Morphing

Multiresolution Mesh Morphing

Goal: generate intermediate models

- Requires common parameterization

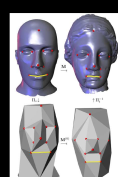


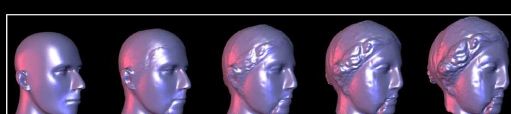
[Lee *et al.*]

Multiresolution Mesh Morphing

Goal: generate intermediate models

- Requires common parameterization





[Lee *et al.*]

Multiresolution Mesh Morphing

[Lee *et al.*]

Multiresolution Mesh Morphing

[Lee *et al.*]

Multiresolution Mesh Morphing

[Lee *et al.*]

Multiresolution Mesh Morphing

with Spatial Control

[Lee *et al.*]

Multiresolution Mesh Morphing

[Lee *et al.*]

Multiresolution Mesh Morphing

with Spatial Control

[Lee *et al.*]

Outline

Completely regular meshes ←
- Geometry image

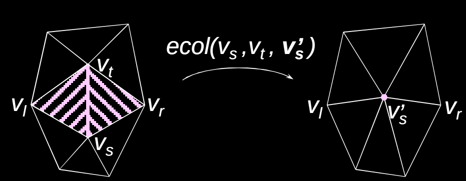
Semi-regular meshes
- Normal mesh

Irregular meshes
- Progressive mesh

Progressive Mesh

Slide by Hoppe

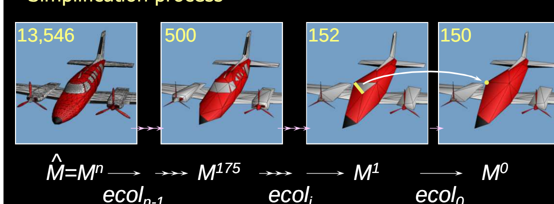
Encode continuous detail as sequence of edge collapses

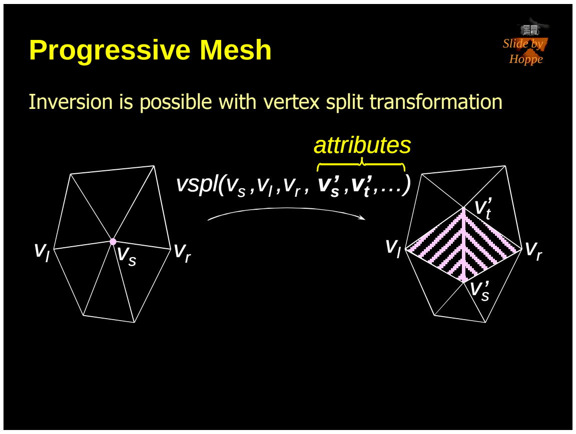


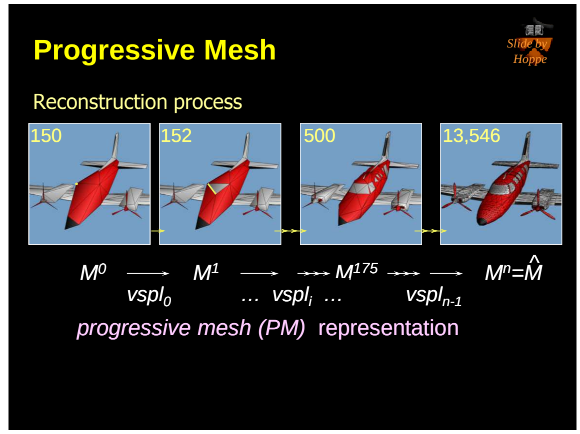
Progressive Mesh

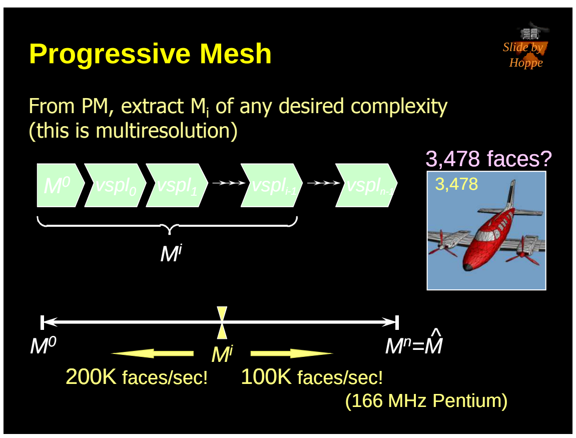
Slide by Hoppe

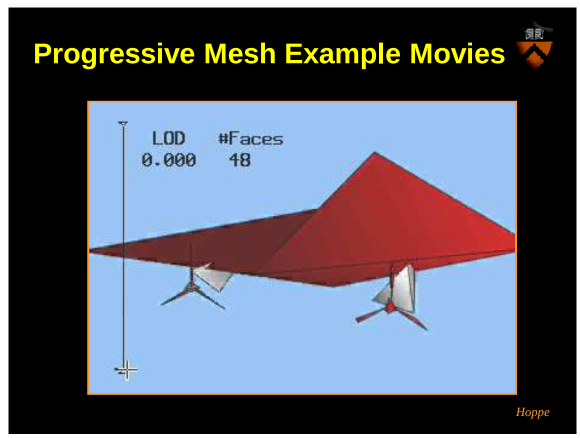
Simplification process

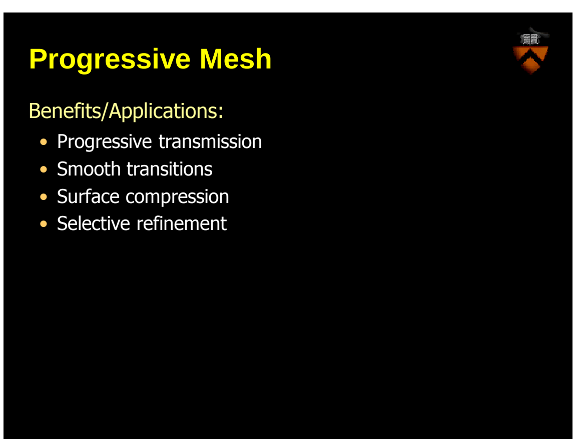


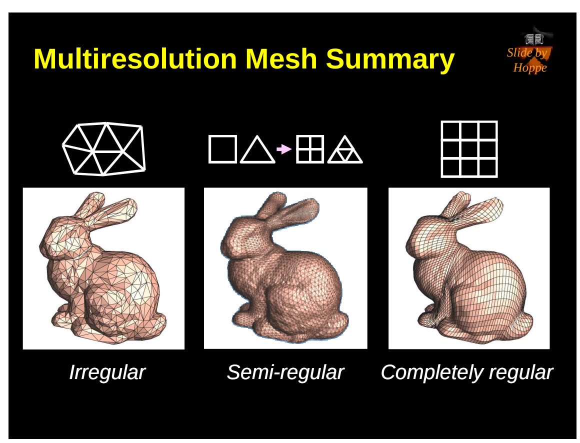

Progressive Mesh
Slide by Hoppe
Inversion is possible with vertex split transformation
attributes
vspl(vs, vl, vr, v's, v't, ...)
vl
vs
vr
v't
v's


Progressive Mesh
Slide by Hoppe
Reconstruction process
150
152
500
13,546
M0
M1
M175
Mn=M̂
vspl0
... vspli ...
vspln-1
progressive mesh (PM) representation


Progressive Mesh
Slide by Hoppe
From PM, extract Mi of any desired complexity
(this is multiresolution)
3,478 faces?
3,478
M0
vspl0
Mi
Mn=M̂
200K faces/sec!
100K faces/sec!
(166 MHz Pentium)


Progressive Mesh Example Movies
LOD
0.000
#Faces
48
Hoppe


Progressive Mesh
Benefits/Applications:
• Progressive transmission
• Smooth transitions
• Surface compression
• Selective refinement


Multiresolution Mesh Summary
Slide by Hoppe
Irregular
Semi-regular
Completely regular

Multiresolution Mesh Summary

Representations are available to support

- Progressive transmission
- Smooth transitions
- Adaptive refinement
- Compression

But limitations remain

- On-line costs not suitable for all applications
- Topological simplification still hard
- Animation largely ignored