Multiresolution Meshes

COS 526

Tom Funkhouser, Fall 2012

Slides by Guskov, Praun, Sweldens, etc.

Multiresolution Meshes

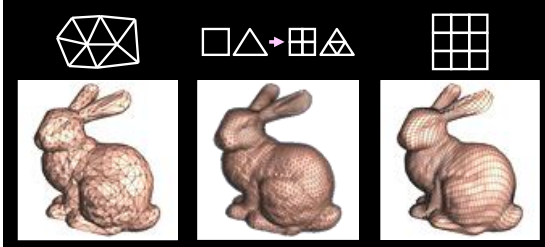
Huge meshes are difficult to

- render
- store
- transmit
- edit

Multiresolution is crucial

[Guskov *et al.*]

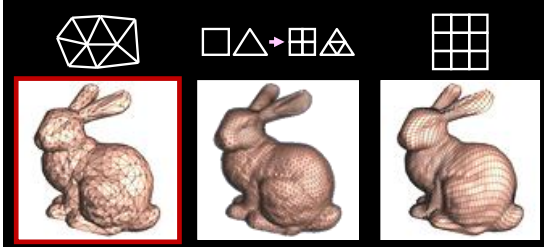
Multiresolution Meshes



Irregular *Semi-regular* *Completely regular*

[Hoppe]

Multiresolution Meshes



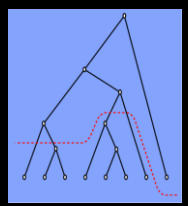
Irregular *Semi-regular* *Completely regular*

[Hoppe]

Irregular Multiresolution Meshes

Encode mesh simplification operations in tree

- Cut through tree defines a mesh
- Move cut up/down to simplify/refine

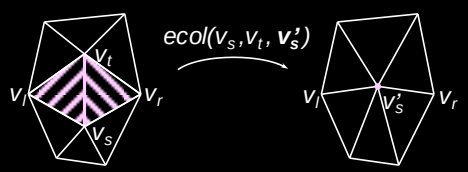


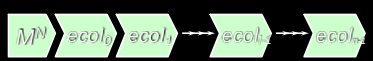
Xia96, Hoppe97, Luebke97

Progressive Mesh

Slide by Hoppe

Encode continuous detail as sequence of edge collapses

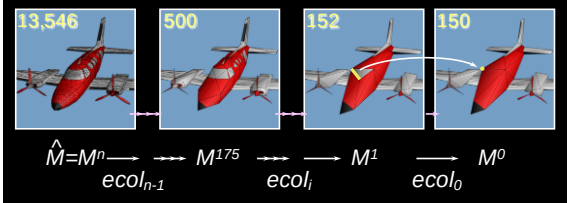




Progressive Mesh

Slide by Hoppe

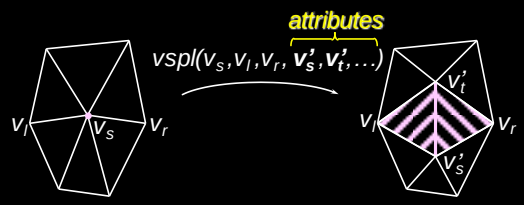
Simplification process



Progressive Mesh

Slide by Hoppe

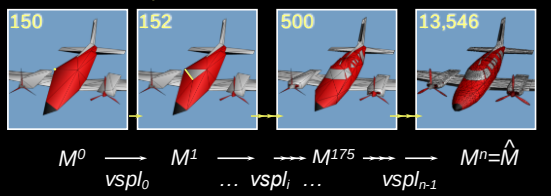
Inversion is possible with vertex split transformation



Progressive Mesh

Slide by Hoppe

Reconstruction process

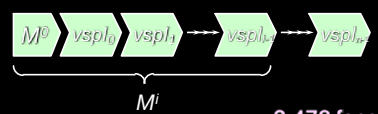


progressive mesh (PM) representation

Progressive Mesh

Slide by Hoppe

From PM, extract M_i of any desired complexity (this is multiresolution)

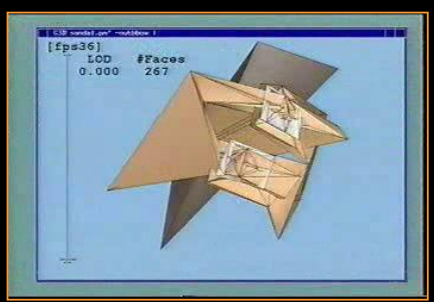


3,478 faces?

Progressive Mesh

Hoppe

Progressive Mesh



Hoppe

Progressive Mesh

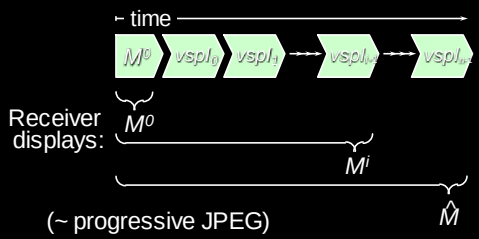
Benefits/Applications:

- Progressive transmission
- Surface compression
- Selective refinement

Progressive Transmission

Slide by Hoppe

Transmit records progressively:



(~ progressive JPEG)

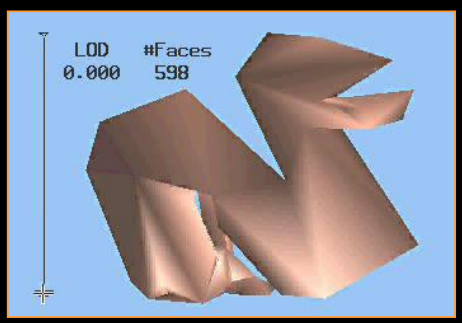
Progressive Transmission

Slide by Southern

Details added while user is browsing.

[Certain *et al.*]

Progressive Transmission



Hoppe

Mesh Compression

Slide by Southern

Lossy compression

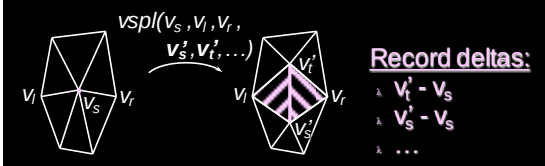
Mesh Compression

Slide by Southern

Lossless compression

Mesh Compression

Slide by Hoppe



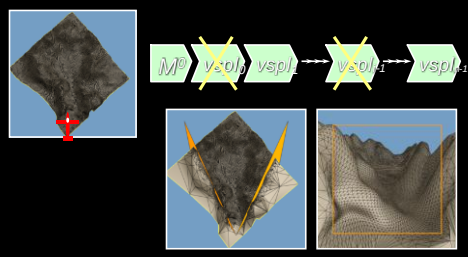
Encoding of *vspl* records:

- connectivity: ~ good triangle strips
- attributes: excellent delta-encoding

Selective Refinement (VDPM)

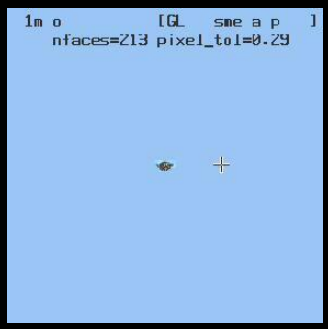
Slide by Hoppe

Refine mesh adaptively based on viewpoint



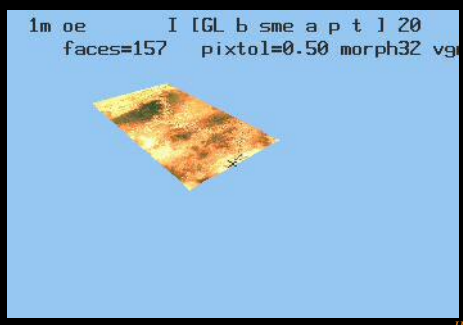
(e.g. view frustum)

Selective Refinement (VDPM)



Hoppe

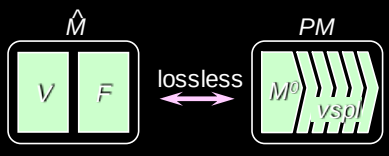
Selective Refinement (VDPM)



Hoppe

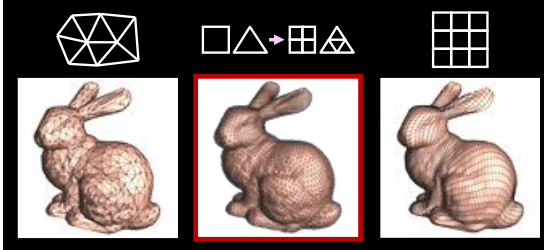
Progressive Mesh Summary

Slide by Hoppe



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

Multiresolution Meshes

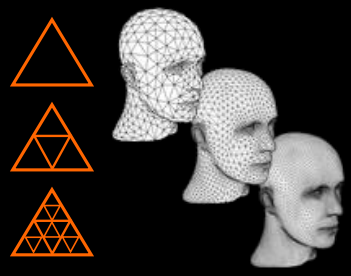


Irregular *Semi-regular* *Completely regular*

[Hoppe]

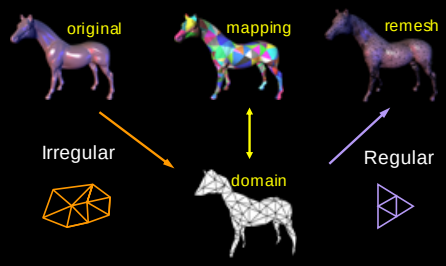
Semi-Regular Mesh

Arbitrary base mesh + refinement via subdivision



[Hoppe]

Multiresolution Analysis



[Guskov *et al.*]

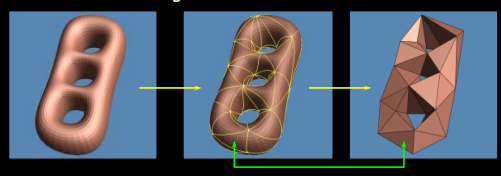
Multiresolution Analysis

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



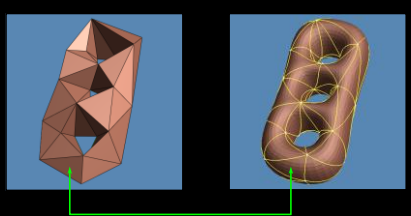
mesh M **partition** *domain mesh K*

[Lounsberry *et al.*]

Multiresolution Analysis

Step 2: construct parameterization

- Map each face of domain mesh to corresponding triangular region



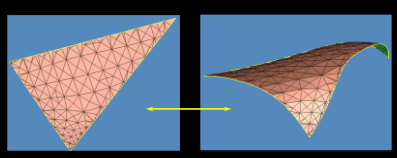
local map

[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



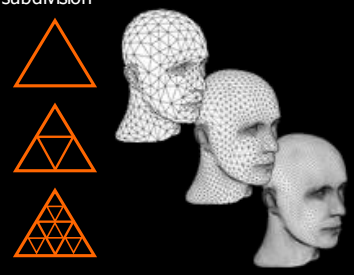
planar triangle *triangular region*

[Lounsberry *et al.*]

Multiresolution Analysis

Step 3: remesh

- Regular subdivision



[Hoppe]

Multiresolution Representation

Wavelet representation

base shape M^0

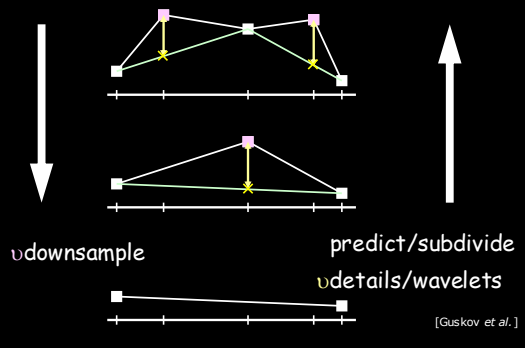
+

sum of local correction terms

(wavelet terms)

[Lounsberry *et al.*]

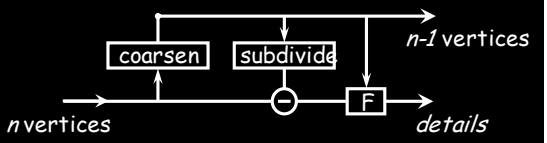
Multiresolution Representation



[Guskov *et al.*]

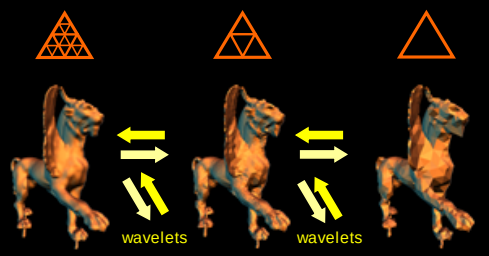
Multiresolution Representation

Burt-Adelson pyramid



[Guskov *et al.*]

Multiresolution Representation

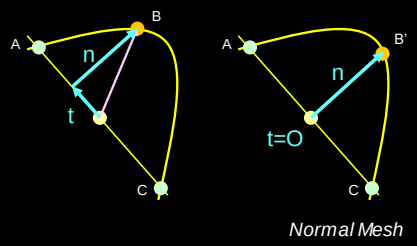


[Guskov *et al.*]

Multiresolution Representation

Two scalar displacement (t,n)

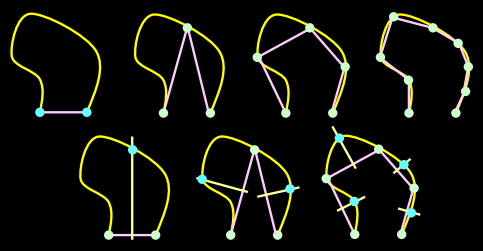
One scalar (normal mesh)



[Guskov *et al.*]

Multiresolution Representation

Normal mesh



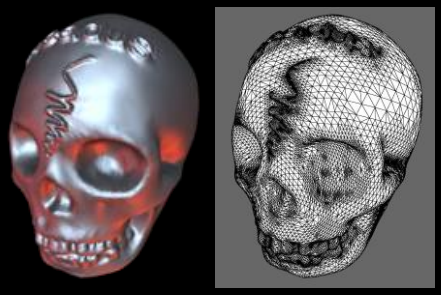
[Guskov *et al.*]

Multiresolution Meshes

Applications:

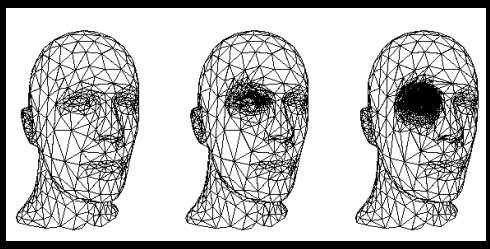
- Adaptive remeshing
- Compression
- Filtering
- Editing
- Morphing

Adaptive Remeshing



[Guskov *et al.*]

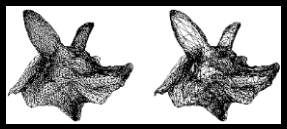
Adaptive Remeshing



[Zorin *et al.*]

Adaptive Remeshing

Both 11K triangles



Uniform Adaptive

[Zorin *et al.*]

Multiresolution Meshes

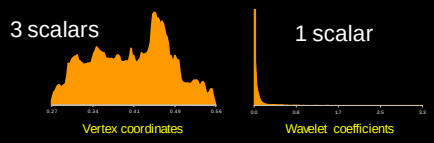
Applications:

- Adaptive remeshing
- ➢ Compression
- Filtering
- Editing
- Morphing

Mesh Compression

Effect of wavelet transform

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



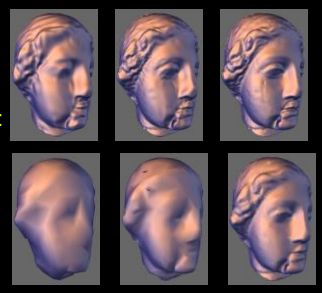
[Guskov *et al.*]

Mesh Compression

Fixed file size

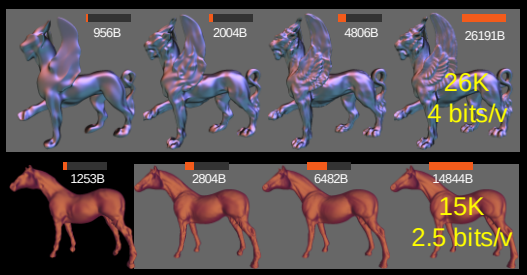
Normal Meshes:

CPM:



[Guskov *et al.*]

Mesh Compression



[Guskov *et al.*]

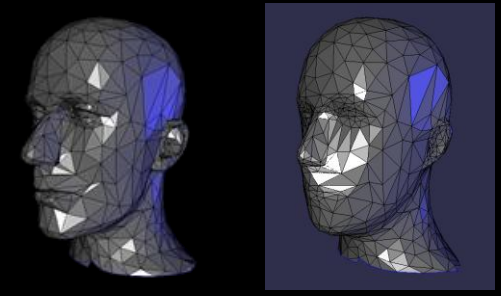
Multiresolution Meshes

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

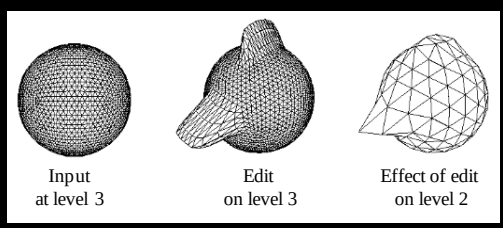
Multiresolution Mesh Editing

Goal: edit surface with operations at various resolutions

[Guskov *et al.*]

Multiresolution Mesh Editing

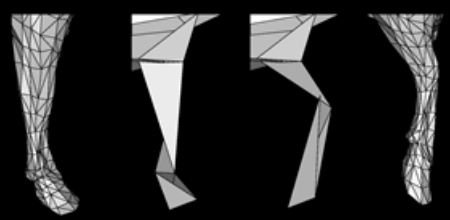
When edit at fine resolution,
update higher levels of multiresolution hierarchy



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

[Zorin *et al.*]

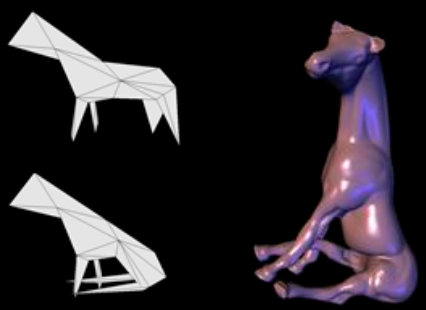
Multiresolution Mesh Editing



original | coarse | edit coarse | edit fine

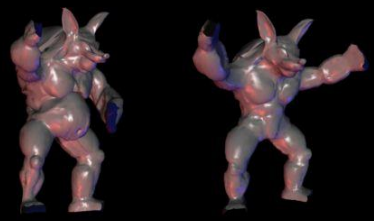
[Guskov *et al.*]

Multiresolution Mesh Editing



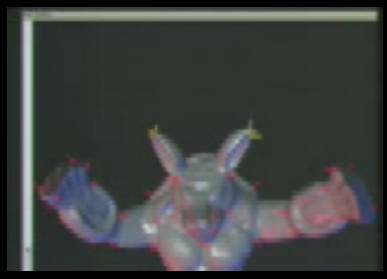
[Guskov *et al.*]

Multiresolution Mesh Editing



[Zorin *et al.*]

Multiresolution Mesh Editing

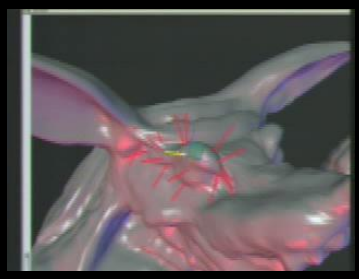


[Zorin *et al.*]

Multiresolution Mesh Editing

[Zorin *et al.*]

Multiresolution Mesh Editing



[Zorin *et al.*]

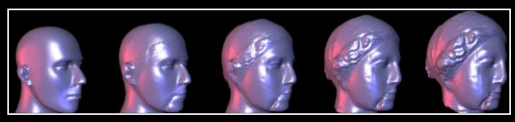
Multiresolution Meshes

Applications:

- Adaptive remeshing
- Compression
- Filtering
- Editing
- ➢ Morphing

Multiresolution Mesh Morphing

Goal: interpolate surfaces

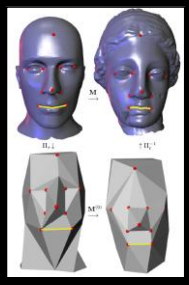


[Lee *et al.*]

Multiresolution Mesh Morphing

Common parameterization

- If two semi-regular meshes have the same base domain, then they share a common parameterization



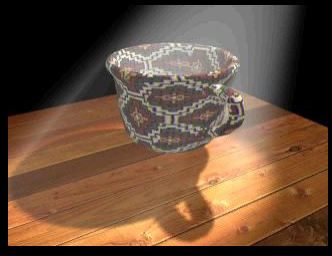
Multiresolution Mesh Morphing

[Lee *et al.*]

Multiresolution Mesh Morphing

[Lee *et al.*]

Multiresolution Mesh Morphing



[Lee *et al.*]

Multiresolution Mesh Morphing

Multiresolution

- Can morph different multiresolution levels at different rates

Multiresolution Mesh Morphing

[Lee *et al.*]

Multiresolution Mesh Morphing

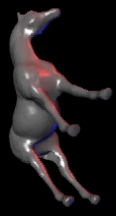
with Spatial Control

[Lee *et al.*]

Multiresolution Mesh Morphing

[Lee *et al.*]

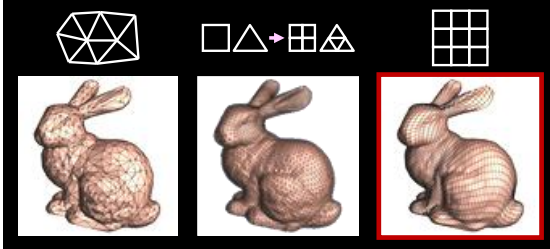
Multiresolution Mesh Morphing



with Spatial Control

[Lee *et al.*]

Multiresolution Meshes



Irregular *Semi-regular* *Completely regular*

[Hoppe]

Completely Regular Mesh

Slide by Hoppe

Regular sampling of parameter domain

Geometry Image

Multiresolution Meshes

Key ideas

- Multiresolution analysis provides parameterization
- Different resolutions represent different frequencies
- Can map operations in parameter domain to operations on mesh (e.g., smoothing, morphing, etc.)

Acknowledgements

Slides by

- Igor Guskov
- Wim Sweldens
- Peter Schroeder
- Denis Zorin
- Aaron Lee
- Emil Praun
- Michael Lounsberry
- Hugues Hoppe