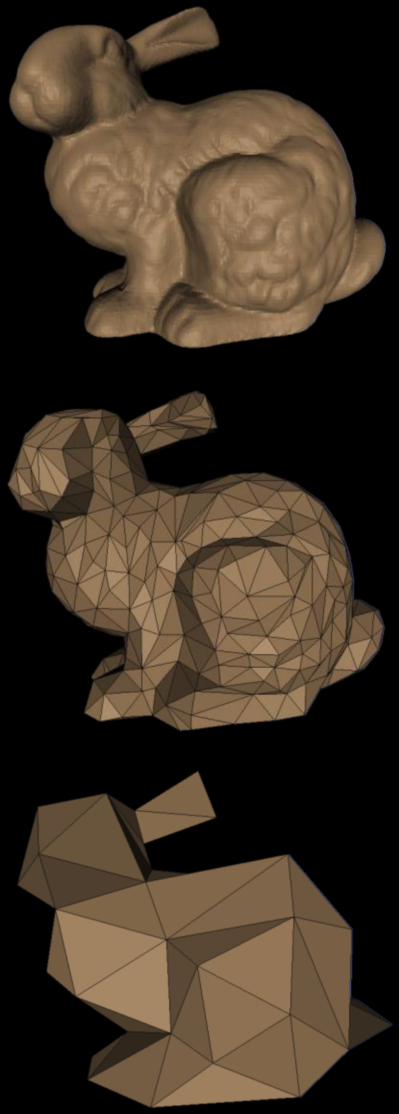
Multiresolution Meshes

COS 526

Tom Funkhouser, Fall 2014

Slides by Guskov,
Praun, Sweldens, etc.

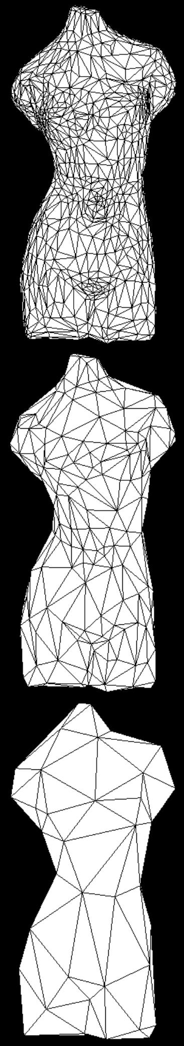


Multiresolution Meshes

Huge meshes are difficult to

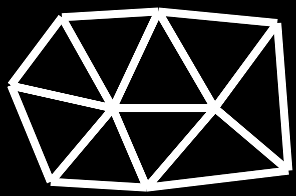
- render
- store
- transmit
- edit

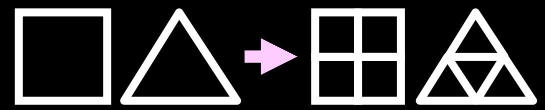
Multiresolution is crucial

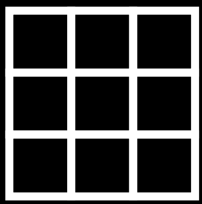


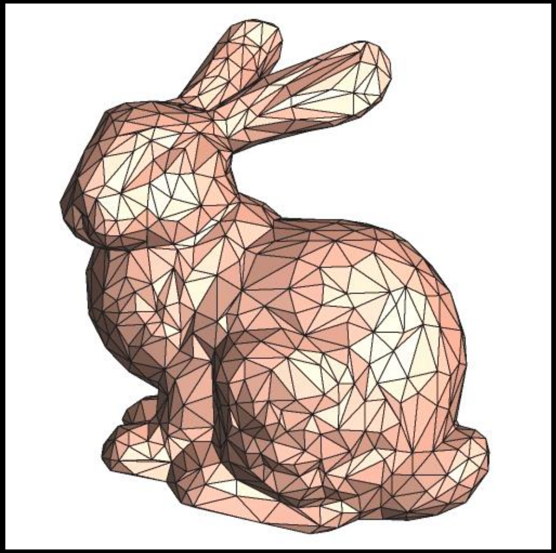
[Guskov *et al.*]

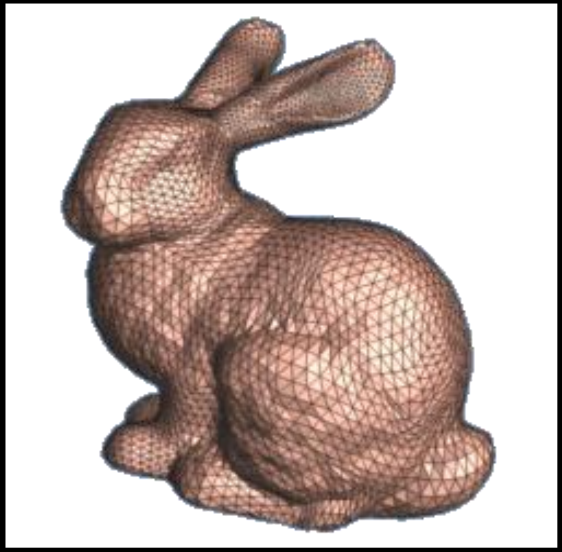
Multiresolution Meshes

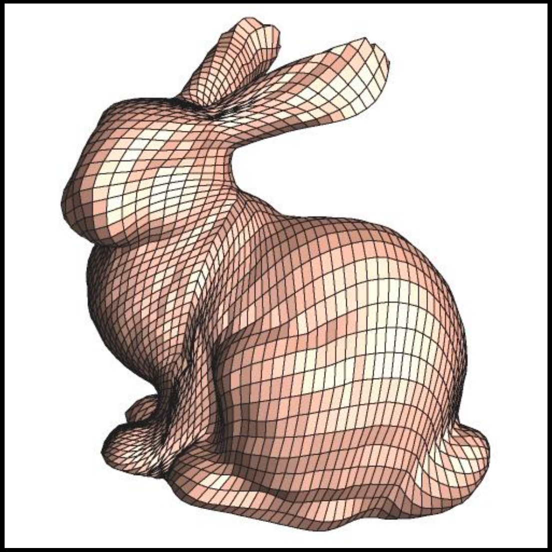












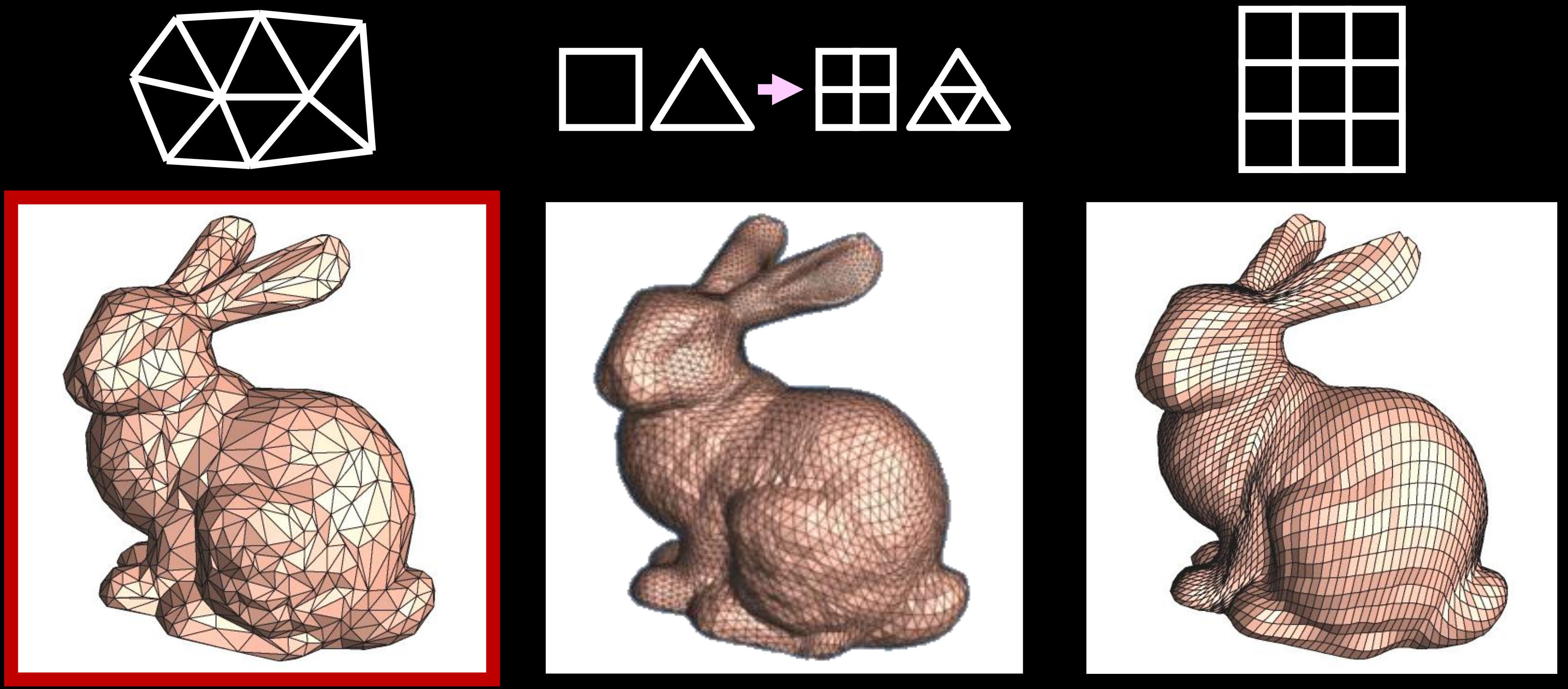
Irregular

Semi-regular

Completely regular

[Hoppe]

Multiresolution Meshes



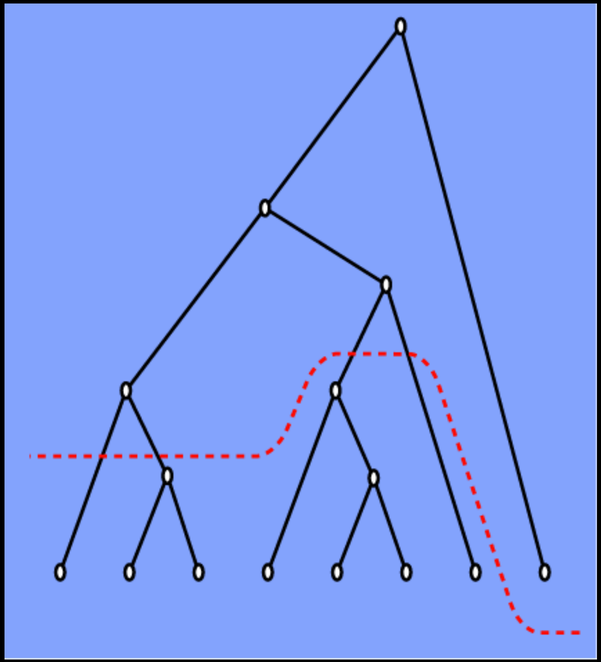
Irregular *Semi-regular* *Completely regular*

[Hoppe]

Irregular Multiresolution Meshes

Encode mesh simplification operations in tree

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

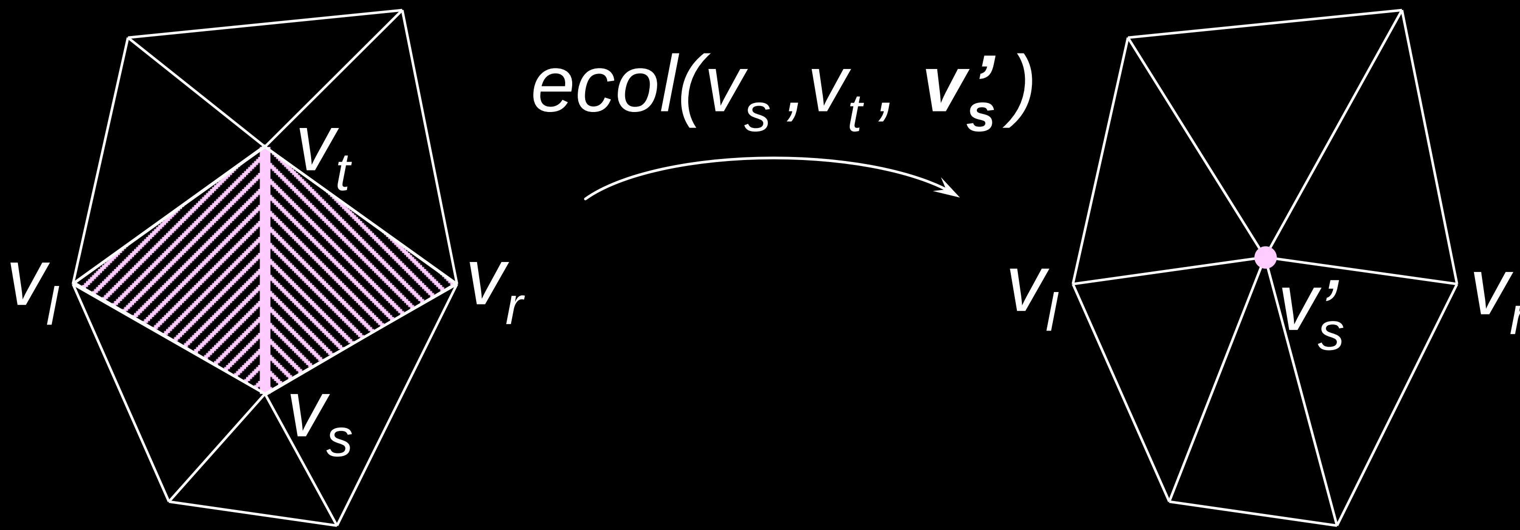


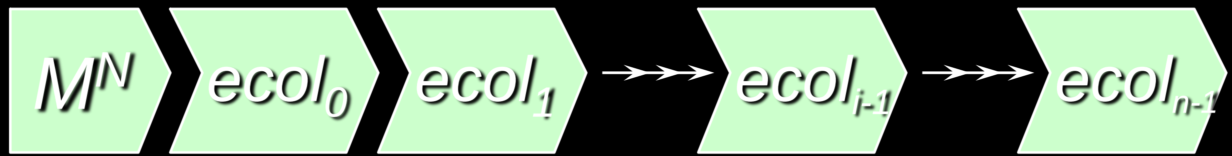
Xia96, Hoppe97, Luebke97

Progressive Mesh

Slide by Hoppe

Encode continuous detail as sequence of edge collapses

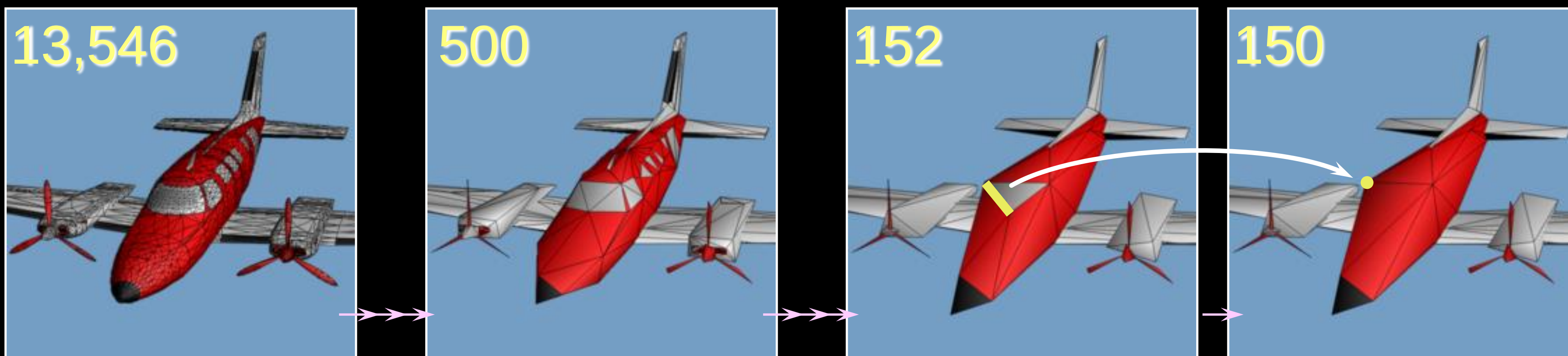




Progressive Mesh

Slide by Hoppe

Simplification process

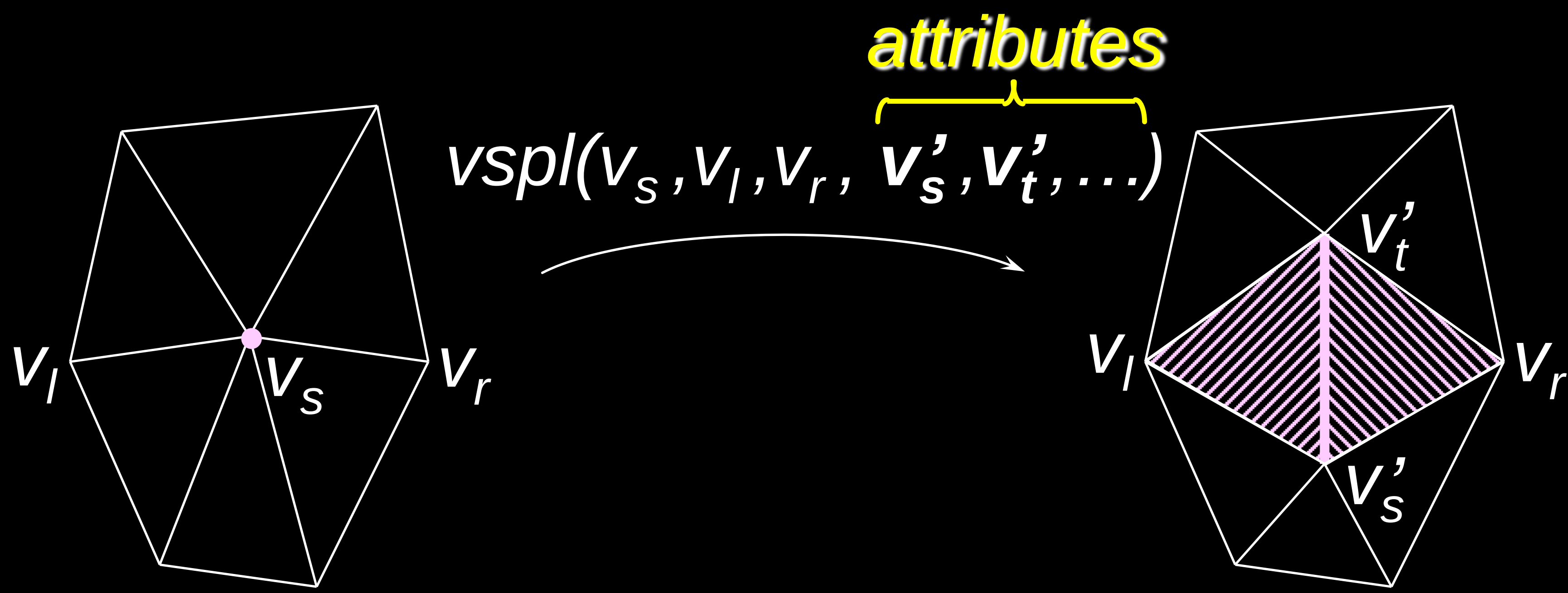


$$\hat{M}=M^n \xrightarrow[ecol_{n-1}]{} \twoheadrightarrow\!\!\rightarrow M^{175} \twoheadrightarrow\!\!\rightarrow \xrightarrow[ecol_i]{} M^1 \xrightarrow[ecol_0]{} M^0$$

Progressive Mesh

Slide by Hoppe

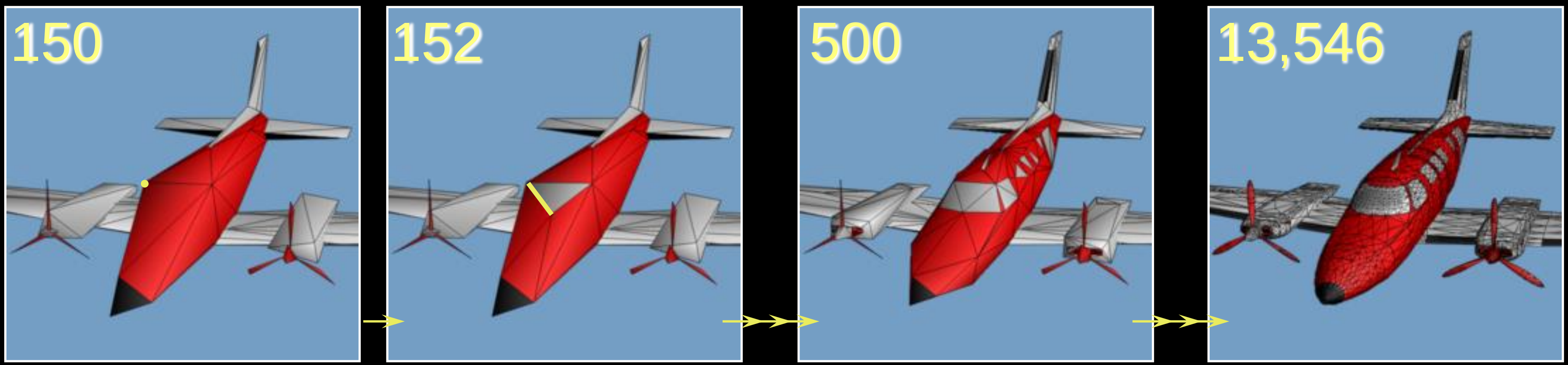
Inversion is possible with vertex split transformation



Progressive Mesh

Slide by Hoppe

Reconstruction process



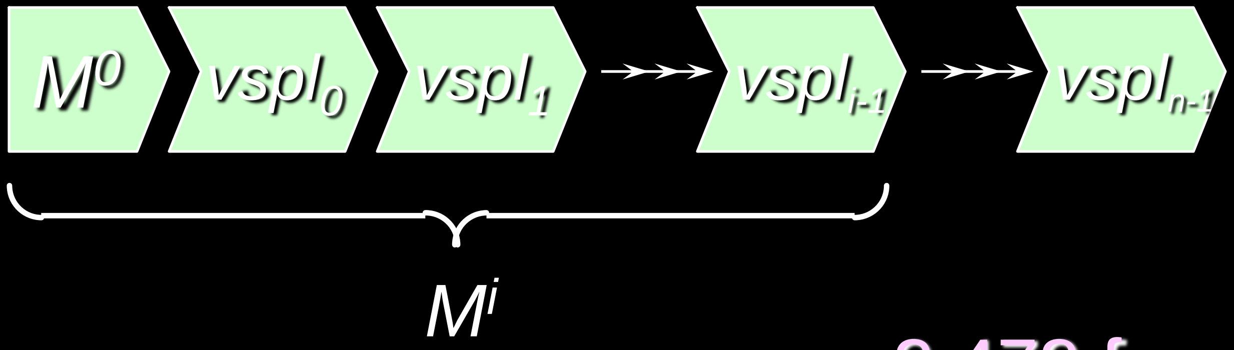
$M^0 \xrightarrow{vspl_0} M^1 \longrightarrow \cdots\ vspl_i\ \cdots \rightarrow M^{175} \rightarrow \cdots \xrightarrow{vspl_{n-1}} M^n = \hat{M}$

progressive mesh (PM) representation

Progressive Mesh

Slide by Hoppe

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

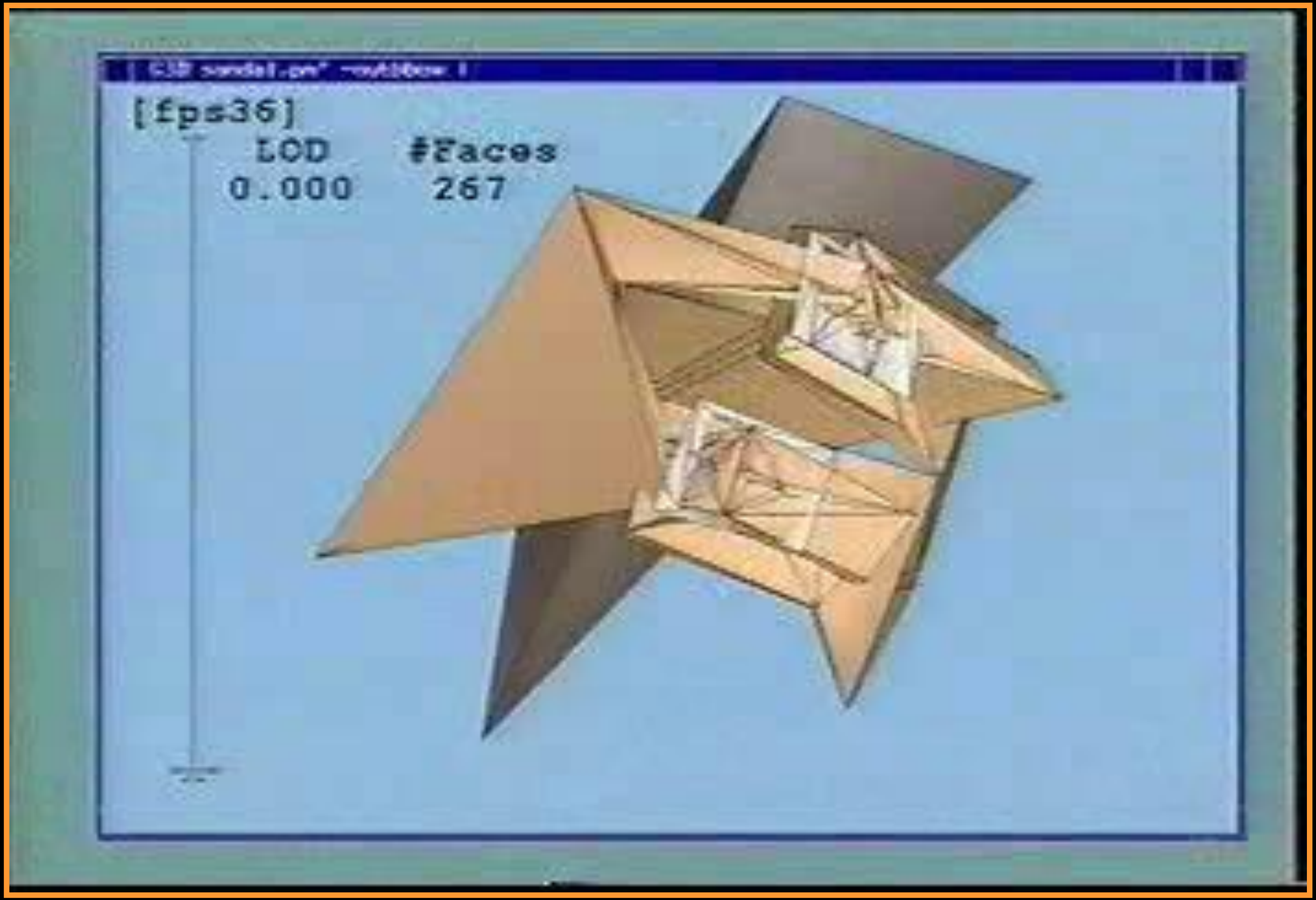


3,478 faces?

Progressive Mesh

Hoppe

Progressive Mesh



Hoppe

Progressive Mesh

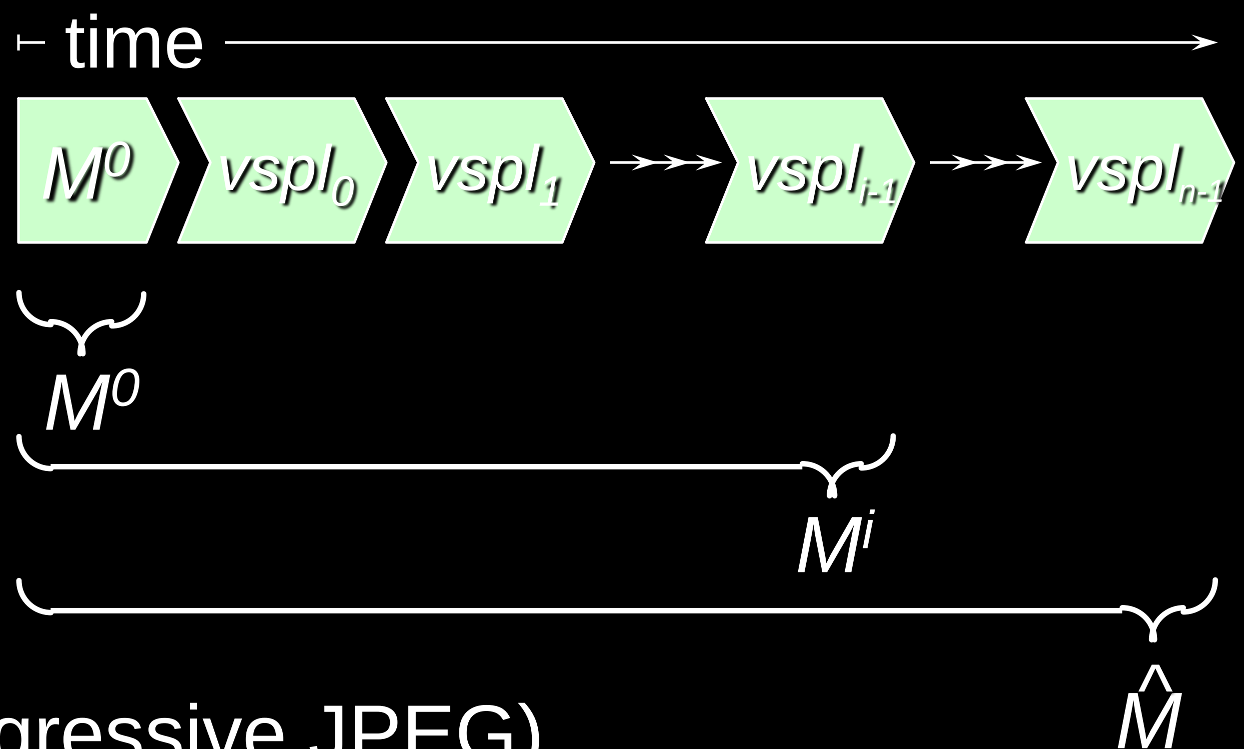
Benefits/Applications:

- Progressive transmission
- Surface compression
- Selective refinement

Progressive Transmission

Slide by Hoppe

Transmit records progressively:



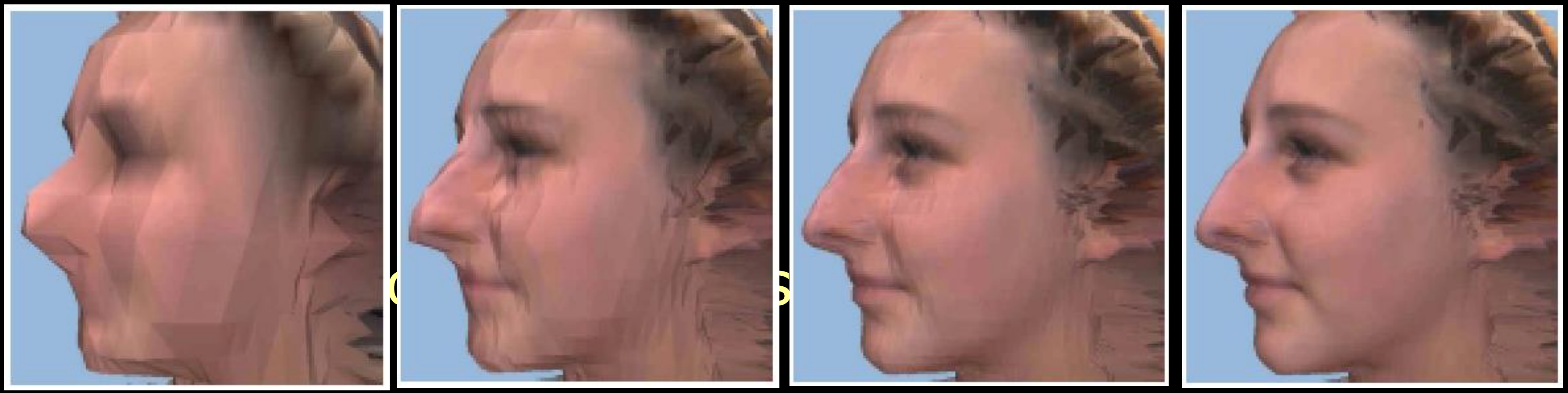
Receiver displays:

(~ progressive JPEG)

Progressive Transmission

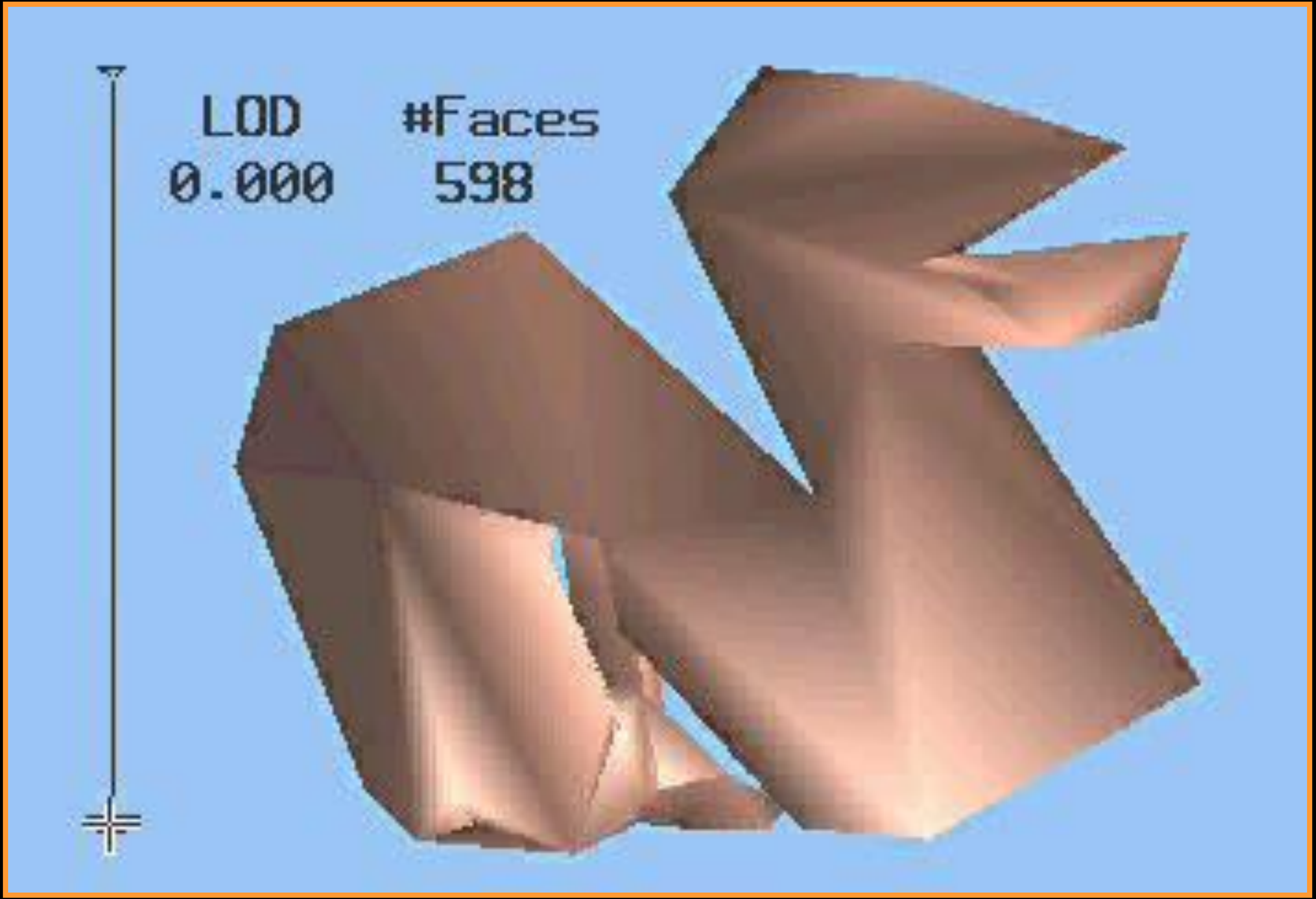
Slide by Southern

Details added while user is browsing.



[Certain *et al.*]

Progressive Transmission

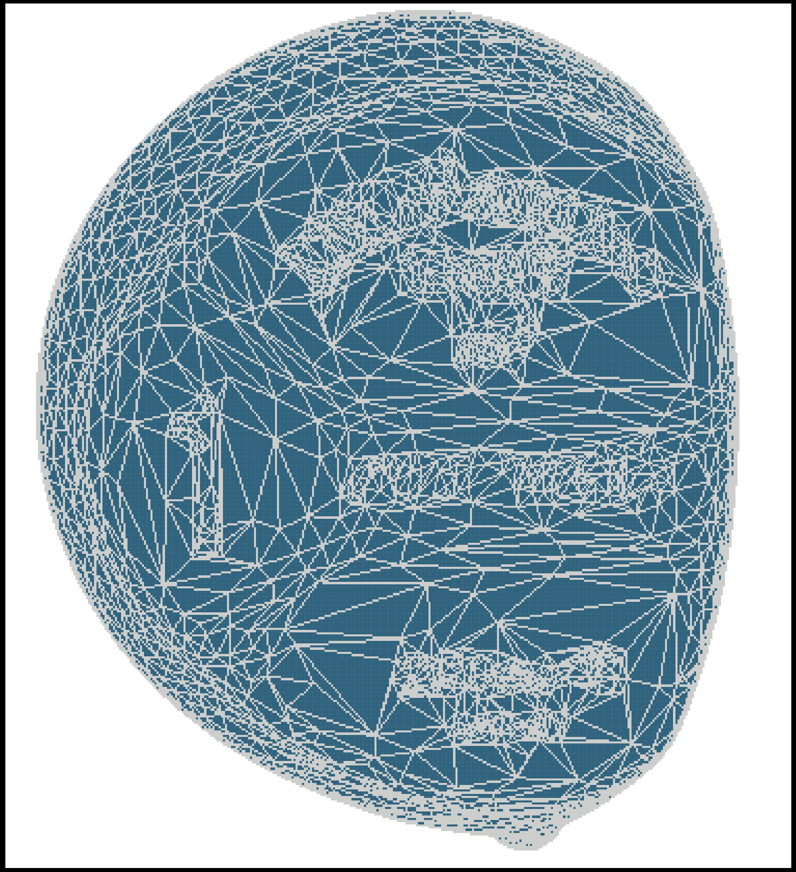


Hoppe

Mesh Compression

Slide by Southern

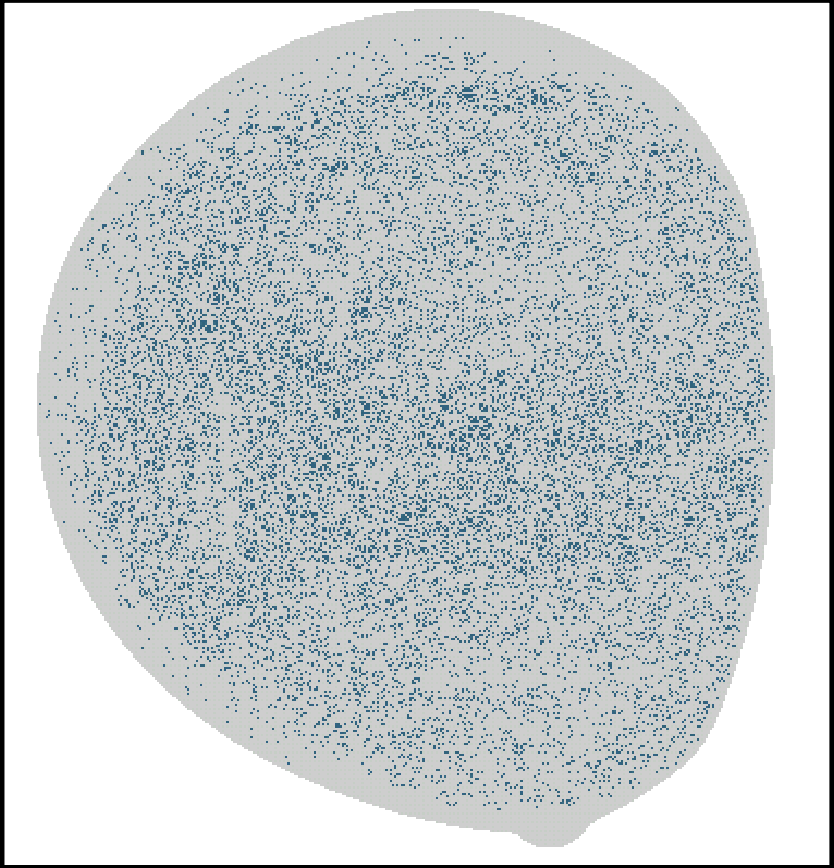
Lossy compression



Mesh Compression

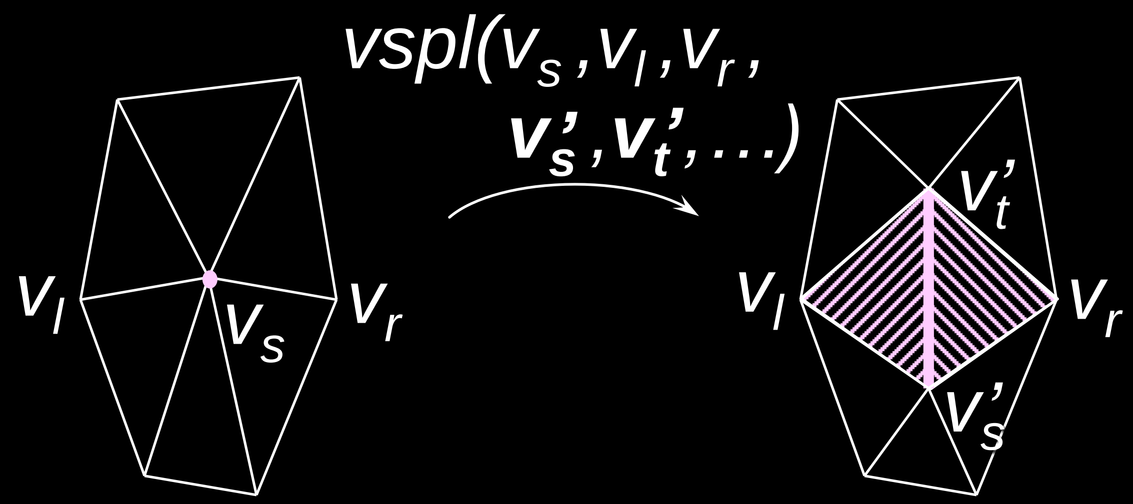
Slide by Southern

Lossless compression



Mesh Compression

Slide by Hoppe



Record deltas:

- $v'_t - v_s$
- $v'_s - v_s$
- …

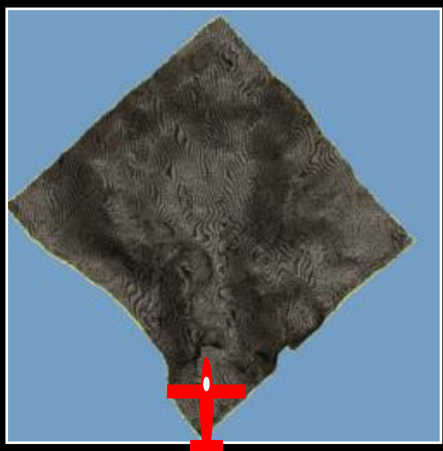
Encoding of *vspl* records:

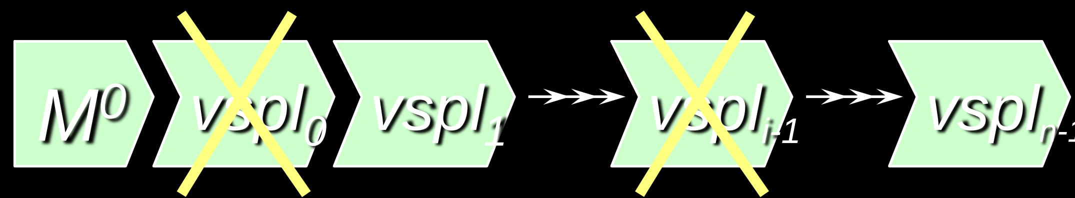
- connectivity: ~ good triangle strips
- attributes: excellent delta-encoding

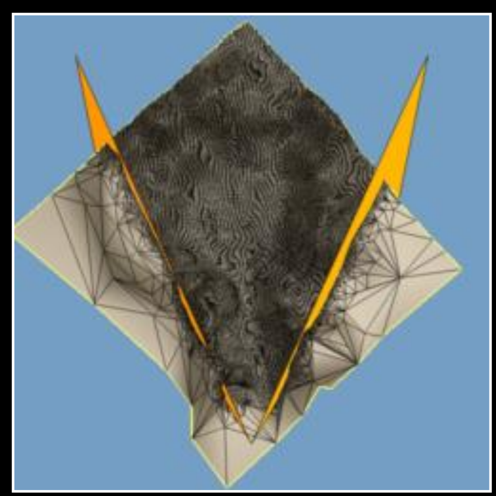
Selective Refinement (VDPM)

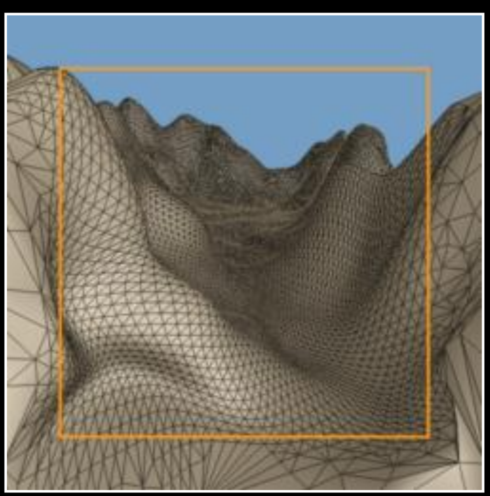
Slide by Hoppe

Refine mesh adaptively based on viewpoint







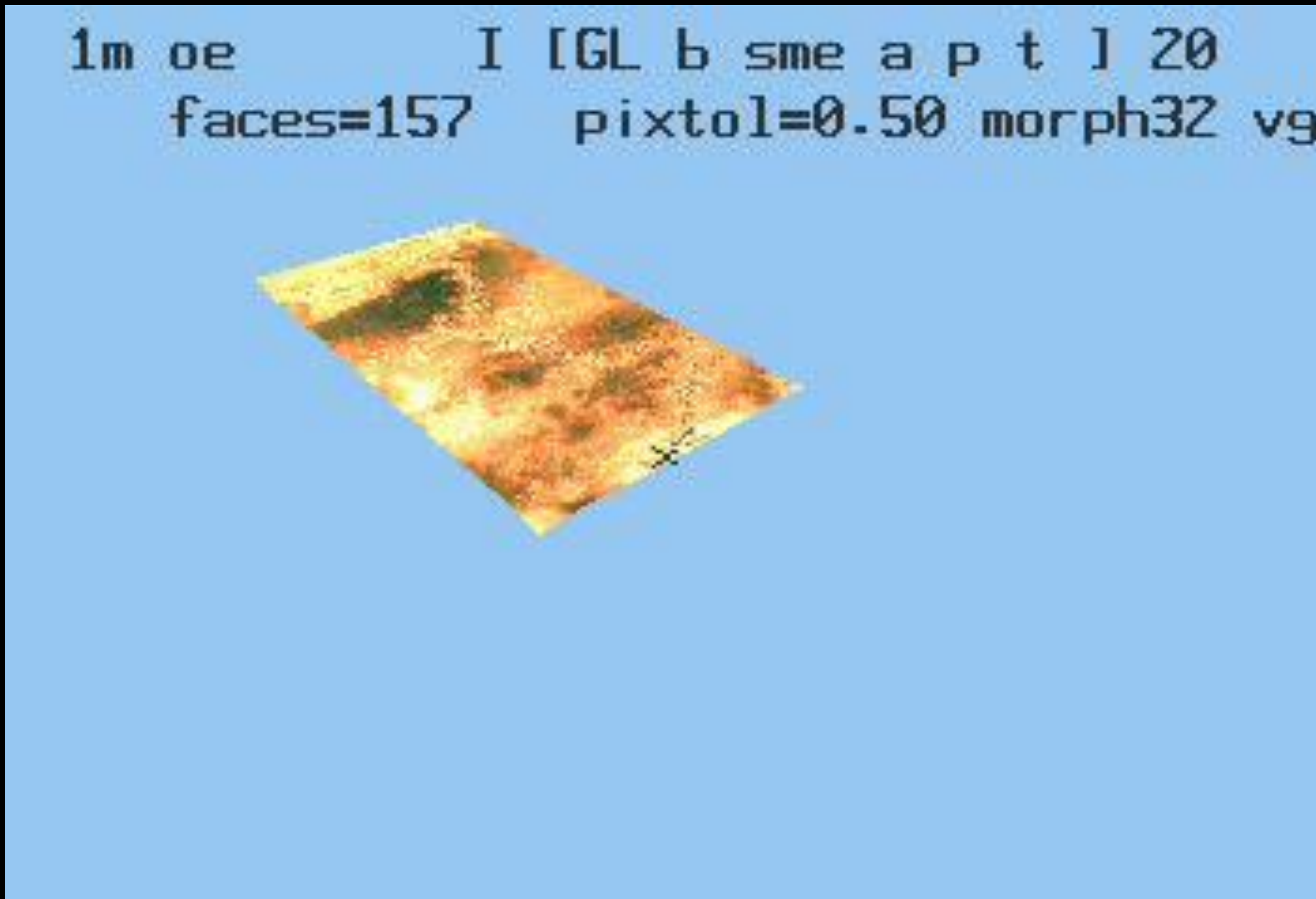


(e.g. view frustum)

Selective Refinement (VDPM)

Hoppe

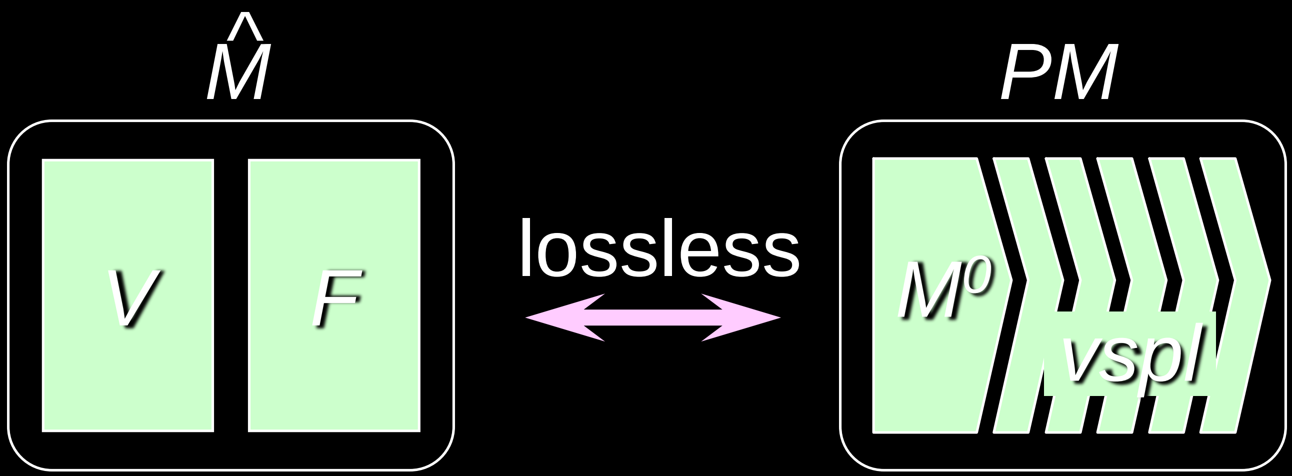
Selective Refinement (VDPM)



Hoppe

Progressive Mesh Summary

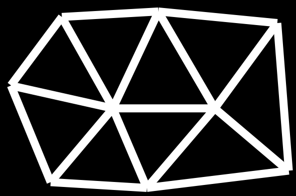
Slide by Hoppe

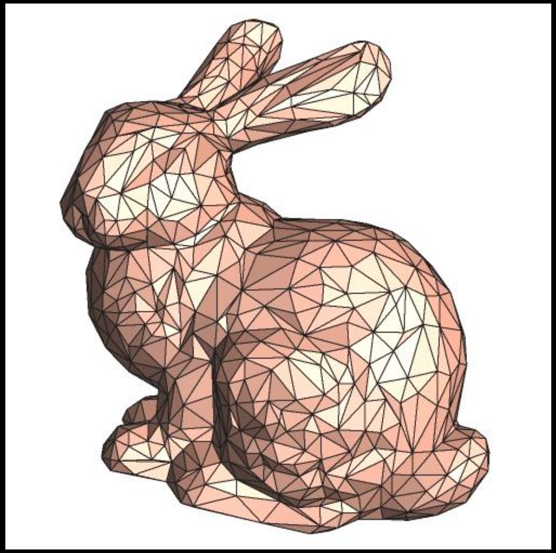


- single resolution

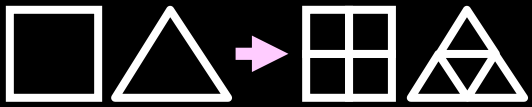
- continuous-resolution
- smooth LOD
- space-efficient
- progressive

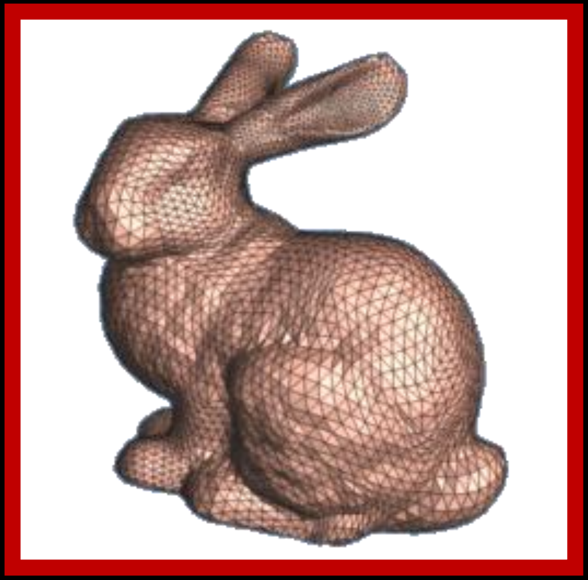
Multiresolution Meshes



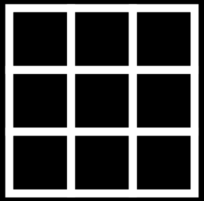


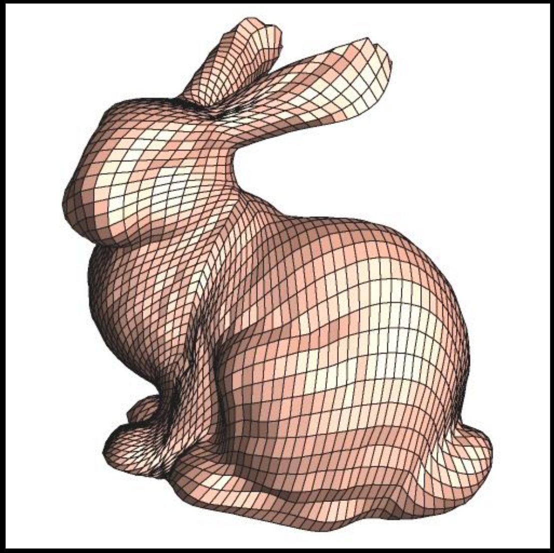
Irregular





Semi-regular



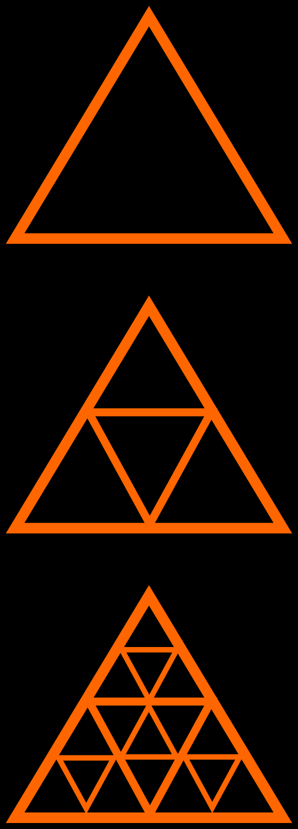


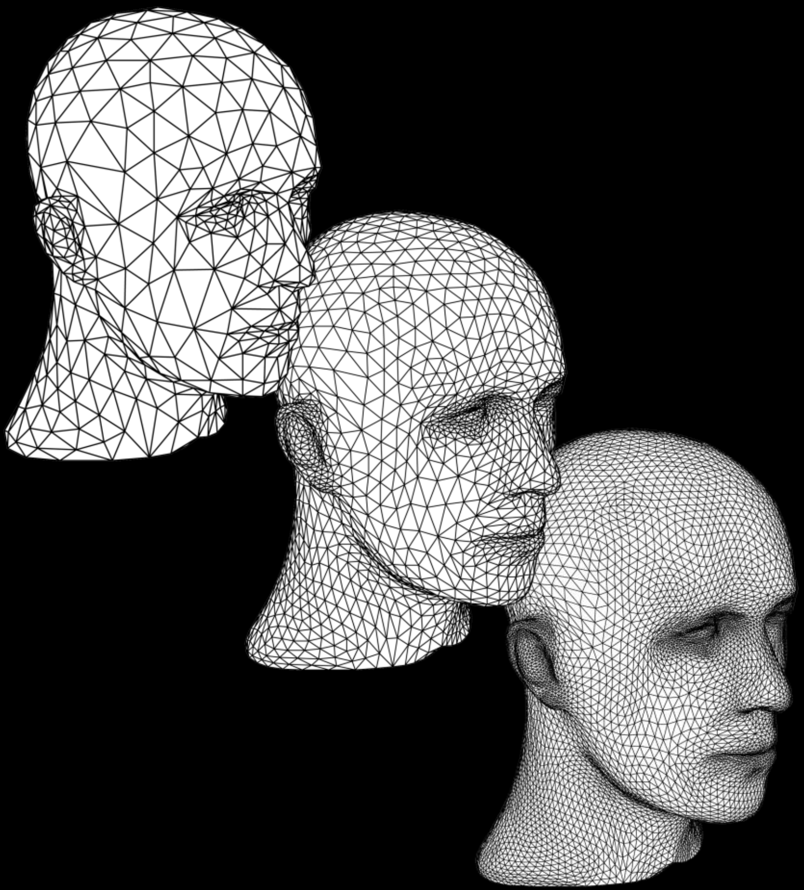
Completely regular

[Hoppe]

Semi-Regular Mesh

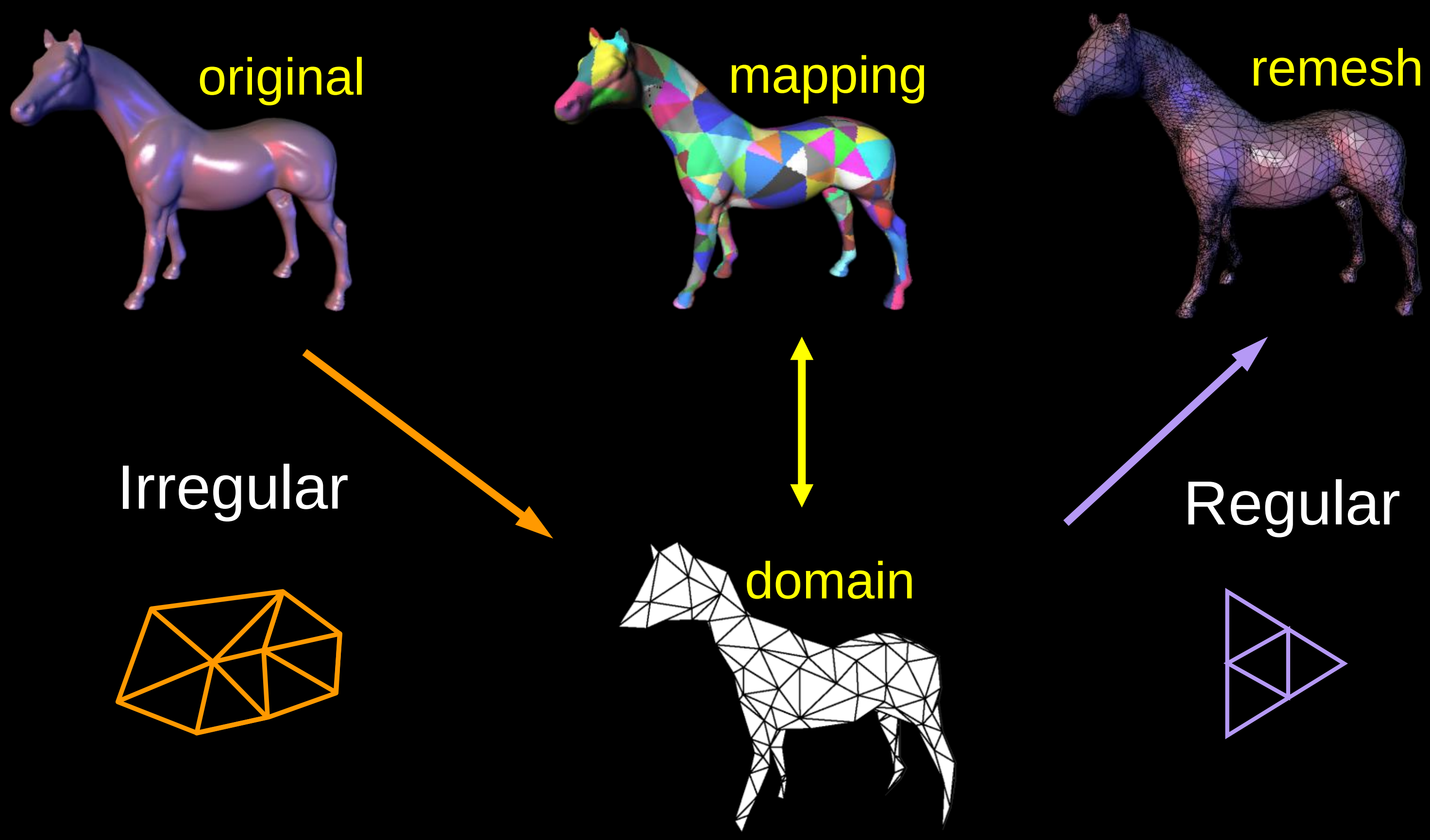
Arbitrary base mesh + refinement via subdivision





[Hoppe]

Multiresolution Analysis



[Guskov *et al.*]

Multiresolution Analysis

step 1: construct a simple domain mesh K

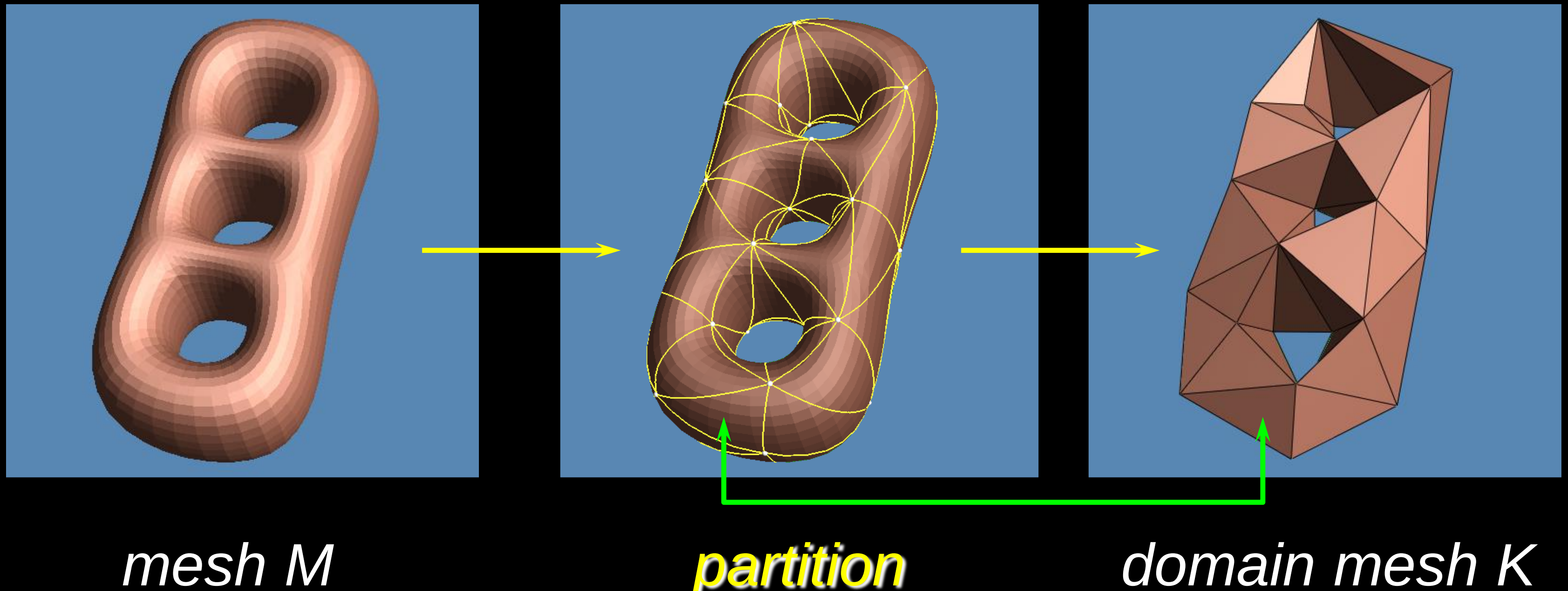
step 2: construct a parametrization r of M over K

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

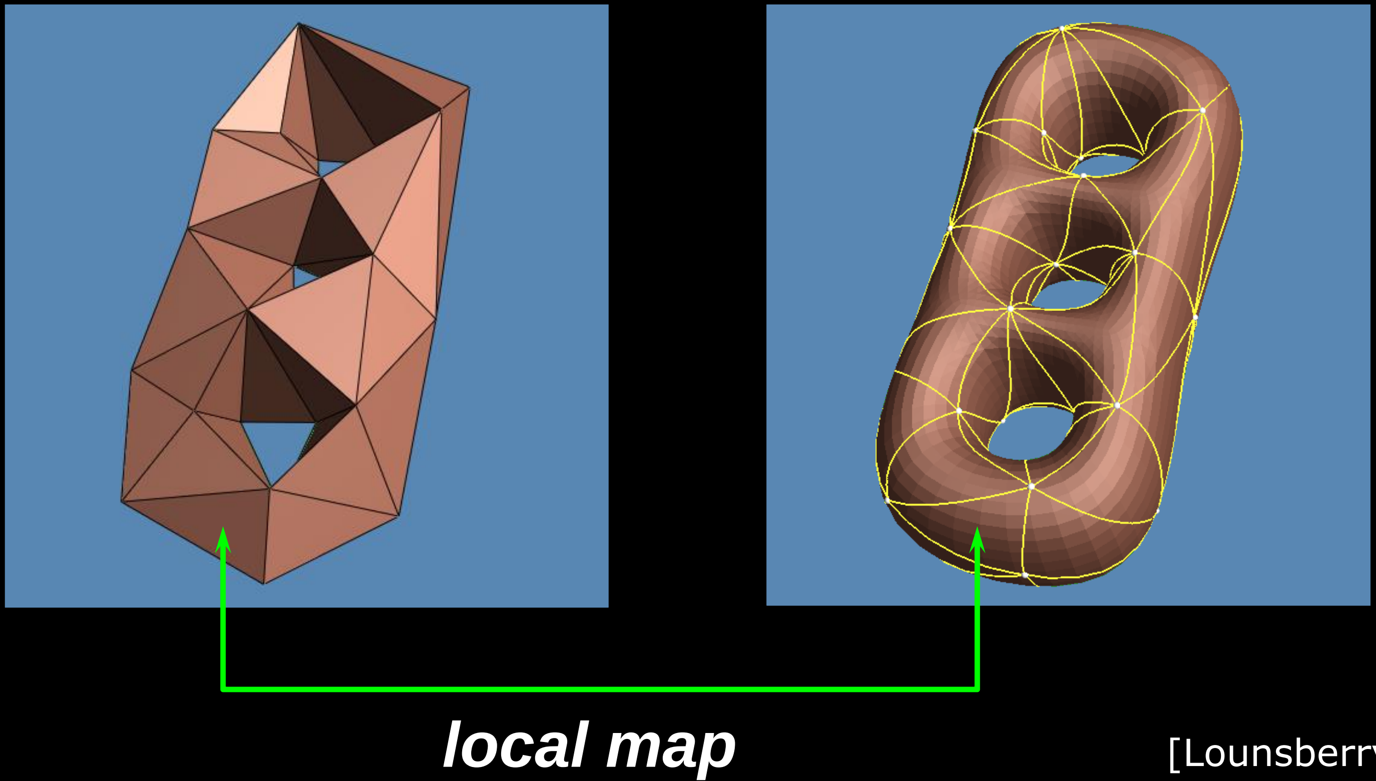


[Lounsberry *et al.*]

Multiresolution Analysis

Step 2: construct parameterization

- Map each face of domain mesh to corresponding triangular region

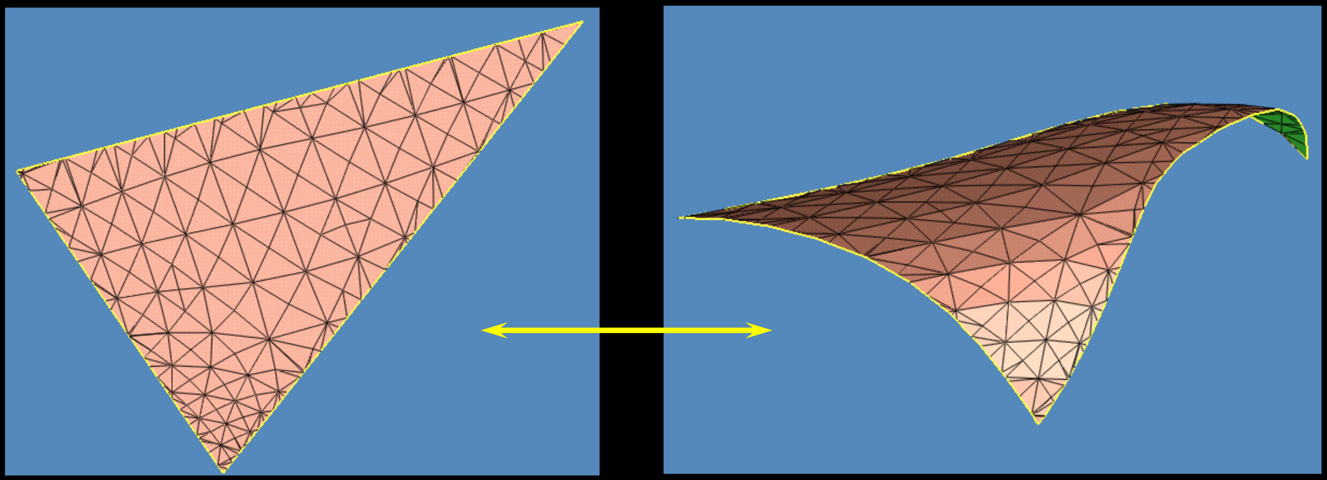


[Lounsberry *et al.*]

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



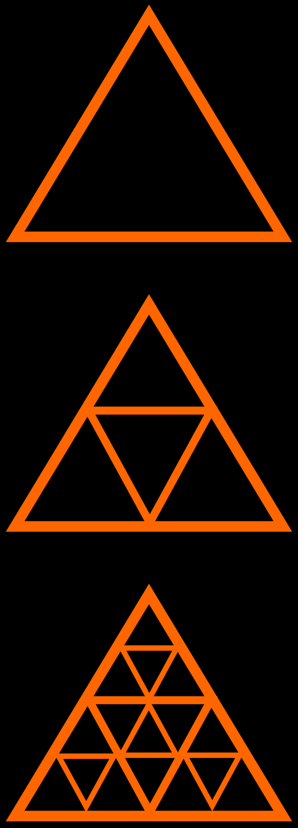
planar triangle *triangular region*

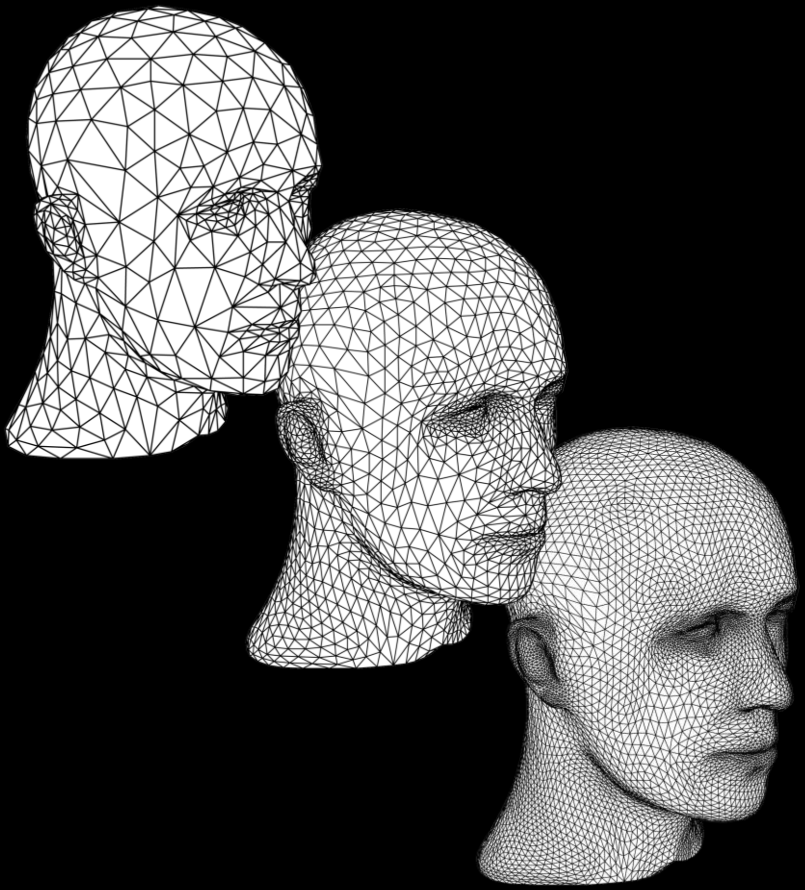
[Lounsberry *et al.*]

Multiresolution Analysis

Step 3: remesh

- Regular subdivision





[Hoppe]

Multiresolution Representation

Wavelet representation

base shape M^0

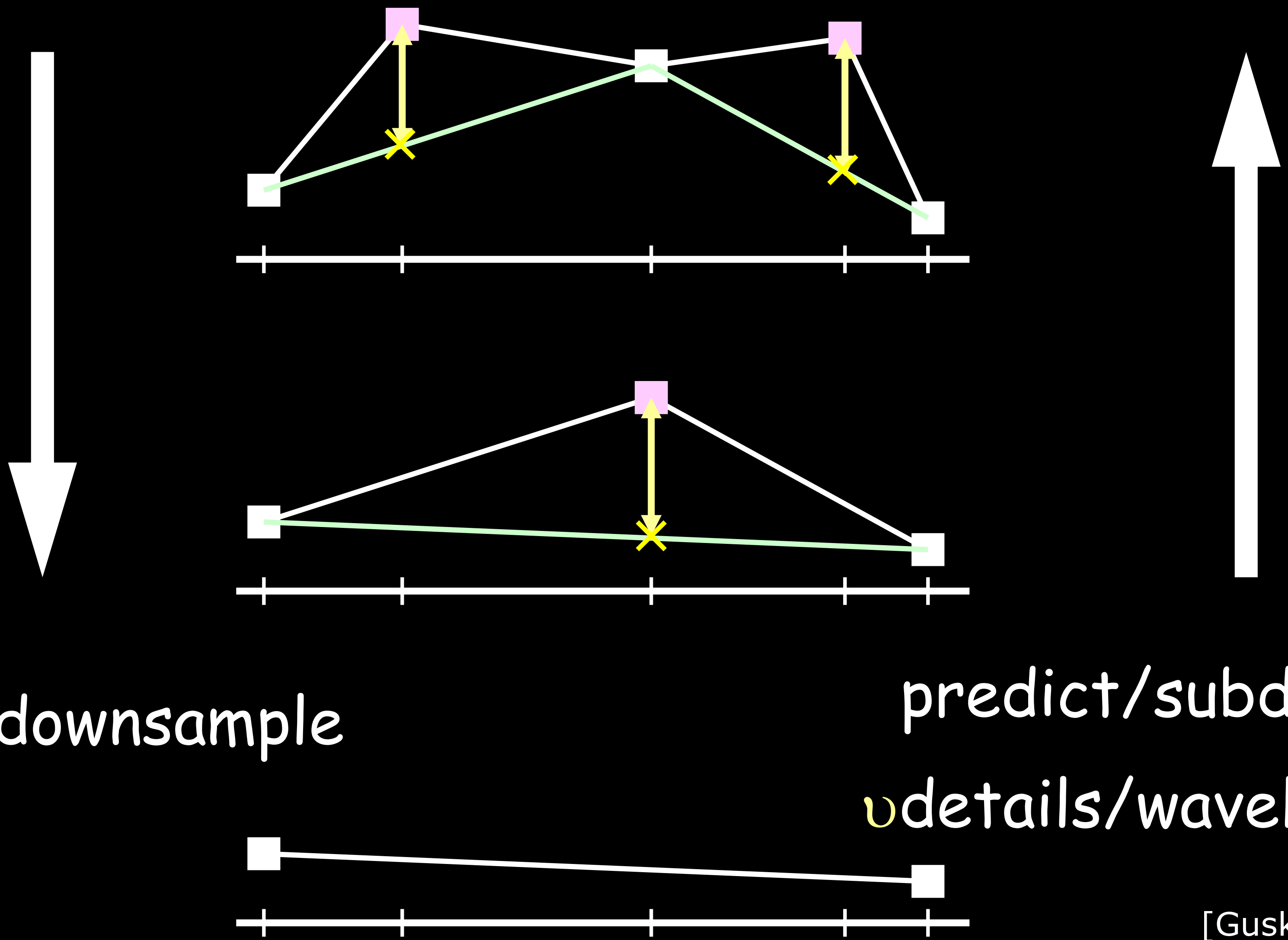
+

sum of local correction terms

(wavelet terms)

[Lounsberry *et al.*]

Multiresolution Representation



υdownsample

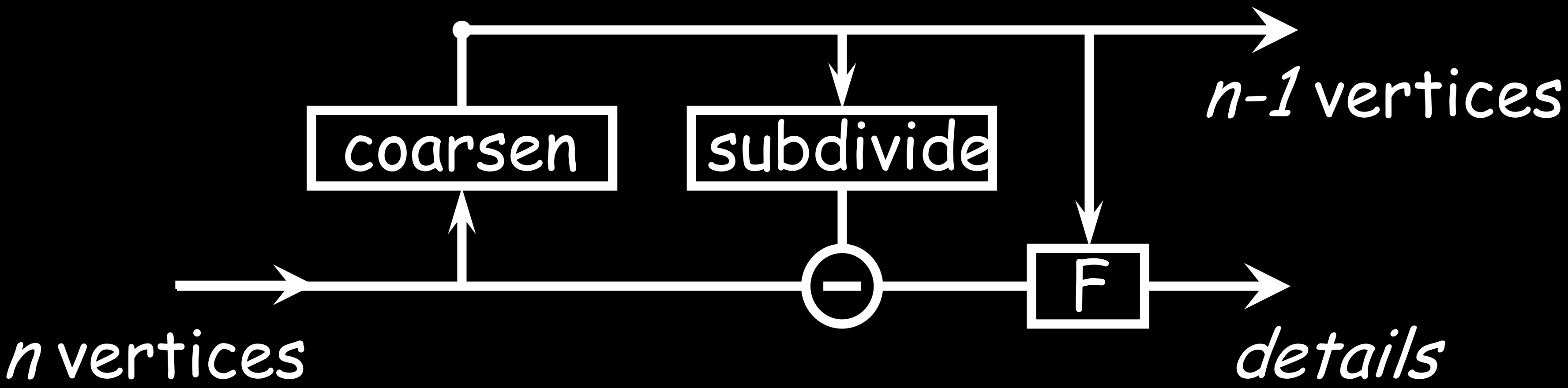
predict/subdivide

υdetails/wavelets

[Guskov *et al.*]

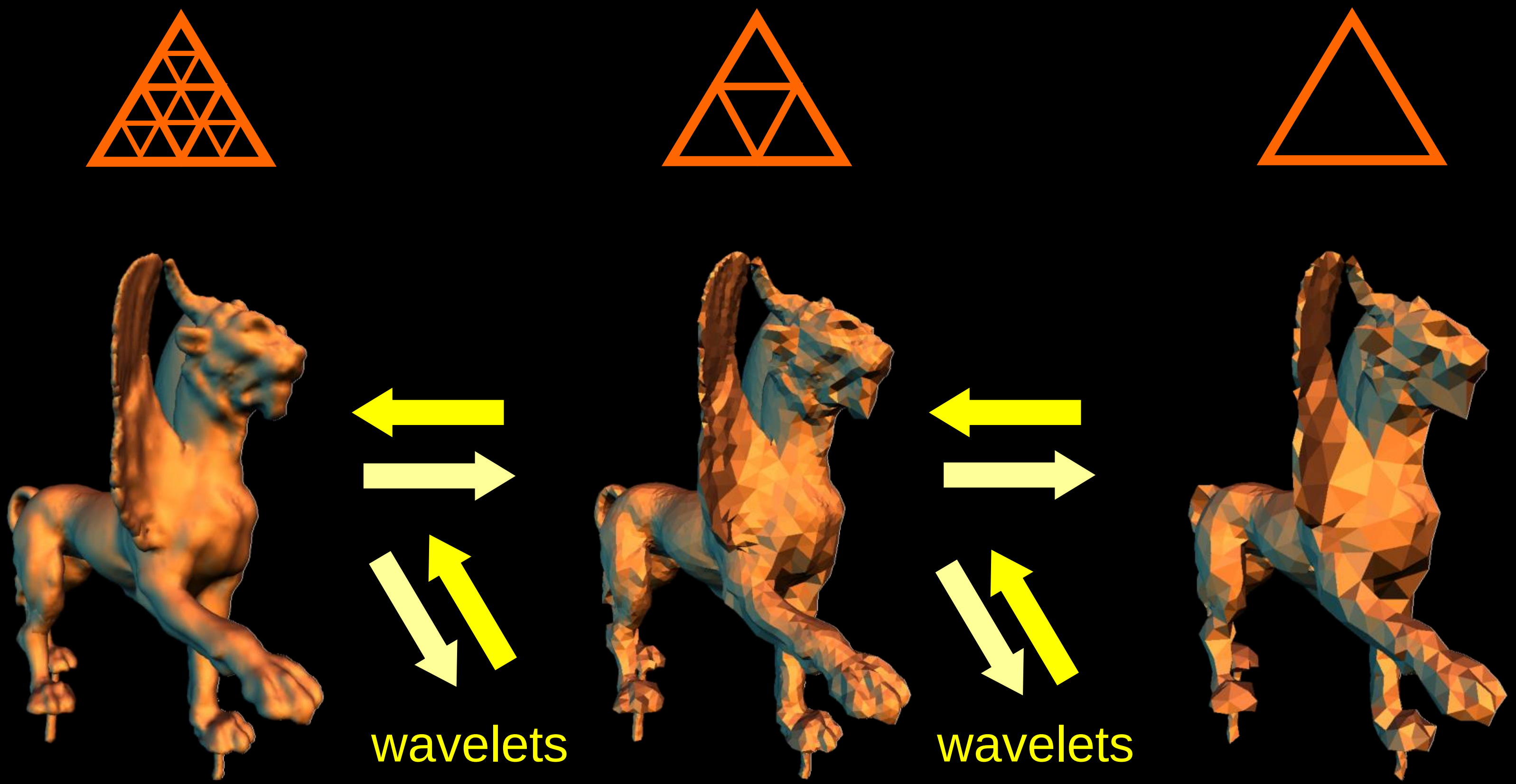
Multiresolution Representation

Burt-Adelson pyramid



[Guskov *et al.*]

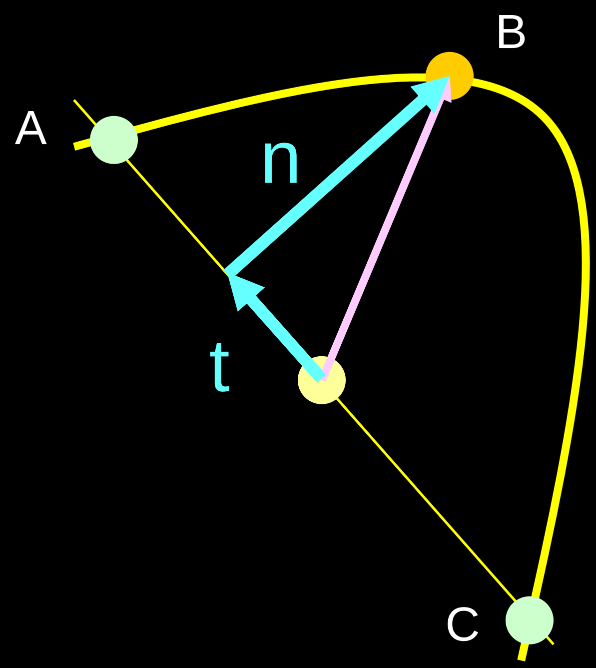
Multiresolution Representation



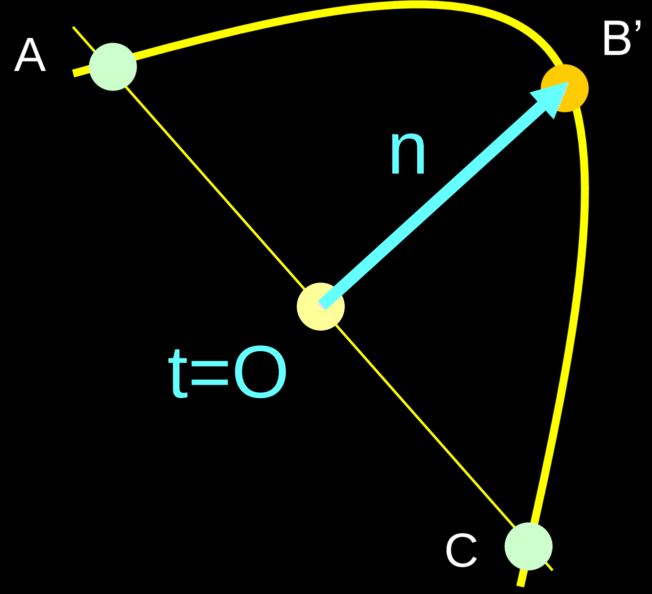
[Guskov *et al.*]

Multiresolution Representation

Two scalar displacement (t,n)



One scalar (normal mesh)

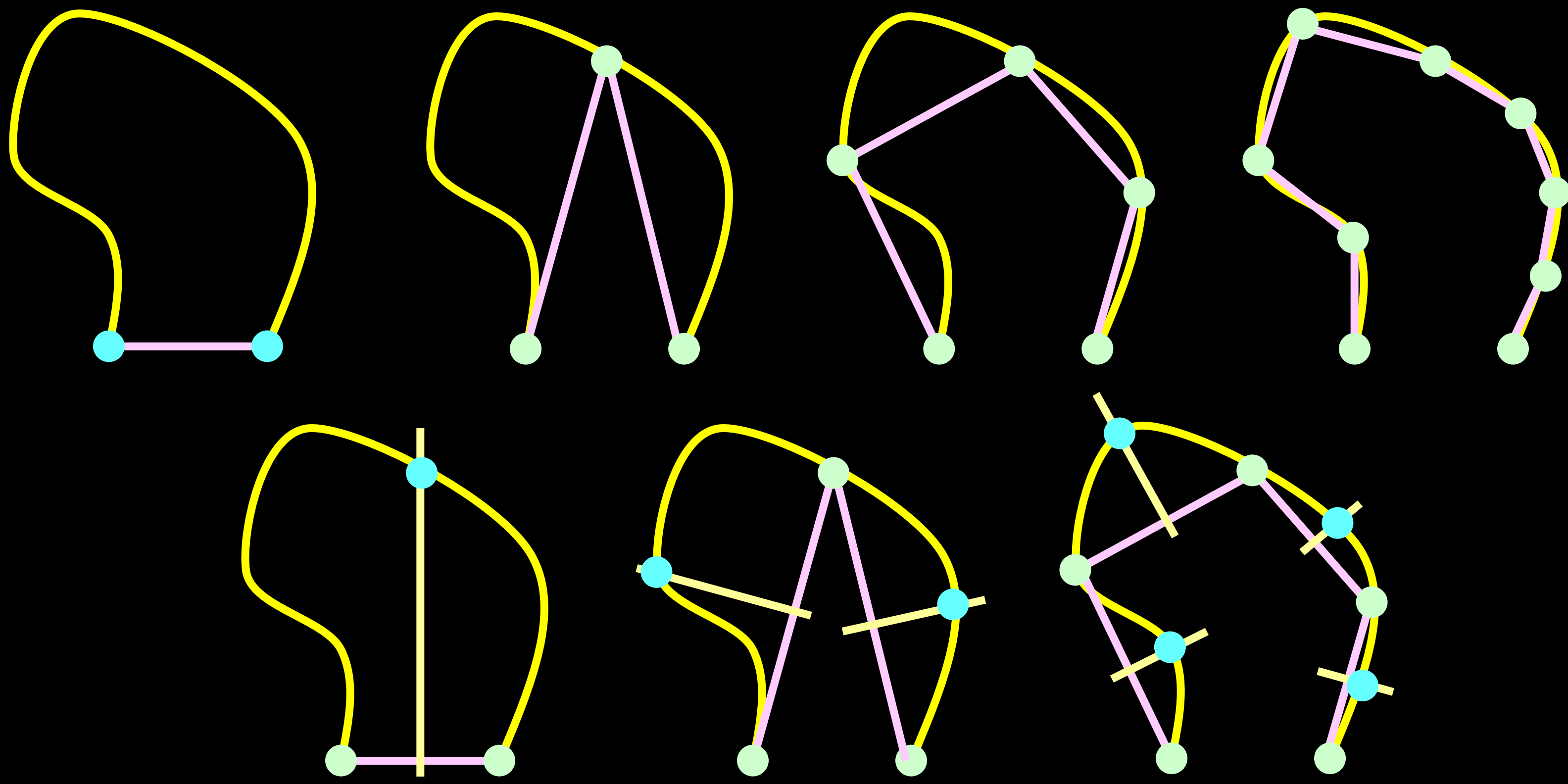


Normal Mesh

[Guskov *et al.*]

Multiresolution Representation

Normal mesh



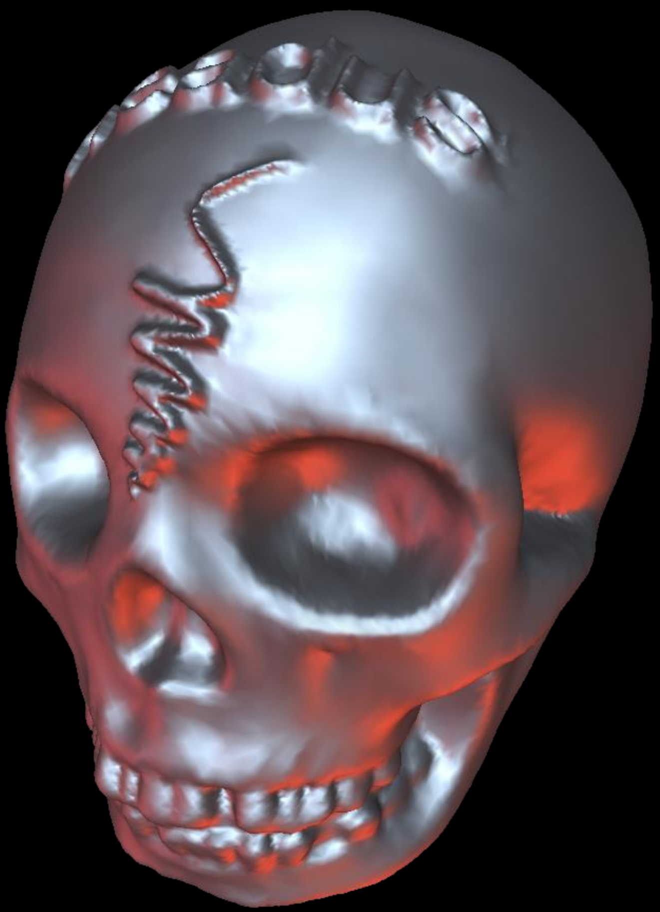
[Guskov *et al.*]

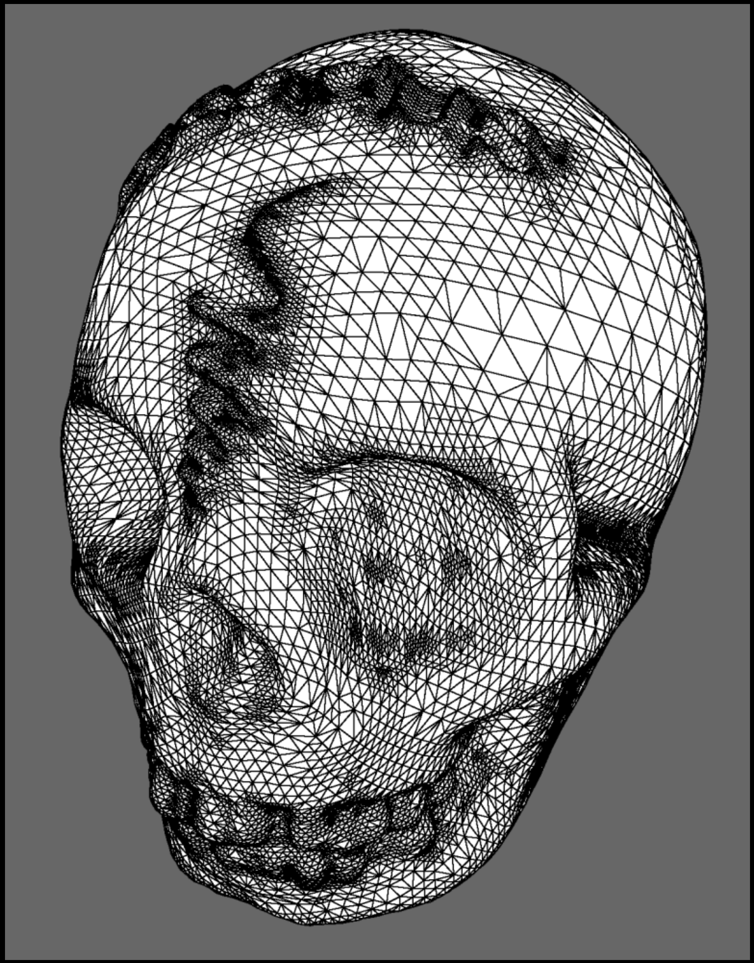
Multiresolution Meshes

Applications:

- Adaptive remeshing
- Compression
- Filtering
- Editing
- Morphing

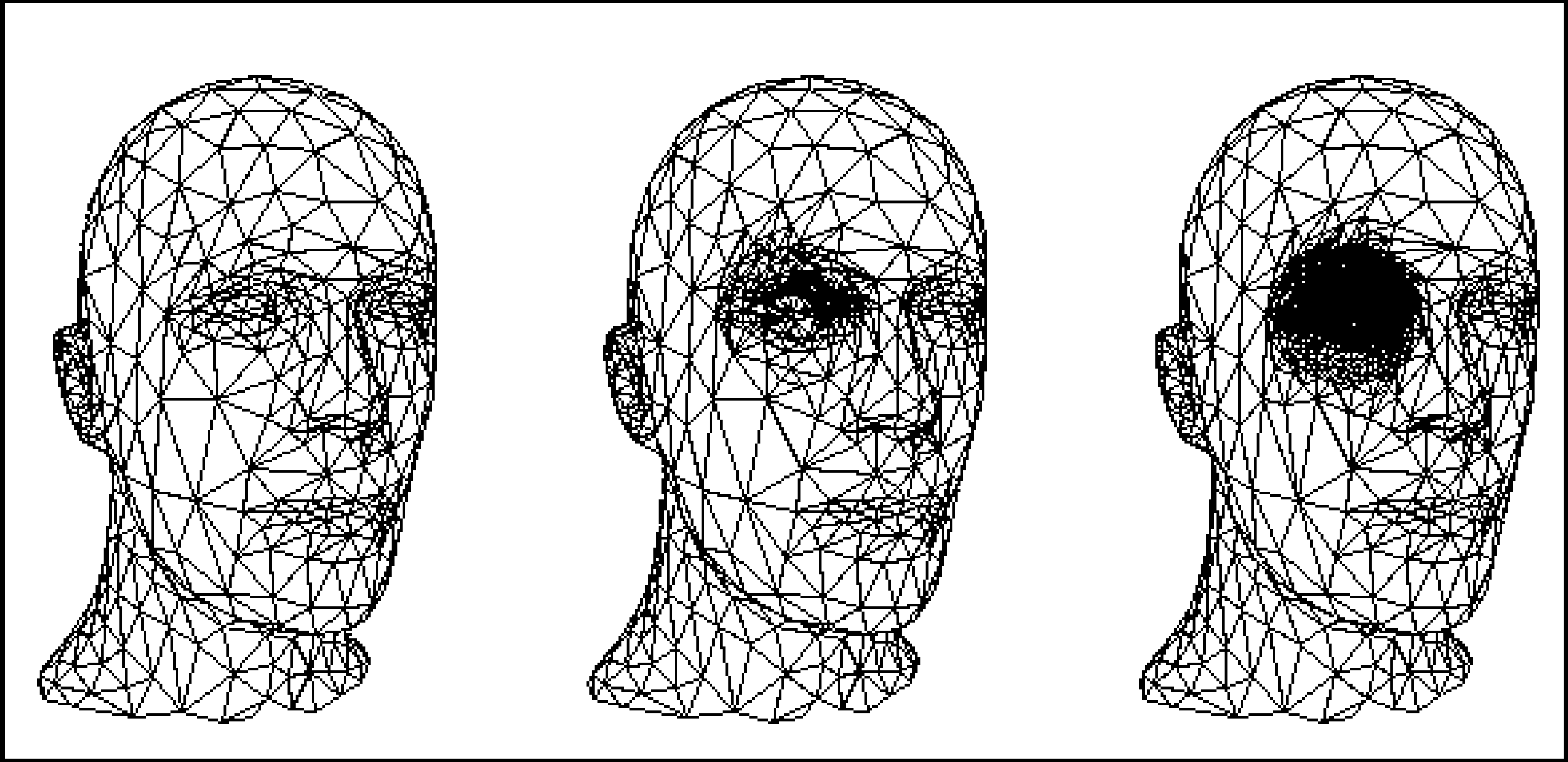
Adaptive Remeshing





[Guskov *et al.*]

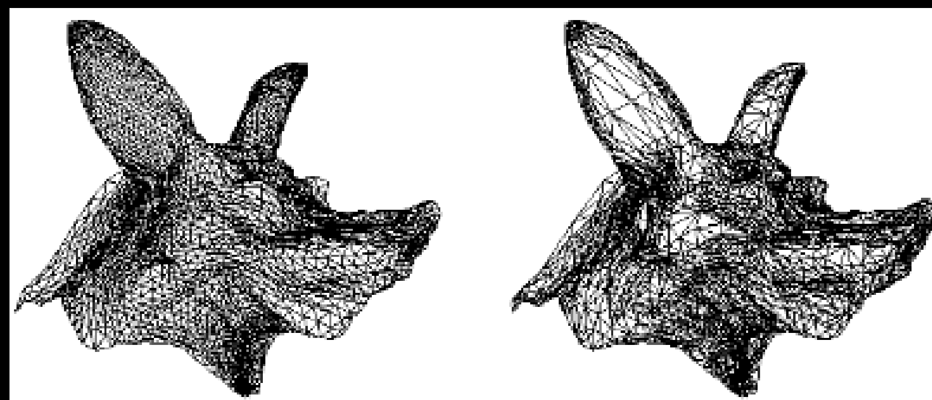
Adaptive Remeshing

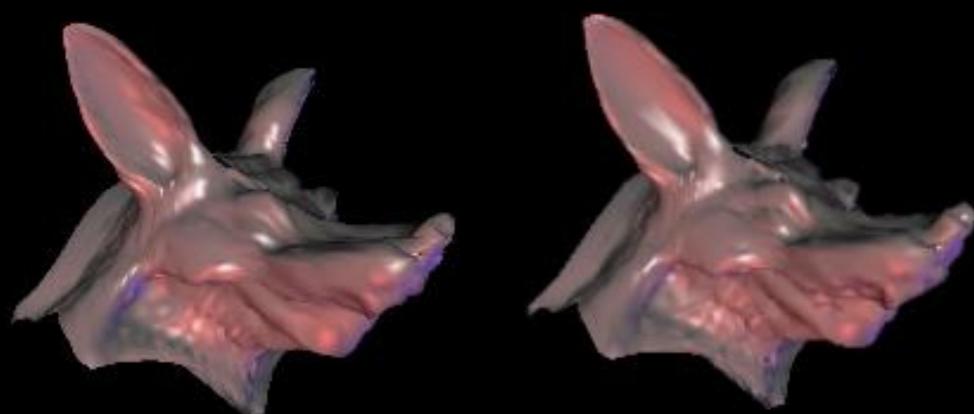


[Zorin *et al.*]

Adaptive Remeshing

Both 11K triangles





Uniform Adaptive

[Zorin *et al.*]

Multiresolution Meshes

Applications:

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

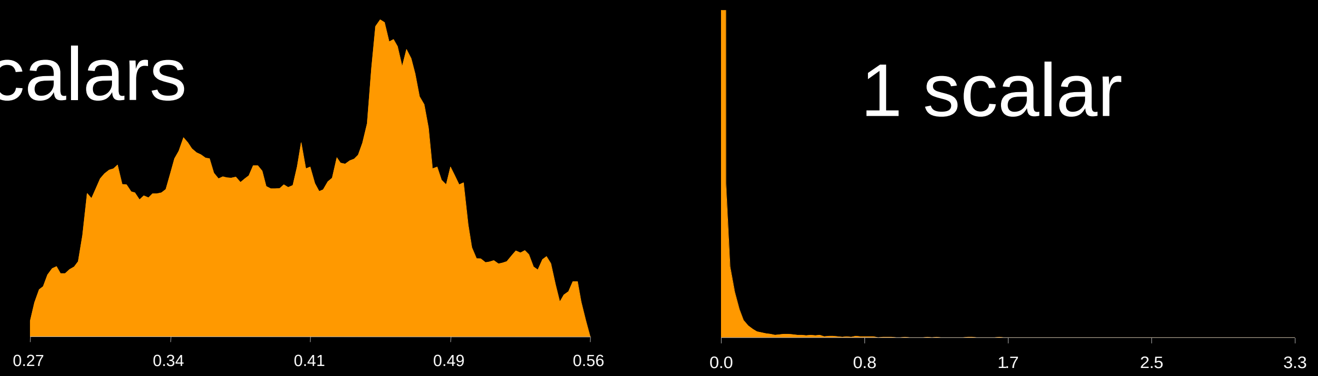
Mesh Compression

Effect of wavelet transform

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

3 scalars

1 scalar



Vertex coordinates

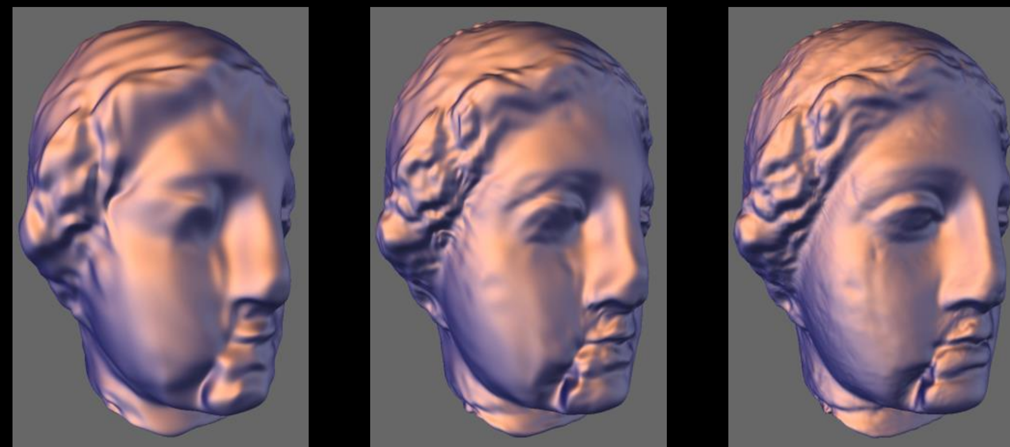
Wavelet coefficients

[Guskov *et al.*]

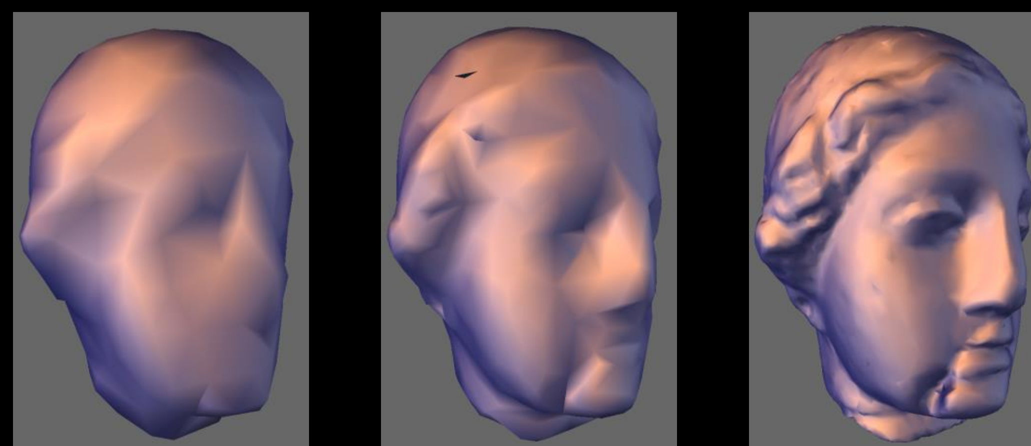
Mesh Compression

Fixed file size

Normal Meshes:

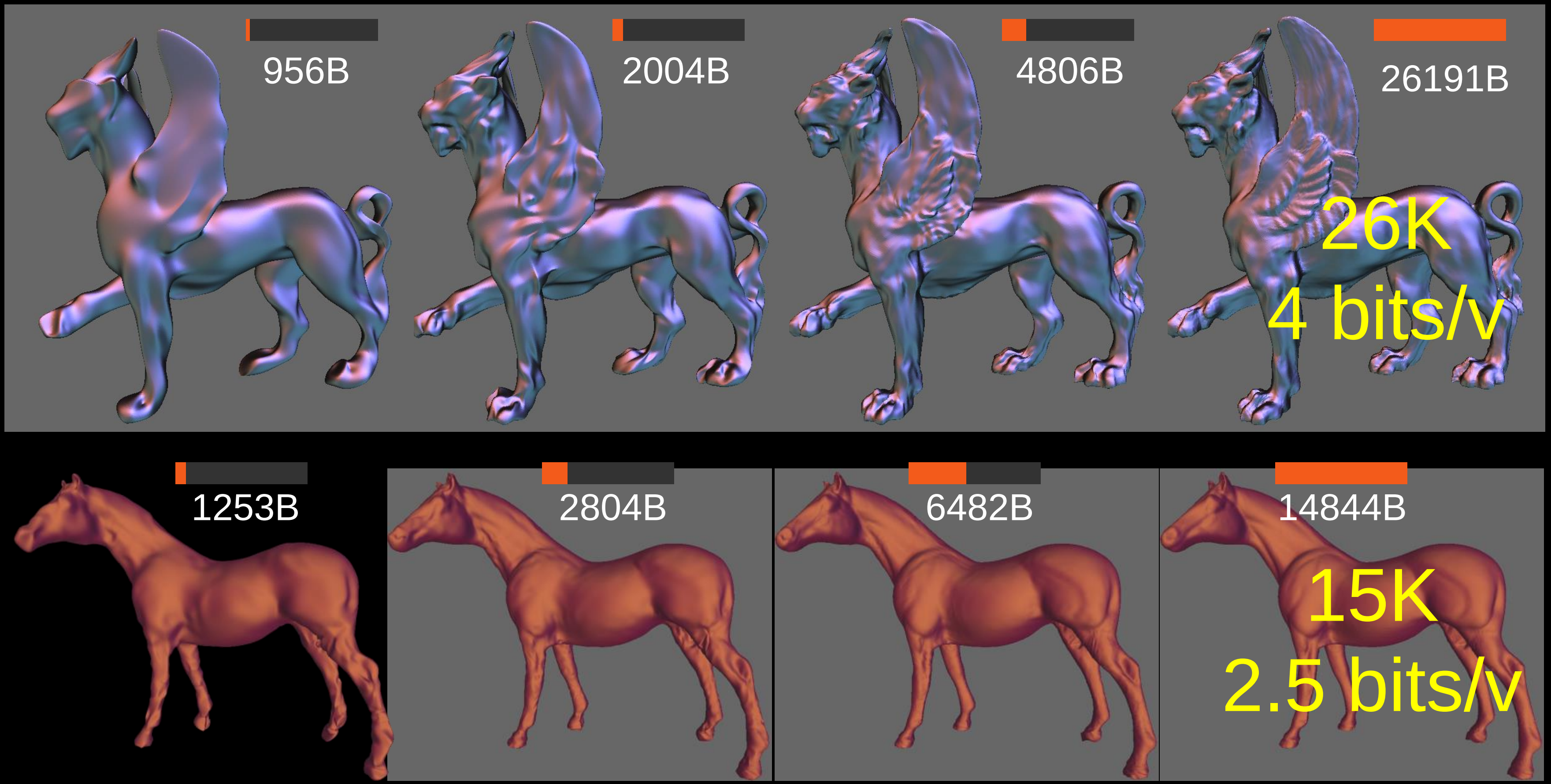


CPM:



[Guskov *et al.*]

Mesh Compression



[Guskov *et al.*]

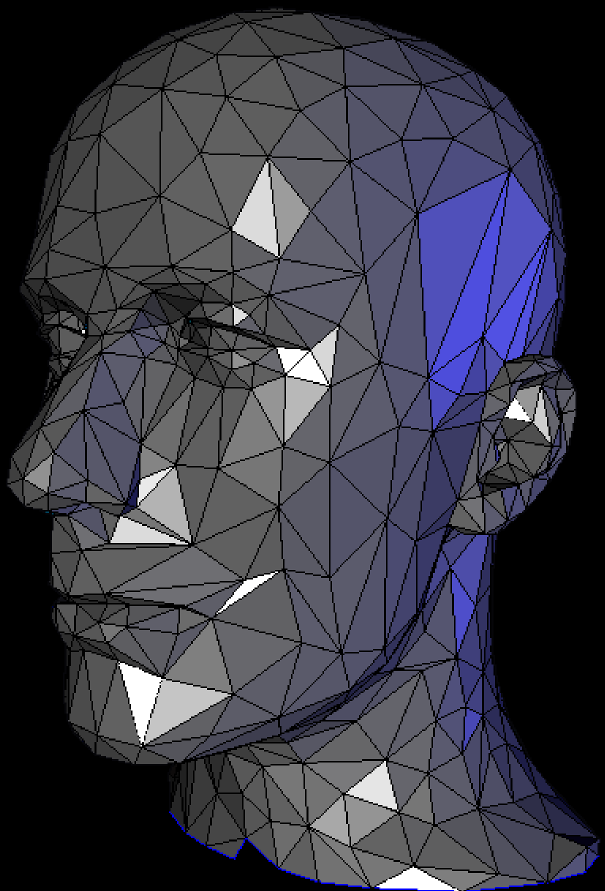
Multiresolution Meshes

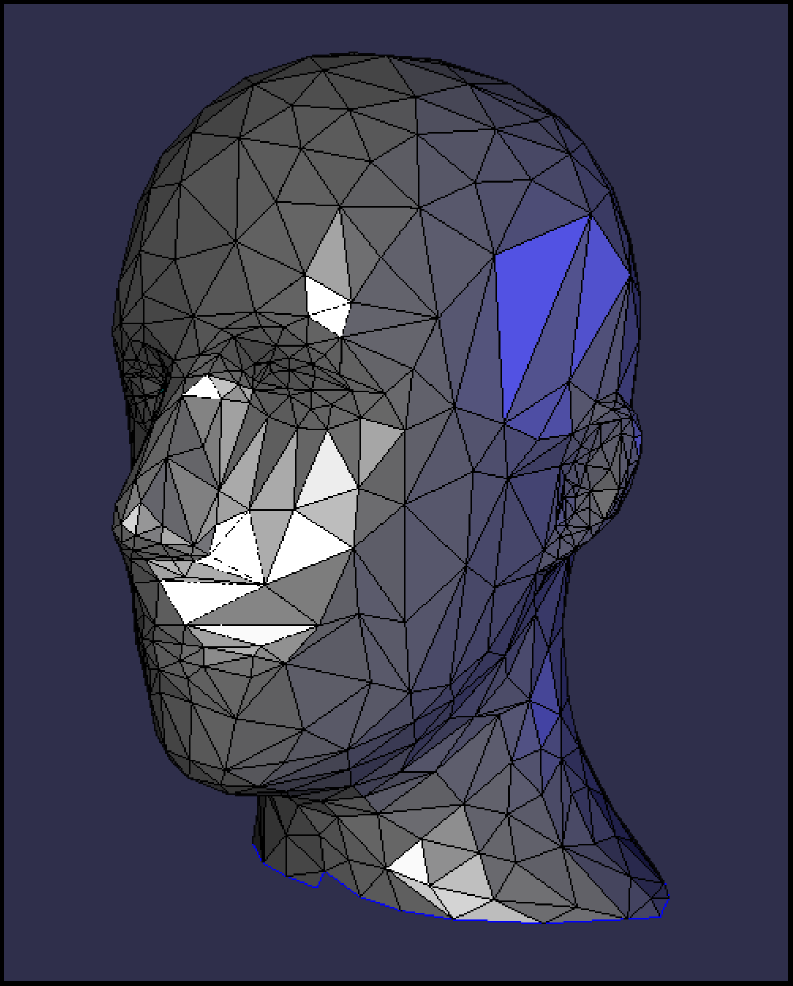
Applications:

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

Multiresolution Mesh Processing

Smoothing

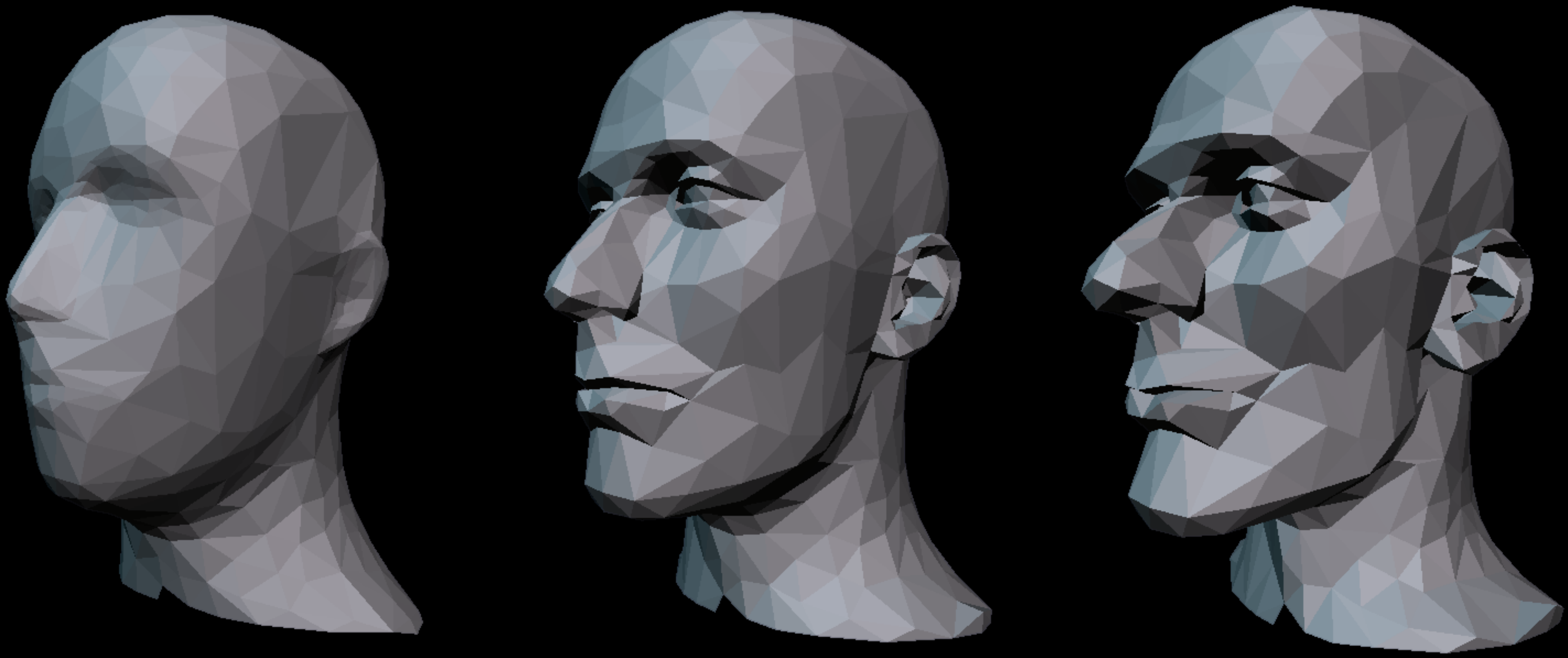




[Guskov *et al.*]

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

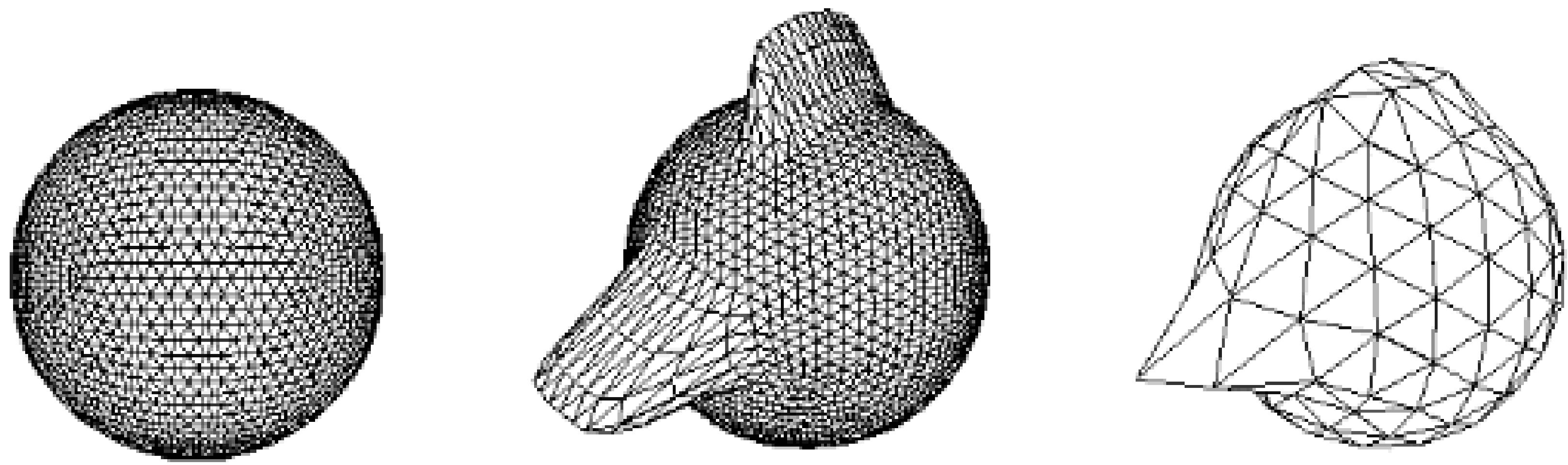
Multiresolution Mesh Editing

Goal: edit surface with operations at various resolutions

[Guskov *et al.*]

Multiresolution Mesh Editing

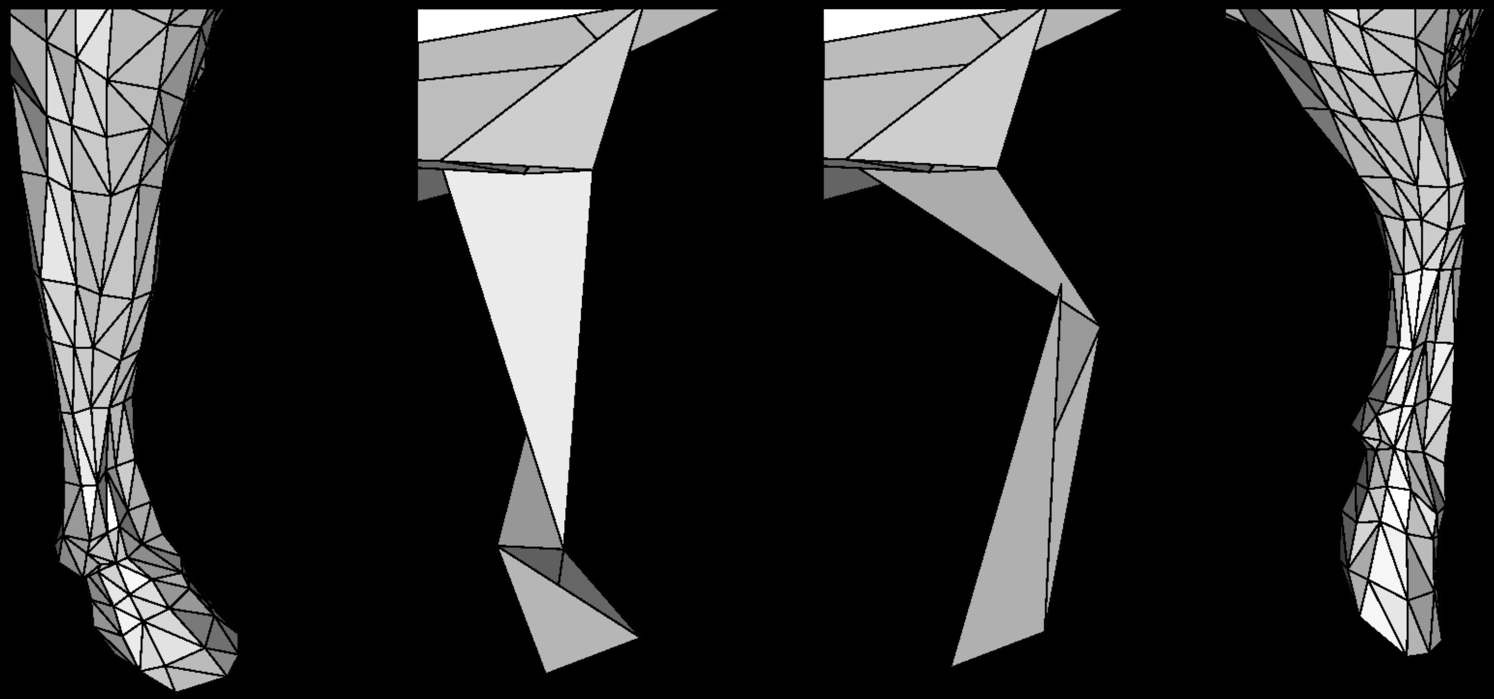
When edit at fine resolution,
update higher levels of multiresolution hierarchy



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

[Zorin *et al.*]

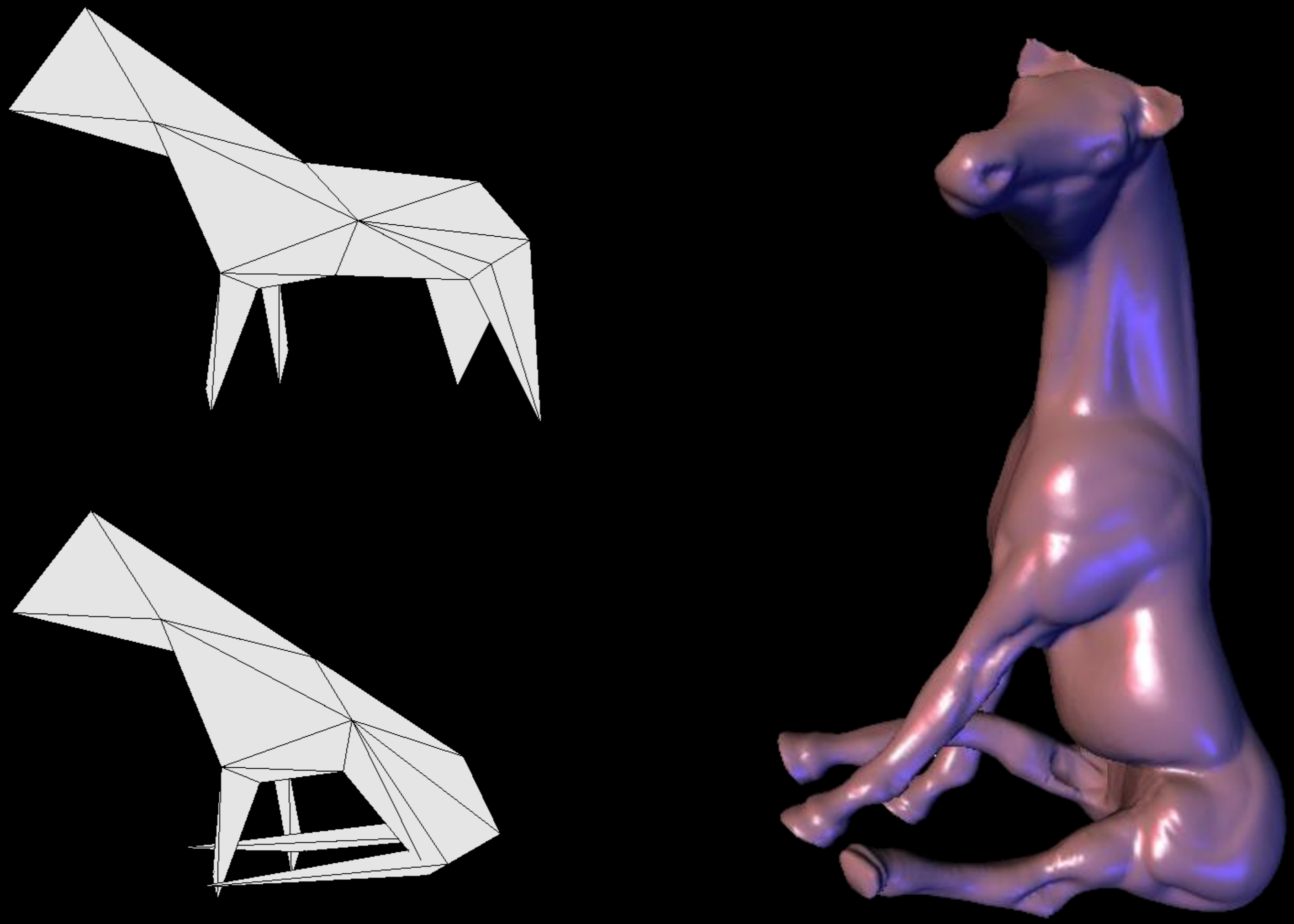
Multiresolution Mesh Editing



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.*]

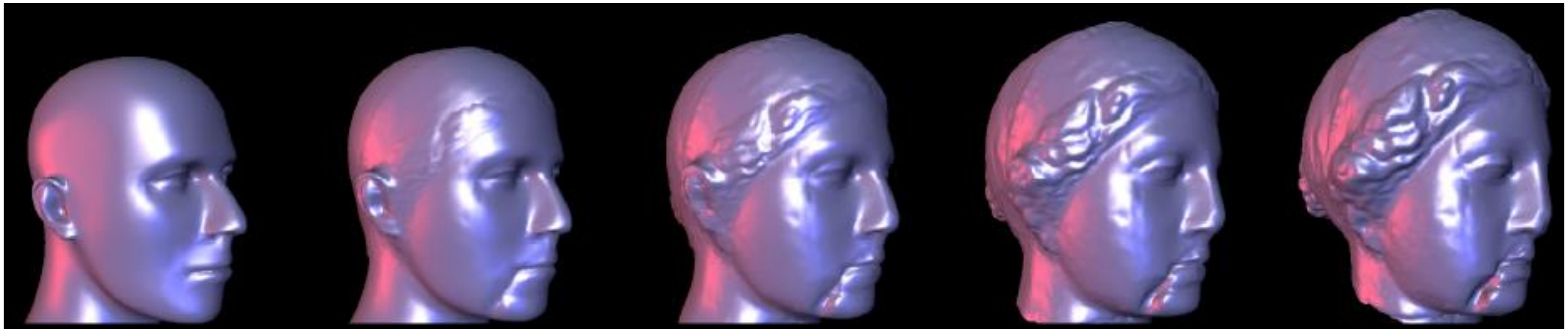
Multiresolution Meshes

Applications:

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

Multiresolution Mesh Morphing

Goal: interpolate surfaces

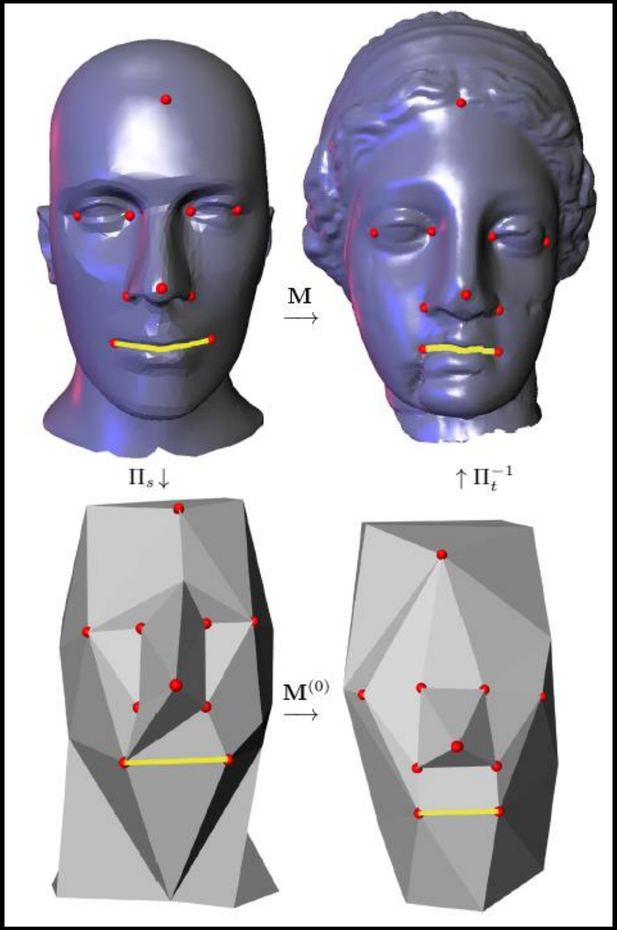


[Lee *et al.*]

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

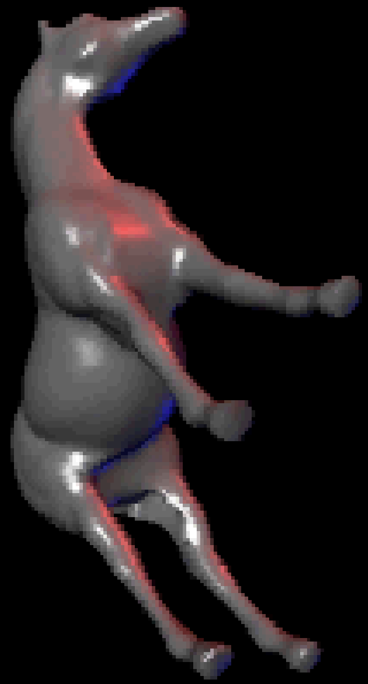
with Spatial Control

[Lee *et al.*]

Multiresolution Mesh Morphing

[Lee *et al.*]

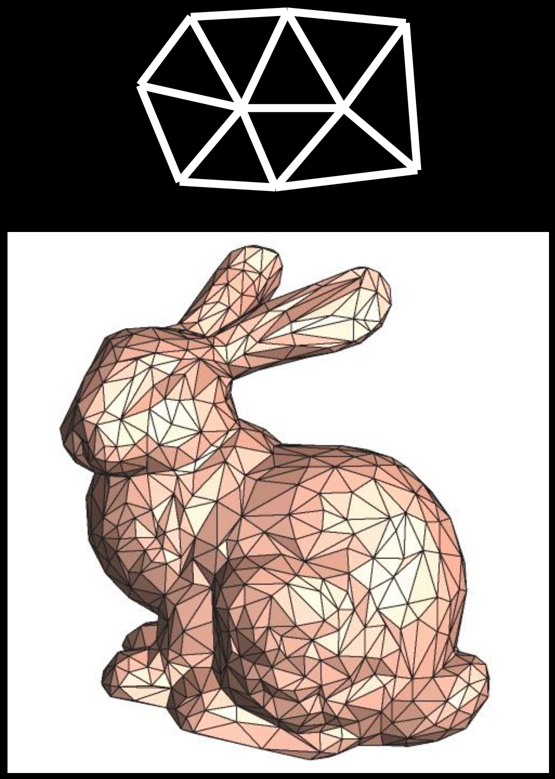
Multiresolution Mesh Morphing



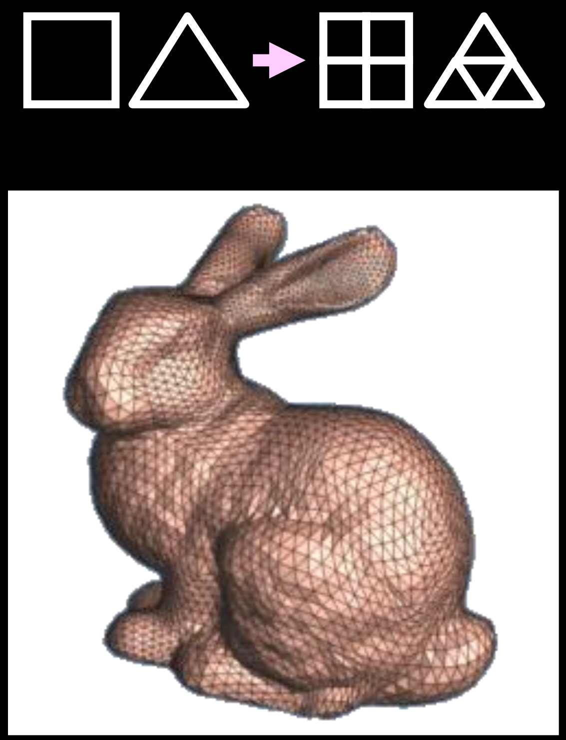
with Spatial Control

[Lee *et al.*]

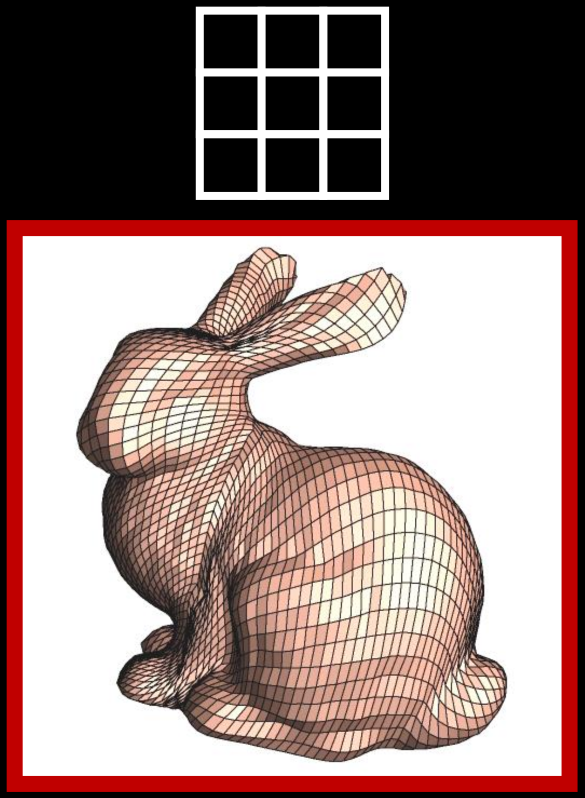
Multiresolution Meshes



Irregular



Semi-regular



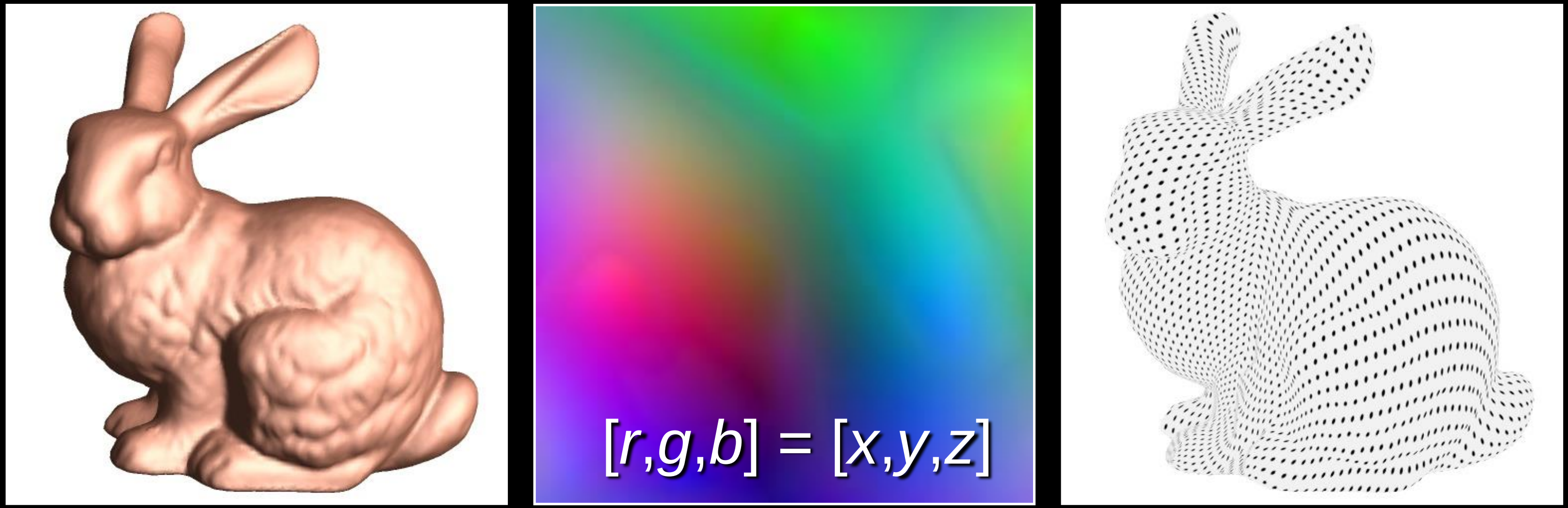
Completely regular

[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

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