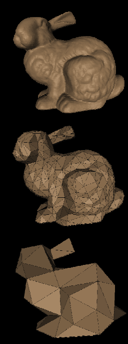
Multiresolution Meshes I

COS 526

Lecture by Tom Funkhouser

Slides by Michael Garland, Hugues Hoppe, and Richard Southern



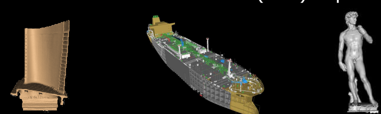
The Problem of Detail

Slide by Garland

Graphics systems are awash in model data
- very detailed CAD databases
- high-precision surface scans

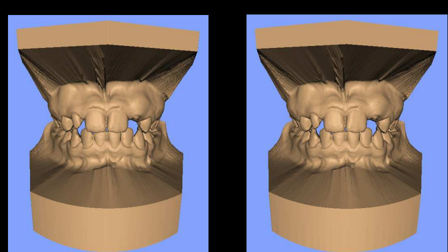
Available resources are constrained
- CPU, space, graphics speed, network bandwidth

We need economical models
- want the minimum level of detail (LOD) required



A Non-Economical Model

Slide by Garland



424,376 faces *60,000 faces*

Detail Elision

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

courtesy of Division and Viewpoint

Levels of Detail (LODs)

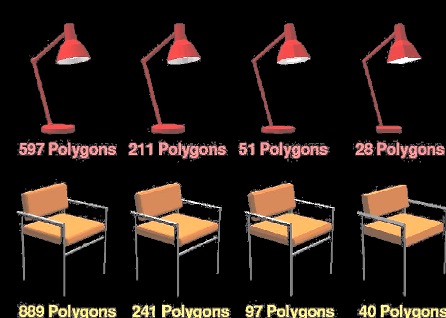
Pre-process
- Generate discrete set of independent levels of detail

Run-time
- Select level of detail according to viewpoint

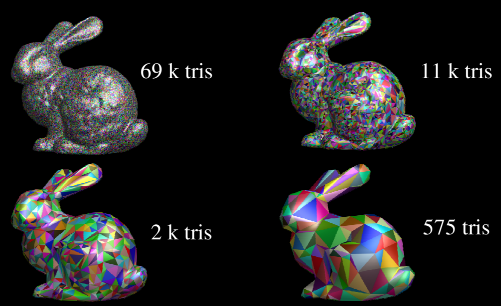
Advantages
- Fairly efficient storage (<2x original)
- No significant run-time overhead

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

Levels of Detail

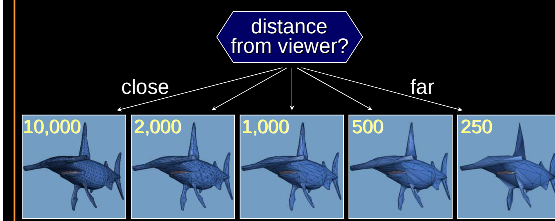


Levels of Detail

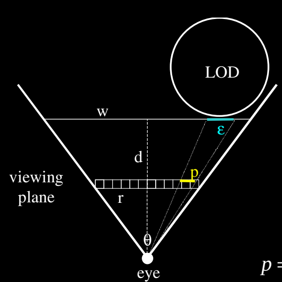


Selecting Levels of Detail

Slide by Hoppe



Selecting Levels of Detail



$$p = \frac{\varepsilon r}{w} = \frac{\varepsilon r}{2d\tan(\theta/2)}$$

Selecting Levels of Detail

Two possibilities:

- Guarantee quality, maximize frame rate
- Guarantee frame rate, maximize quality

Guaranteeing Frame Rate

No Detail Elision
0.22 Seconds
(19,881 Polygons)

Optimization Detail Elision
0.05 Seconds
(3,568 Polygons)

Guaranteeing Frame Rate

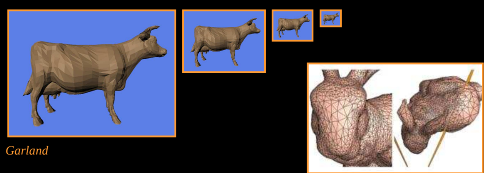
Objects Shaded by LOD
(Higher LODs appear darker)

Pixel-by-Pixel Differences
(Larger differences appear brighter)

LODs are NOT the Whole Answer

Switching discrete LODs causes popping
- Want continuous change in detail

Cannot choose single LOD sometimes
- May need different amounts of detail on same surface



Garland

Hoppe

Multiresolution Meshes

Pre-process
- Generate tree of simplification operations

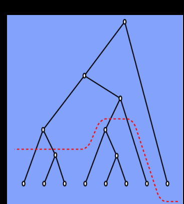
Run-time
- Refine/coarsen current model according to viewpoint

Advantages
- Allows finer control of tessellation (simplify part of object, but not rest)

Disadvantages
- More run-time computation and complexity
- Difficult for retained-mode graphics

Multiresolution Meshes

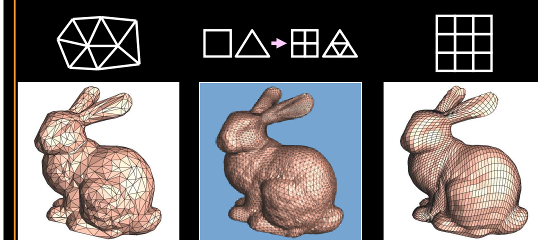
Encode simplification operations in tree
- Subtrees are independent of one another
- Cut through tree defines a mesh
- Move cut up/down to simplify/refine



Xia96, Hoppe97, Luebke97

Multiresolution Meshes

Slide by Hoppe



Irregular *Semi-regular* *Completely regular*

Outline

Irregular meshes
- Progressive mesh

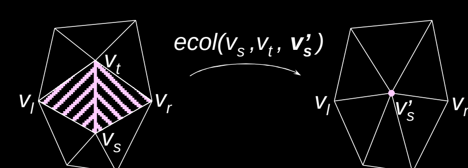
Semi-regular meshes
- Normal mesh

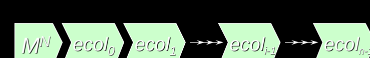
Completely regular meshes
- Geometry image

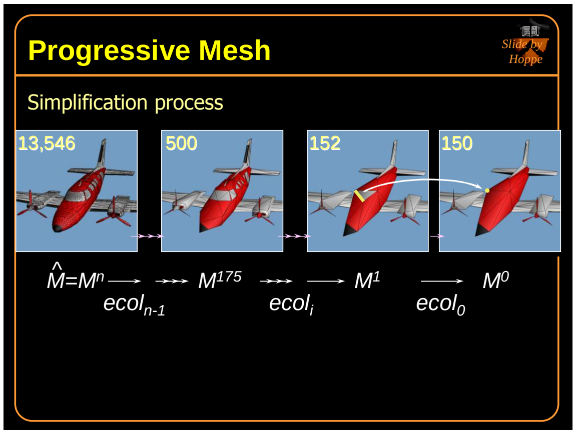
Progressive Mesh

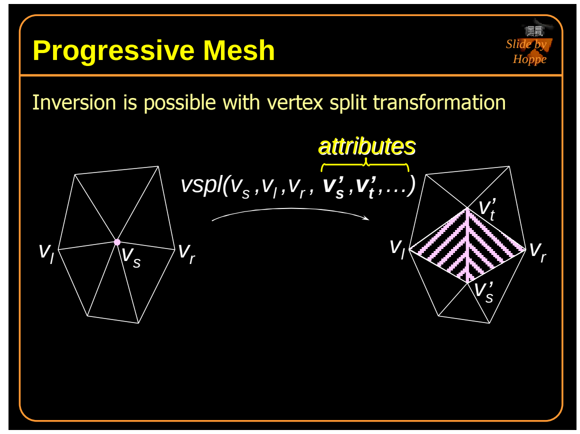
Slide by Hoppe

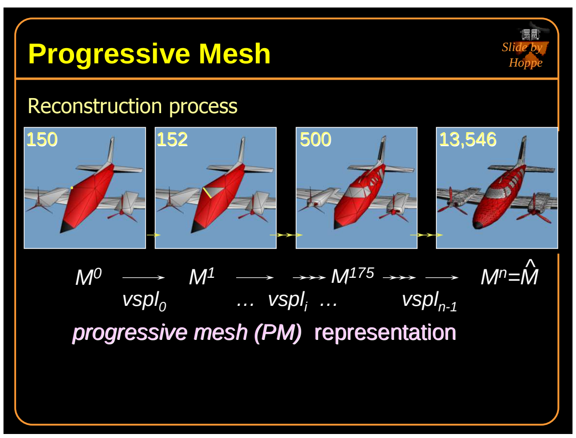
Encode continuous detail as sequence of edge collapses

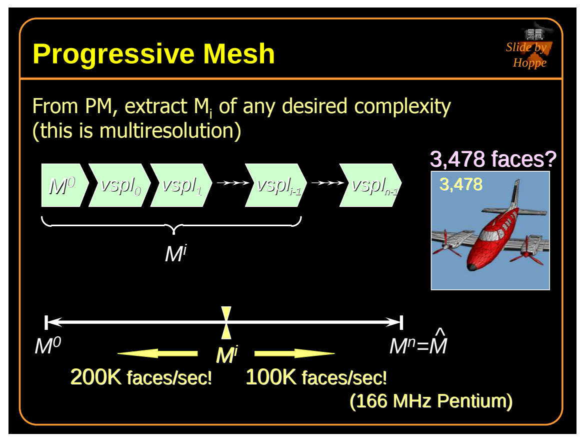


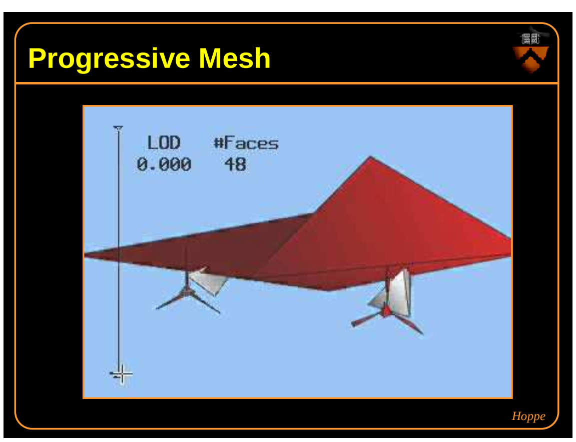


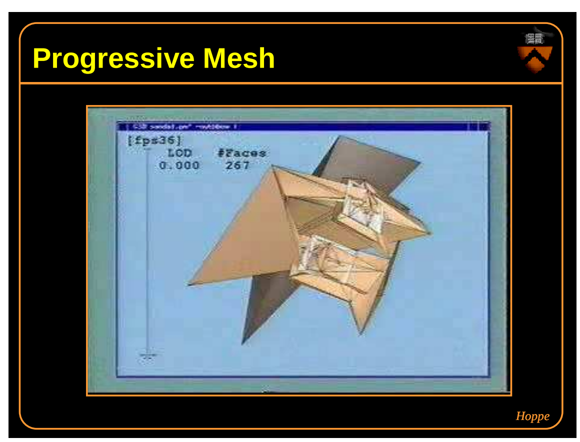

Progressive Mesh
Slide by Hoppe
Simplification process
13,546
500
152
150
M̂=M^n → M^175 → M^1 → M^0
ecol_{n-1}
ecol_i
ecol_0


Progressive Mesh
Slide by Hoppe
Inversion is possible with vertex split transformation
attributes
vspl(v_s, v_l, v_r, v'_s, v'_t, …)
v_l
v_s
v_r
v'_t
v'_s


Progressive Mesh
Slide by Hoppe
Reconstruction process
150
152
500
13,546
M^0 → M^1 → M^175 → M^n=M̂
vspl_0
… vspl_i …
vspl_{n-1}
progressive mesh (PM) representation


Progressive Mesh
Slide by Hoppe
From PM, extract M_i of any desired complexity
(this is multiresolution)
3,478 faces?
3,478
M^0
vspl_0
vspl_1
vspl_{i-1}
vspl_{n-1}
M^i
M^0
M^i
M^n=M̂
200K faces/sec!
100K faces/sec!
(166 MHz Pentium)

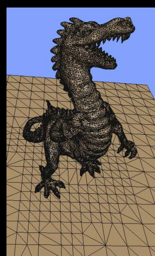

Progressive Mesh
LOD #Faces
0.000 48
Hoppe


Progressive Mesh
LOD #Faces
0.000 267
Hoppe

Progressive Mesh

Slide by Garland

Can also consider attributes in error function

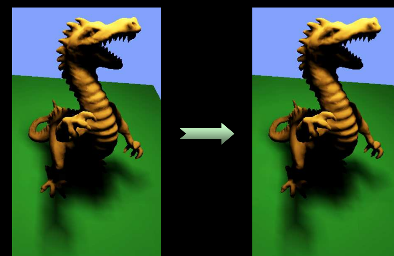

Mesh for solution


Radiosity solution

Progressive Mesh

Slide by Garland

Can also consider attributes in error function


50,761 faces → *10,000 faces*

Progressive Mesh

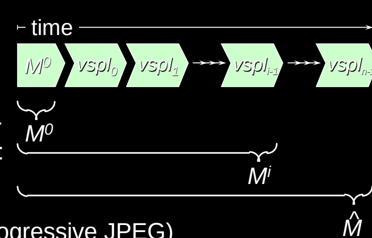
Benefits/Applications:

- Progressive transmission
- Smooth transitions
- Surface compression
- Selective refinement

Progressive Transmission

Slide by Hoppe

Transmit records progressively:



(~ progressive JPEG)

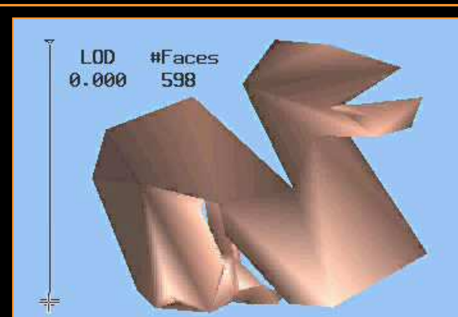
Progressive Transmission

Slide by Southern

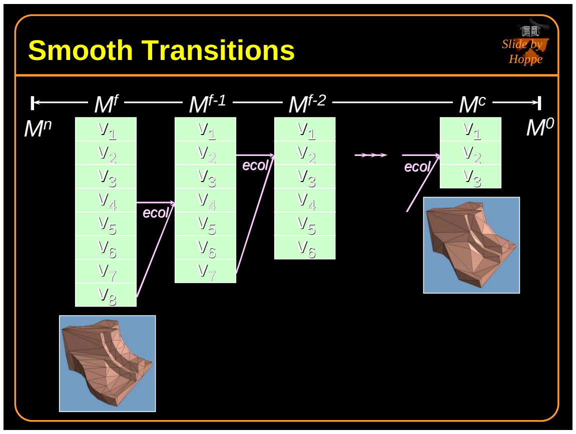
Details added while user is browsing.

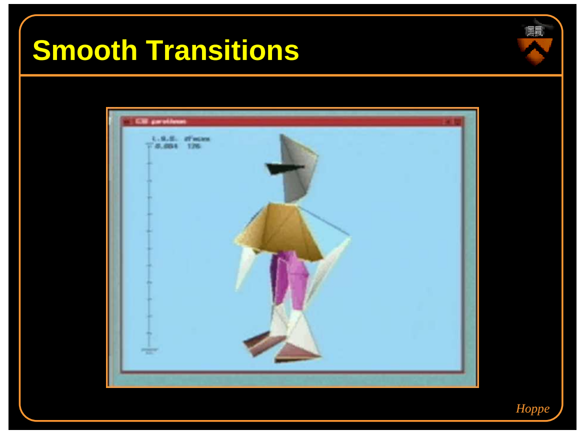
[Certain *et al.*]

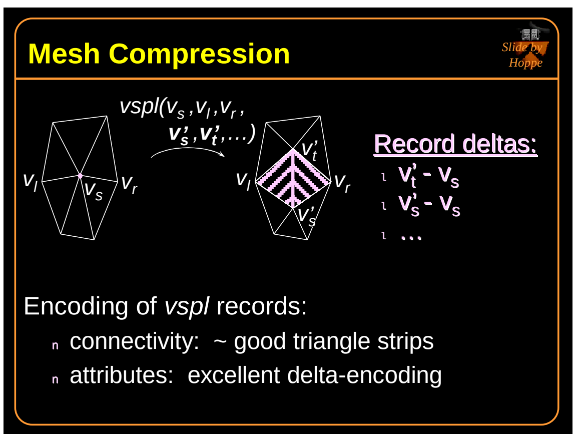
Progressive Transmission

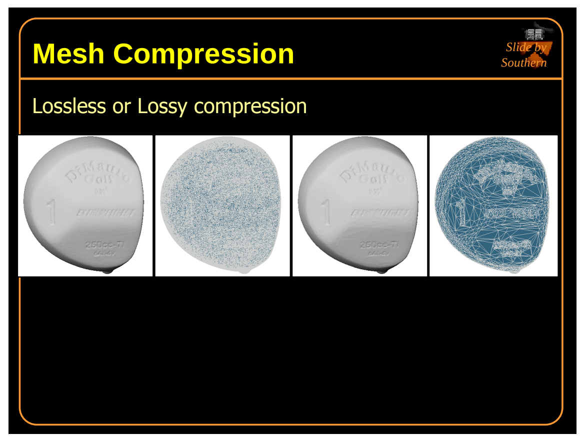


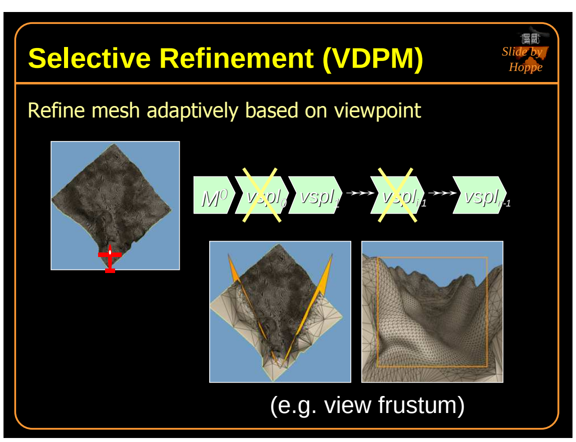
Hoppe

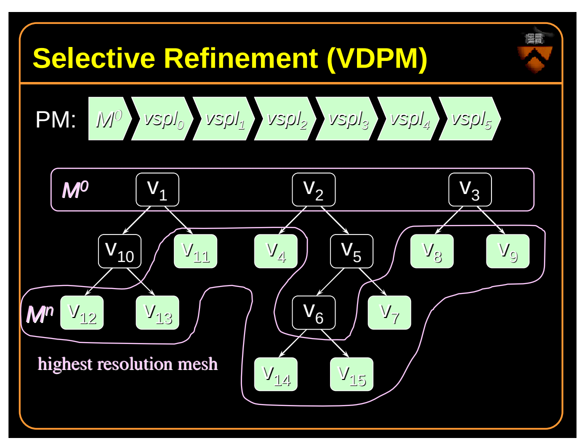

Smooth Transitions
Slide by Hoppe
M^n M^f M^{f-1} M^{f-2} M^c M^0
ecol
ecol
ecol


Smooth Transitions
Hoppe

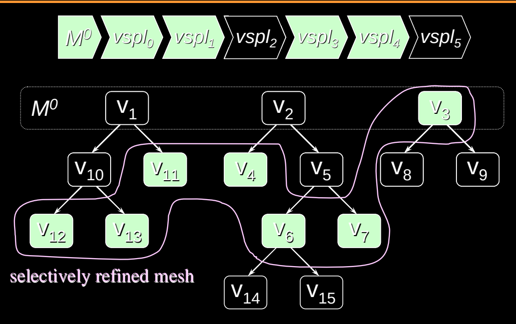

Mesh Compression
Slide by Hoppe
vspl(v_s, v_l, v_r, v'_s, v'_t, …)
Record deltas:
v'_t - v_s
v'_s - v_s
…
Encoding of vspl records:
connectivity: ~ good triangle strips
attributes: excellent delta-encoding


Mesh Compression
Slide by Southern
Lossless or Lossy compression

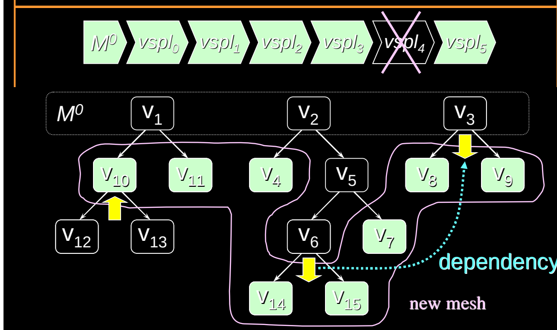

Selective Refinement (VDPM)
Slide by Hoppe
Refine mesh adaptively based on viewpoint
(e.g. view frustum)


Selective Refinement (VDPM)
PM: M^0 $vspl_0$ $vspl_1$ $vspl_2$ $vspl_3$ $vspl_4$ $vspl_5$
M^0 v_1 v_2 v_3
v_{10} v_{11} v_4 v_5 v_8 v_9
M^n v_{12} v_{13} v_6 v_7
highest resolution mesh
v_{14} v_{15}

Selective Refinement (VDPM)



Selective Refinement (VDPM)



Selective Refinement (VDPM)

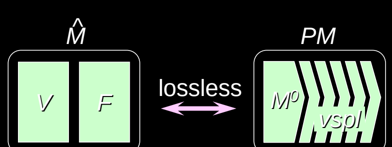
Hoppe

Selective Refinement (VDPM)

Hoppe

Progressive Mesh Summary

Slide by Hoppe



- single resolution

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

Outline

Irregular meshes
- Progressive mesh

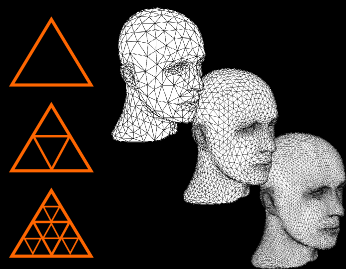
Semi-regular meshes
- Normal mesh

Completely regular meshes
- Geometry image

Semi-Regular Mesh

Slide by Sweldens

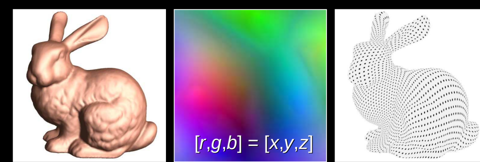
Arbitrary base mesh + refinement via subdivision



Completely Regular Mesh

Slide by Hoppe

Regular sampling of parameter domain



Geometry Image

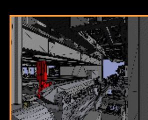
Multiresolution Mesh Summary

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



Acknowledgements

Slides by

- Michael Garland
- Hugues Hoppe
- Richard Southern