Multiresolution Meshes

Garland, Hoppe, and Southern

The Problem of Detail

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

- Select level of detail according to viewpoint

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

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

Outline
- Completely regular meshes
  - Geometry image
- Semi-regular meshes
  - Normal mesh
- Irregular meshes
  - Progressive mesh

Completely Regular Mesh

Regular sampling of parameter domain

Irregular Semi-regular Completely regular

Geometry Image
Semi-Regular Mesh
Arbitrary base mesh + refinement via subdivision

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

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

Multiresolution Analysis
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Multiresolution Analysis

Step 3: remesh
- Regular subdivision

Multiresolution Representation
Wavelet representation

\[
\text{base shape } M^0 + 
\text{sum of local correction terms (wavelet terms)}
\]

Multiresolution Representation

Burt-Adelson pyramid

Wavelet Computation

Multiresolution Meshes
Applications:
- Adaptive remeshing
- Compression
- Filtering
- Editing
- Morphing
Adaptive Remeshing

Both 11K triangles

Uniform

Adaptive

Mesh Compression

Effect of wavelet transform
- changes distribution of coefficients
- almost all coefficients close to zero

3 scalars

1 scalar

Multiresolution Meshes

Applications:
- Adaptive remeshing
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Mesh Compression

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

Progressive compression:
- Encode largest coefficients first
- Encode only most significant bits
- Subsequent bits in later iterations

Encode only most significant bits

Multiresolution Meshes

Applications:
- Adaptive remeshing
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- Editing
- Morphing

Multiresolution Mesh Processing

Smoothing

[Guishov et al.]
Multiresolution Mesh Processing

Enhancing

\[
\text{smoothed} + 2 \times (\text{original} - \text{smoothed}) = \text{enhanced}
\]

Multiresolution Meshes

Applications:
- Adaptive remeshing
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Multiresolution Mesh Editing

Goal: edit surface with operations at various resolutions

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

Original | Coarse | Edit coarse | Edit fine

[Zorin et al.]
**Multiresolution Meshes**

Applications:
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**Multiresolution Mesh Morphing**

Goal: generate intermediate models
- Requires common parameterization

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**Multiresolution Mesh Morphing**

[Lee et al.]

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**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**

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**Progressive Mesh**

Encode continuous detail as sequence of edge collapses

**Simplification process**

\[
M^0 \xrightarrow{ecol_{n-1}} M^{n-1} \xrightarrow{ecol_{n}} M^{n} \xrightarrow{ecol_{0}} M^0
\]
Progressive Mesh
Inversion is possible with vertex split transformation

Progressive Mesh
Reconstruction process

Progressive Mesh
From PM, extract $M$ of any desired complexity (this is multiresolution)

Progressive Mesh Example Movies

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

Multiresolution Mesh Summary
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