Multiresolution Meshes

Huge meshes are difficult to
- render
- store
- transmit
- edit

Multiresolution is crucial

Irregular Multiresolution Meshes

Encode mesh simplification operations in tree
- Cut through tree defines a mesh
- Move cut up/down to simplify/refine

Progressive Mesh

Encode continuous detail as sequence of edge collapses

\[ \text{ecol}(v_s, v_t, v'_s) \]
**Progressive Mesh**

Simplification process

13,546 → 500 → 152 → 150

Progressive mesh (PM) representation

\[
M = M_0 \xrightarrow{ecol_1} M_1 \xrightarrow{ecol_i} M_i \xrightarrow{ecol_0} M^0
\]

Progressive Mesh

Inversion is possible with vertex split transformation

\[
v_{spl}(v_s, v_l, v_r, v_t, \ldots)
\]

Progressive Mesh

Reconstruction process

150 → 152 → 500 → 13,546

Progressive mesh (PM) representation

\[
M_0 \xrightarrow{v_{spl_0}} M_1 \xrightarrow{v_{spl_1}} \ldots \xrightarrow{v_{spl_i}} \ldots \xrightarrow{v_{spl_{n-1}}} M^0
\]

Progressive Mesh

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

\[
M_0 \xrightarrow{v_{spl_0}} v_{spl_1} \xrightarrow{v_{spl_i}} \ldots \xrightarrow{v_{spl_{n-1}}} M^0
\]

Progressive Mesh

3,478 faces?
Progressive Mesh

Benefits/Applications:
- Progressive transmission
- Surface compression
- Selective refinement

Progressive Transmission

Transmit records progressively:

\[ M_0 \rightarrow vspl_1 \rightarrow vspl_2 \rightarrow \ldots \rightarrow vspl_n \]

Receiver displays:

\[ M_0 \rightarrow M_i \rightarrow M \]

(\sim \text{progressive JPEG})

Progressive Transmission

Details added while user is browsing.

Mesh Compression

Lossy compression

Mesh Compression

Lossless compression
**Mesh Compression**

$\text{vspl}(v_s, v_l, v_r, v_s', v_l', v_r', ...)$

**Record deltas:**
- connectivity: ~ good triangle strips
- attributes: excellent delta-encoding

**Encoding of vspl records:**
- connectivity: ~ good triangle strips
- attributes: excellent delta-encoding

**Selective Refinement (VDPM)**

Refine mesh adaptively based on viewpoint

(e.g. view frustum)

**Selective Refinement (VDPM)**

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<th>o</th>
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**Progressive Mesh Summary**

- $\hat{M}$ lossless
- 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

Multiresolution Analysis
step 1: construct a simple domain mesh $K$
step 2: construct a parametrization $r$ of $M$ over $K$
step 3: remesh

Step 1: construct simple base domain
- topological type of $K$ = topological type of $M$
- small number of triangular regions
- smooth and straight boundaries

Step 2: construct parameterization
- Map each face of domain mesh to corresponding triangular region

Step 2: construct parameterization
- Map each face of domain mesh to corresponding triangular region
- Local maps must agree on boundaries and introduce small distortions $\rightarrow$ harmonic maps
Multiresolution Analysis

Step 3: remesh
- Regular subdivision

Multiresolution Representation

Wavelet representation
- base shape $M^0$
- sum of local correction terms (wavelet terms)

Multiresolution Representation

Burt-Adelson pyramid
- coarsen
- subdivide
- $n$ vertices
- $n-1$ vertices
details

Multiresolution Representation

Two scalar displacement $(t,n)$
- A
- B
- C

Multiresolution Representation

One scalar (normal mesh)
- A
- B
- C
- Normal Mesh
Multiresolution Representation

Normal mesh

Multiresolution Meshes

Applications:
- Adaptive remeshing
- Compression
- Filtering
- Editing
- Morphing

Adaptive Remeshing

[Both 11K triangles]

Uniform  Adaptive

[Both 11K triangles]
Mesh Compression

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

3 scalars

1 scalar

Mesh Compression

Normal Meshes:

CPM:

Mesh Compression

Fixed file size

Normal Meshes:

CPM:

Multiresolution Meshes

Applications:
- Adaptive remeshing
- Compression
  - Filtering
  - Editing
  - Morphing

Multiresolution Mesh Processing

Smoothing

Enhancing

smoothed + 2 * (original - smoothed) = enhanced
Multiresolution Mesh Processing

Filtering

Multiresolution Meshes

Applications:
- Adaptive remeshing
- Compression
- Filtering
- Editing
- Morphing

Multiresolution Mesh Editing

Goal: edit surface with operations at various resolutions

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

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

Multiresolution Mesh Editing

original  coarse  edit coarse  edit fine

Multiresolution Mesh Editing

[Guskov et al.]
Multiresolution Mesh Editing

Applications:
- Adaptive remeshing
- Compression
- Filtering
- Editing
- 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
- Can morph different multiresolution levels at different rates
Multiresolution Mesh Morphing with Spatial Control

[Lee et al.]

Multiresolution Meshes

Irregular Semi-regular Completely regular

[Hoppe]

Completely Regular Mesh

Regular sampling of parameter domain

[\text{r.g.b}]=[\text{x,y,z}]

Geometry Image

[Lee et al.]

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.)
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