Special Module on Media Processing and Communication

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SIV 864
Geometry Compression
Historical Perspective: Digital Media

- **Sound**
- **Video**
- **Image**
- **Geometry**

Timeline:
- 75
- 80
- 85
- 90
- 95
- 00
- 05

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Geometric Models

Representations

- Constructed Solid Geometry
- Polygonal Surface
- Implicit Surface
- Parametric Surface

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Geometric Models

Applications

Engineering

Medical

Topography

Art

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Geometric Models

Polygonal Representation

For rendering often object is represented as collection of polygons

Object | Surfaces
Polygonal Representation

Polygonal mesh is a collection of edges, vertices and polygons such that each edge is shared by at most two polygons.

- **Vertex**: Node
- **Edge**: Connects two vertices
- **Polygon**: Closed sequence of edges
Explicit Representation

Each polygon is represented by

\[ P=((x_1,y_1,z_1), (x_2,y_2,z_2), \ldots, (x_n,y_n,z_n)) \]

i.e. vertices are stored in the order of traversal

Edges connect the successive vertices plus the last one

This representation has restrictive manipulation and has multiple storage of points.
Geometric Models

Polygonal Representation

Pointer to Vertex List

Each vertex is stored once in a list $V$
$V = ((x_1,y_1,z_1), (x_2,y_2,z_2), \ldots, (x_n,y_n,z_n))$

Each polygon is represented as $P = (V_1, V_2, V_3)$
e.g. $P_1 = (1,2,4)$ and $P_2 = (4,2,3)$

In this representation it is difficult to find polygons that share an edge.
Geometric Models

Polygonal Representation

Pointer to Edge List

Edge: \( E = (V_i, V_j, P_m, P_n) \)

Polygon=(\(E_p, E_q, E_r\))

\(V = (V_1, V_2, V_3, V_4)\)
\(E_1 = (V_1, V_2, P_1, \text{null})\)
\(E_2 = (V_2, V_3, P_2, \text{null})\)
\(E_3 = (V_3, V_4, P_2, \text{null})\)
\(E_4 = (V_4, V_2, P_1, P_2)\) \(P_1 = (E_1, E_4, E_5)\)
\(E_5 = (V_4, V_1, P_1, \text{null})\) \(P_2 = (E_2, E_3, E_4)\)
Geometric Models

Typically,
- **Geometry Data: Meshes**
  - Points
  - Connectivity
Geometric Compression

Connectivity Coding

Indexed Face Set

\[ T_0 : v_0v_1v_4 \]
\[ T_1 : v_1v_4v_3 \]
\[ T_2 : v_1v_2v_3 \]

Simple approach

Vertex index of 32 bits

\[ 3 \times 32 = 96 \text{ bits/triangle} \]

\[ 3 \times \log_2(V) \text{ bits/triangle} \]

= 50 bits/triangle

(for 100k vertices)
Geometric Compression

Connectivity Coding

Triangle strip

Generalized triangle strip

Triangle fan

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Geometric Compression

Connectivity Coding

Triangle strip

Generalized triangle strip

Triangle fan
Geometric Compression

Connectivity Coding

Triangle strips
Geometric Compression

Connectivity Coding
Spanning Trees
**Geometry Coding**

Scalar quantization

- $v_0: x_0y_0z_0$
- $v_1: x_1y_1z_1$
- $v_2: x_2y_2z_2$

Simple approach

- Each coordinate of 32 bits
- $3 \times 32 = 96 \text{ bits/vertex}$
- Quantization: 10 bits
- $= 3 \times 10 \text{ bits/vertex}$
Geometric Compression

Geometry Coding

Uniform quantization

12 bits  8 bits  6 bits
Geometry Coding

**Prediction**: Exploits correlation between adjacent vertex coordinates

Linear prediction: Linear combination of $K$ previous vertices

$$P = V_{i-1} + (V_{i-1} - V_{i-2})$$

error $e_i = V_i - P$
Geometry Coding

Vertex Coordinates: $V_1 V_2 V_3 V_4 \ldots$

Using prediction error: $V_1 V_2 e_3 e_4 \ldots$

Decoding: $V_1 V_2$

$$V_i = P + e_i \text{ where } P = V_{i-1} + (V_{i-1} - V_{i-2})$$
Parallelogram prediction:

\[ v_p = v_2 + v_3 - v_1 \]
Geometric Coding

K-way prediction:

Vertex is average of its neighbours
Geometric Compression

Geometry Coding

Downsampling
Geometry Coding

Downsampling
Geometry Coding

Downsampling

Resolution

Level of details

Mesh
Geometric Compression

Geometry Coding
Multi-resolution Representation

- Analysis
  - Remove vertex
  - Subdivide
  - n Vertices → Details form spectrum → Coarsest

- Synthesis
  - Details → n-1 Vertices

Down sample

Wavelet

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Geometric Compression

Animated Mesh Coding

- Animation can be modeled as a transformation
- Partitioning or clustering of data
- Prediction based method for vertices which move
- Measure to preserve time variant geometry features

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References


http://imson.usc.edu/research/project/digitalgeometry/