Progressive Deforming Meshes based on Deformation Oriented Decimation and Dynamic Connectivity Updating

Fu-Chung Huang  Bing-Yu Chen  Yung-Yu Chuang

National Taiwan University
Goal - Level of Details

- Well-established for static mesh.
  
  ![Hoppe '96](image)
  ![Garland & Heckbert '97](image)

- Not for deforming meshes.
  
  ![Mohr & Gleicher '03](image)
  ![DeCoro & Rusinkiewicz '05](image)
Main Idea - Deformation

- The key distinction.

- Technique by previous work

Mohr & Gleicher ‘03
DeCoro & Rusinkiewicz ‘05
Agenda

- **Static Connectivity**
  - Quadric Error Metric (QEM)
  - Deformation Sensitive Decimation (DSD)
  - Deformation Oriented Decimation (DOD)

- **Dynamic Connectivity**
  - Vertex Tree (View Dependent Simplification)
  - Dynamic Connectivity Updating (DCU)
Quadric Error Metric (QEM)

1. Prepare $Q$.
2. Select min.
3. Contract and re-compute
4. Repeat
Deformation Sensitive Decimation (DSD)
Deformation Sensitive Decimation (DSD)

Criteria = $\sum_t Q^t$

Interpretation?
What we perceive in animation
Problem with DSD
Problem with DSD

\[ \text{Cost} = x \ n \]

\[ \text{Cost} = \text{segment} + \text{segment} + \text{segment} + \ldots \]
Deformation Oriented Decimation (DOD)

Deformation = $\Delta l^t$

$\Delta l^{t+1}$

$\Delta l^{t+2}$

Criteria = $\sum_t \left( Q^t + \text{weight} \times \Delta l^t \right)$
Comparison

Our method

DSD

(a) original mesh

(b) simplified mesh using DOD

(c) simplified mesh using DSD
Agenda

- Static Connectivity
  - QEM
  - Deformation Sensitive Decimation (DSD)
  - Deformation Oriented Decimation (DOD)

- Dynamic Connectivity
  - Vertex Tree (View Dependent Simplification)
  - Dynamic Connectivity Updating (DCU)
The need for dynamic connectivity

- Extreme deformation or 3D morphing
Previous Approach – Dynamic Connectivity

- Progressive Multiresolution Meshes for Deforming Surfaces
  - by Kircher and Garland, SCA 2005
Vertex Tree (View Dependent Simplification)

Specific LOD

Vertex Front

\[ \min_{F \in \Phi_m} \sum_{n \in F} \eta(n) \]

Hoppe '97
Vertex Tree for deforming meshes

\[ \min_{F \in \Phi_m} \sum_{n \in F} \eta(n) \]

Geometry cost
Vertex Tree for deforming meshes

**Tail**

- $V_1$
- $V_{10}$
- $V_{12}$
- $V_{13}$

**Limbs**

- $V_2$
- $V_4$
- $V_6$
- $V_{14}$

**Head**

- $V_3$
- $V_5$
- $V_7$
- $V_{15}$

**Dramatic Change**

1. No Tail
2. Fingers
Vertex Tree for deforming meshes

Dramatic Change
1. No Tail
2. Fingers
Vertex Tree for deforming meshes

1. No constraints on temporal coherences
2. Updating b2n frames
Video: Without Coherence
Revised Cost Function

\[ \sum_{n \in F^t} \eta(n) \]

**Problem:**
- Huge minimization
- Local minimum
Approximation

• Facts:

\[
\min_{F^1,...,F^f \in \Phi_m} \left( \sum_{t=1}^{f} \sum_{n \in F^t} \eta(n) + k \sum_{t=1}^{f-1} D(F^t, F^{t+1}) \right)
\]

\text{distortion}

\text{coherence}

= 0, \quad F^t = F^{t+1} = \overline{F}

• Given initial guess

  – 1\textsuperscript{st} term
  – 2\textsuperscript{nd} term

\[
\min_{F \in \Phi_m} \left( \sum_{n \in F} \eta(n) + k \ast D(F, \overline{F}) \right)
\]
Result: DCU against DOD only

Dynamic Connectivity

Static Connectivity
Video: Connectivity Updating
Statistics - Updating
Results

Previous method
Kircher and Garland (SCA05)
Statistics - Distortion

![Graph showing distorted shapes over time with different lines representing different distortion methods.]
Result: Elephant-Horse Morphing

Elephant-Horse Morphing
42900v/85796f
Result: SpaceTime Face

SpaceTime Faces Animation
Summary

- **DOD**
  - Addition of deformation term
  - Better triangulation and more tri.

- **DCU**
  - Utilization of vertex trees
  - Lower distortion and less updating
Limitation

- Heuristics formulation for DOD
  - Used for contract-priority only
- Sub-optimal solution for DCU
  - Approximated objective function
- Not incremental
  - As opposed to [Kircher and Garland ‘05]
- No hardware support
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Goal – Level of Details

- Static connectivity (DOD)
  - Articulated mesh

- Dynamic connectivity (DCU)
  - Extreme deformation, 3D morphing
Related Work
Related Work

• Static Mesh
  – Re-meshing approach
  – Simplification

Eck et al. ‘95

Cohen-Steiner et al. ‘04

Garland & Heckbert ‘97

Hoppe ‘96
Related Work

• Deforming Mesh
  – Static connectivity
  – Dynamic connectivity

Mohr & Gleicher ‘03
Shamir et al. ‘00, ‘01
DeCoro & Rusinkiewicz ‘05
Kircher & Garland ‘05