Is Subdivision the Representation Scheme for Future Visualization & Animation Applications

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• **Objective:**

Presenting a subdivision based representation scheme

• **So, you can judge:**

If this is the ultimate representation scheme we need for all graphics applications, including **visualization** and **animation**.
What is subdivision based representation?

Subdivision Surfaces
What is so special?

- Multi-resolution (Scalability)
- One piece representation™ (arbitrary topology)
- Numerical stability
- Code Simplicity
- Covers both polygon form and surface form (Uniformity)
One piece representation™
Multi-resolution (Scalability)
another example
Covers both polygon form and surface form
(Uniformity of representation)
So, just what is a subdivision surface?
Basic Concept (Catmull-Clark Scheme):

- : vertices from mesh $M^0$
- , , : vertices to be generated for $M^1$

Around a vertex $v$ of degree 5
Basic Concept (Catmull-Clark Scheme):

Generating new face points
Face point: centroid of each face
Basic Concept (Catmull-Clark Scheme):

Generating new edge points

\[ e_i^1 = \frac{v^0 + e_i^0 + f_{i-1}^0 + f_i^0}{4} \]

\( v \): edge point
Basic Concept (Catmull-Clark Scheme):

Generating new vertex points

\[ v^1 = \frac{n - 2}{n} v^0 + \frac{1}{n^2} \sum e_i^0 + \frac{1}{n^2} \sum f_i^1 \]

\( v^1 \): vertex point
Basic Concept (Catmull-Clark Scheme):

Forming new edges

\[ v_0, f_1, e_2, f_3, e_4, v^1 \]

\[ e_5 \text{ : vertex point} \]
• Repeatedly refining the control meshes, one gets $M^0, M^1, M^2, M^3, \ldots \rightarrow$ limit surface (subdivision surface)
Modeling made much easier. Why?

- No restrictions on the topology of the control points
- Local refinement is possible
Example of control meshes of Catmull-Clark subdivision surfaces
Can model any kind of special features (by modifying the subdivision rules)
Most importantly, can represent any shape with just one surface

(one piece representation™)

One Piece  Solid Modeling  Multi-Piece
Is One Piece Representation™ Good?

- **Data Management:** Simpler
- **Rendering:** More efficient
- **Machining:** More precise
- **Animation:** Crack free
One Piece Representation is good **ONLY IF**
the representation is precise
Am I giving you a confusing picture?
What is subdivision based representation?

Subdivision Surfaces
What is missing in the picture?

1. No parameterization
2. No error control
3. No adaptive tessellation
• **Without parameterization**
  Difficult to perform picking, rendering, texture mapping

• **Without error control**
  No CAD/CAM applications

• **Without adaptive tessellation**
  Too expensive to use
A major **breakthrough** happened in 1998

- Jos Stam
- Parameterization of Catmull-Clark Subdivision Surfaces
- 1998
Work on Subdivision Surface Parameterization

The Extended Subdivision Diagram
Applications of the new parameterization technique

- Surface Evaluation
- Texture Mapping
- Boolean Operations
- Surface Trimming
- Adaptive Tessellation
- Animation
Surface Evaluation

Fast, Exact Rendering
Texture Mapping\textsuperscript{1}

\textsuperscript{1} Lai and Cheng, 2005
Texture Mapping

1: Lai and Cheng, 2005
Texture Mapping

1: Lai and Cheng, 2005
Boolean Operations$^2$

2: Lai and Cheng, 2005
Real time Boolean Operations
Surface Trimming\textsuperscript{2}

2: Lai and Cheng, 2005
Adaptive Tessellation³

3: Lai and Cheng, 2005
Special Features: Corners, Creases, Darts, Edges
Animation
What is error control?
Error Control: Given $\varepsilon > 0$, when would $\|M^n - S\| < \varepsilon$?
A solution is finally available...

- F. Cheng, G. Chen, J. Yong
- Subdivision Depth Computation for Catmull-Clark Subdivision Surfaces
- 2005
This work is also important for adaptive subdivision\textsuperscript{5}.

\textsuperscript{5}: J. Yong, F. Cheng, (2004)
**Basic Idea**: Use *unbalanced subdivision*\(^6\) to provide smooth transition between areas with different densities.

Example of adaptive subdivision
• Subdivision surfaces have already been used in

  – Pixar’s Renderman
  – Alias|Wavefront’s Maya
  – Nichimen’s Mirai
  – Micropace’ Lightwave 3D
My question:

“Is subdivision the representation scheme for future visualization & animation applications?”
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The End