Is Subdivision the Representation Scheme for Future Visualization & Animation Applications

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- **Objective**:

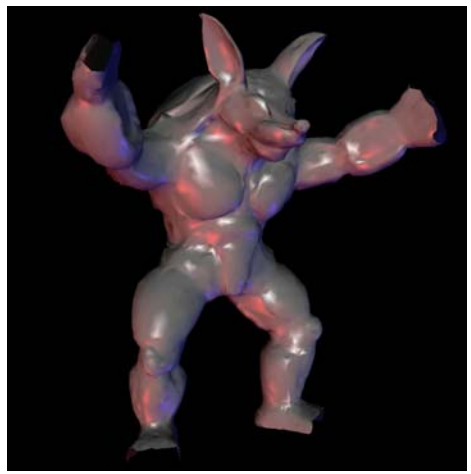
  Presenting a subdivision based representation scheme

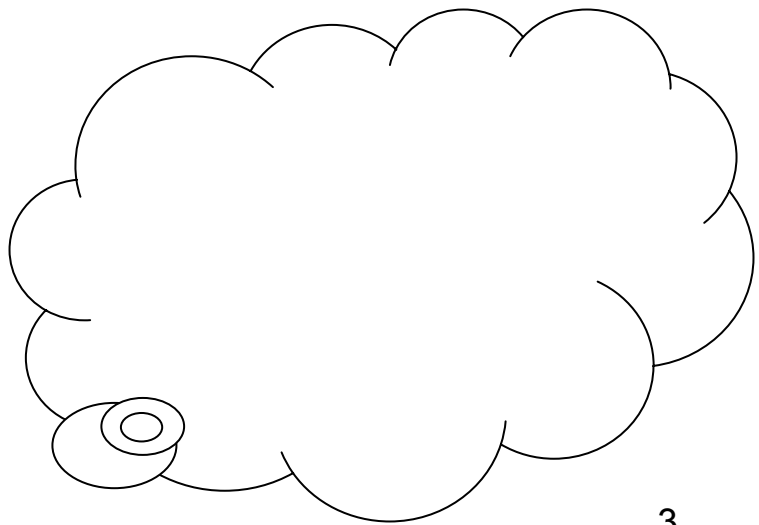
- **So, you can judge:**

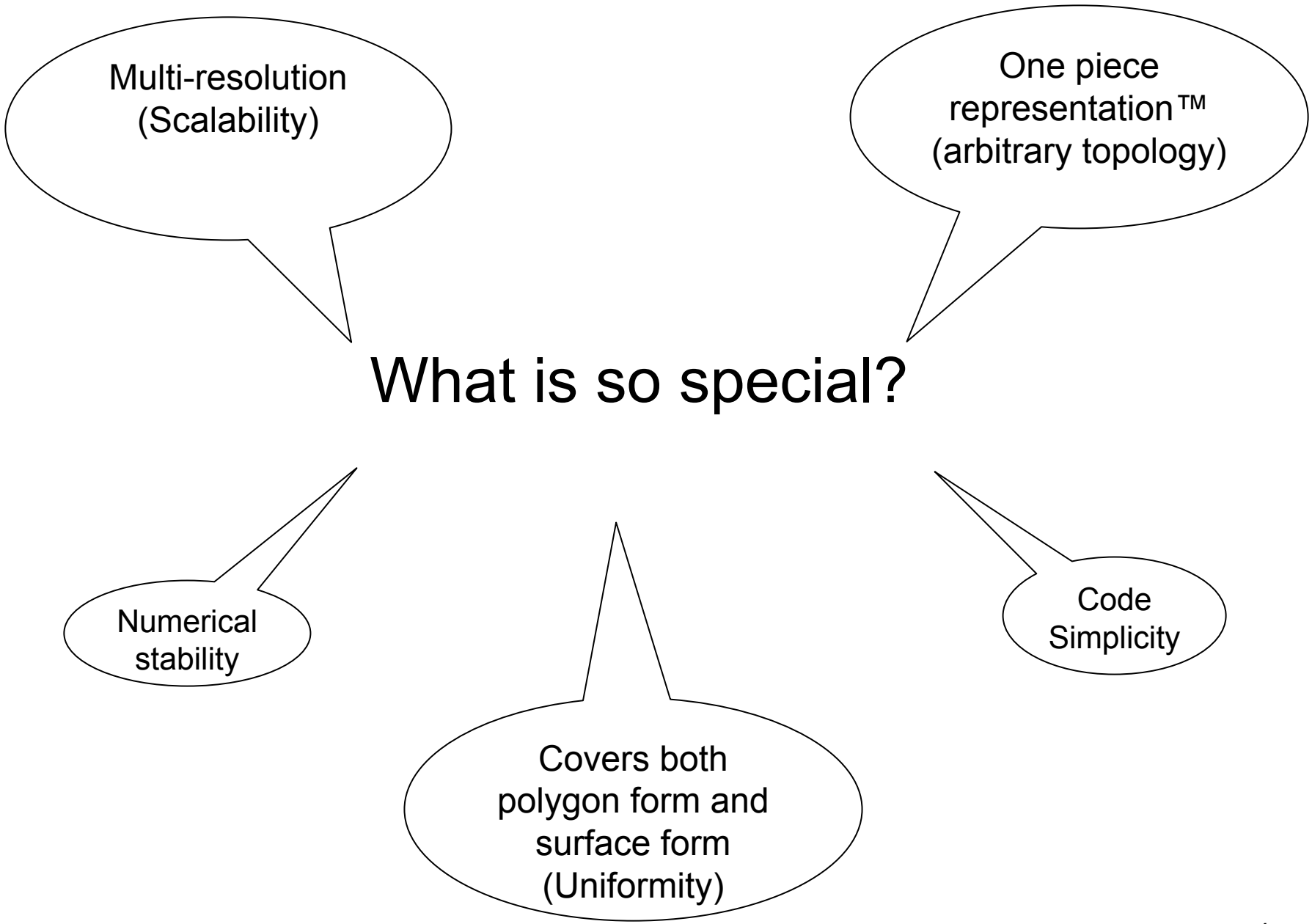
  If this is the ultimate representation scheme we need for all graphics applications, including visualization and animation.

What is subdivision based representation?

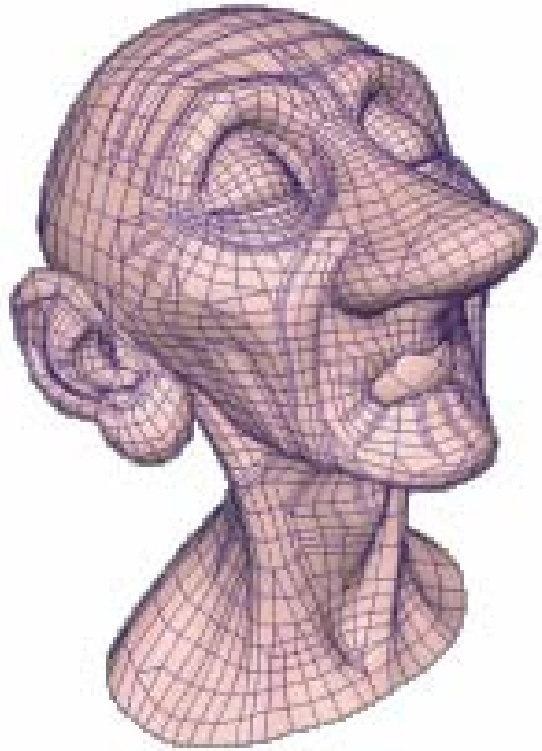
Subdivision Surfaces

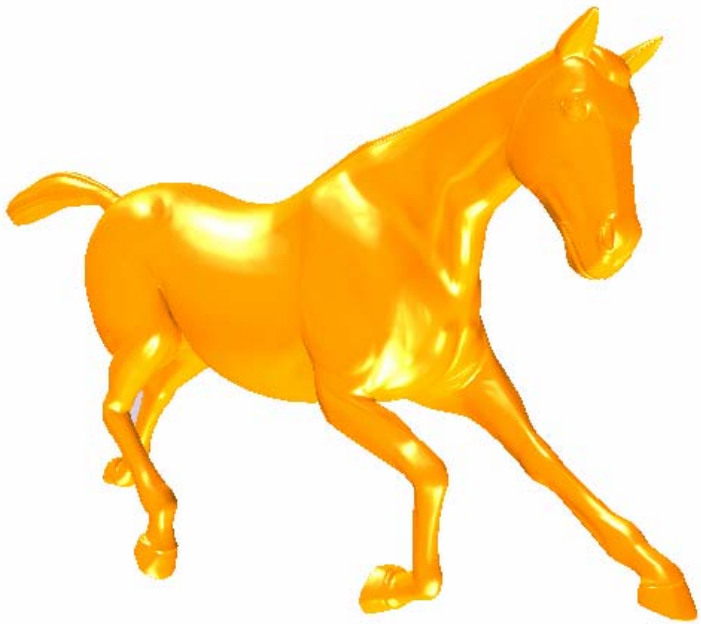




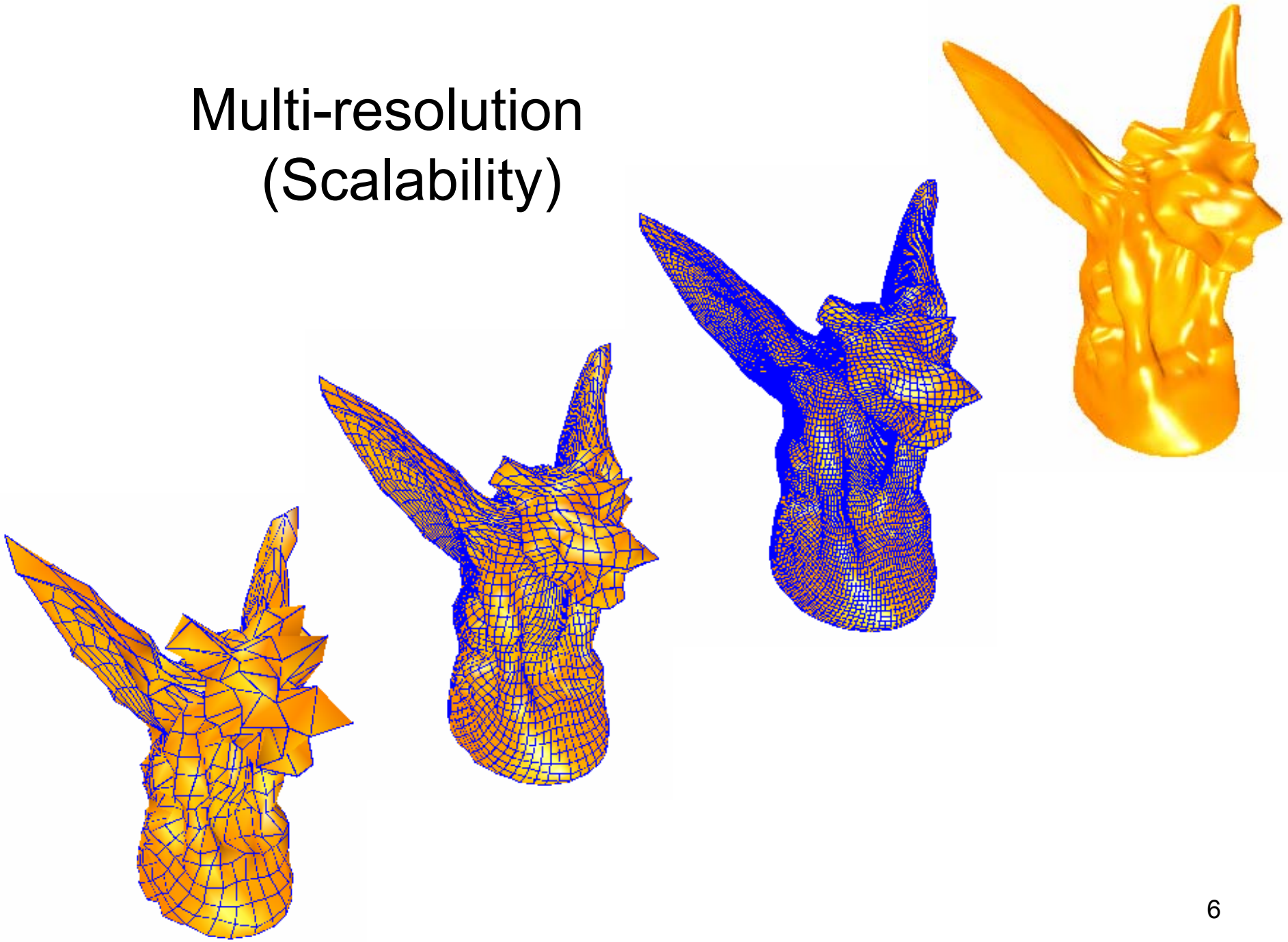

Multi-resolution
(Scalability)
One piece
representation™
(arbitrary topology)
What is so special?
Numerical
stability
Covers both
polygon form and
surface form
(Uniformity)
Code
Simplicity

One piece representation™

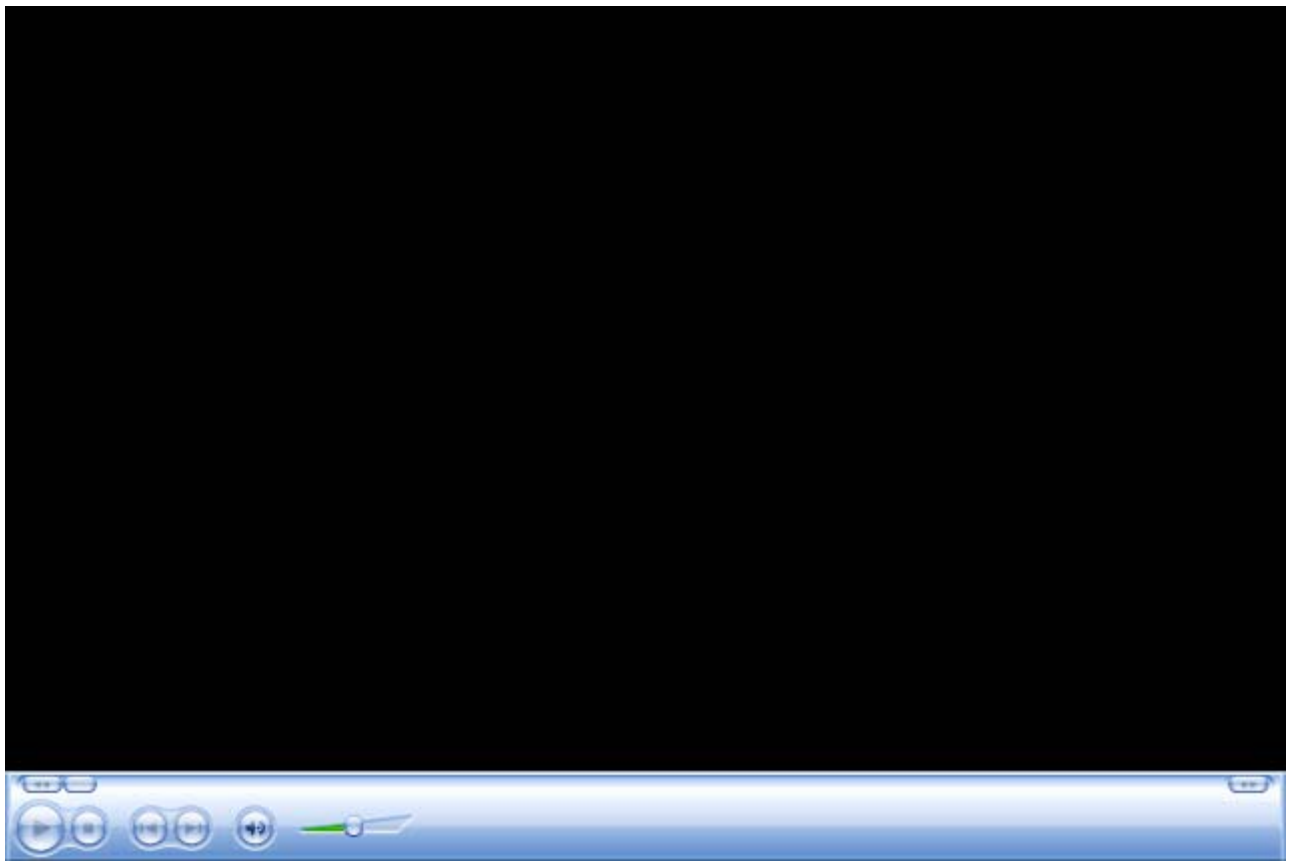


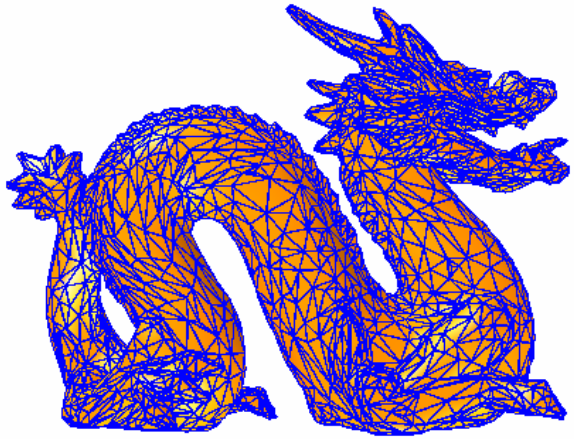


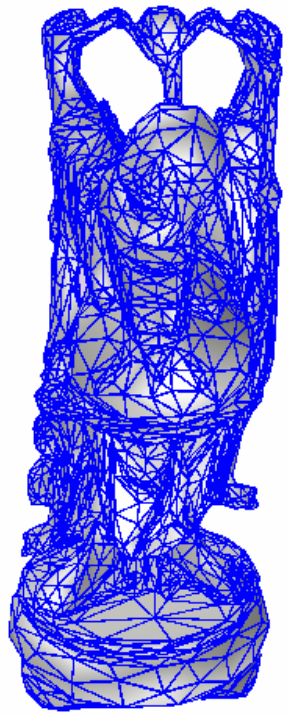
Multi-resolution (Scalability)



another example

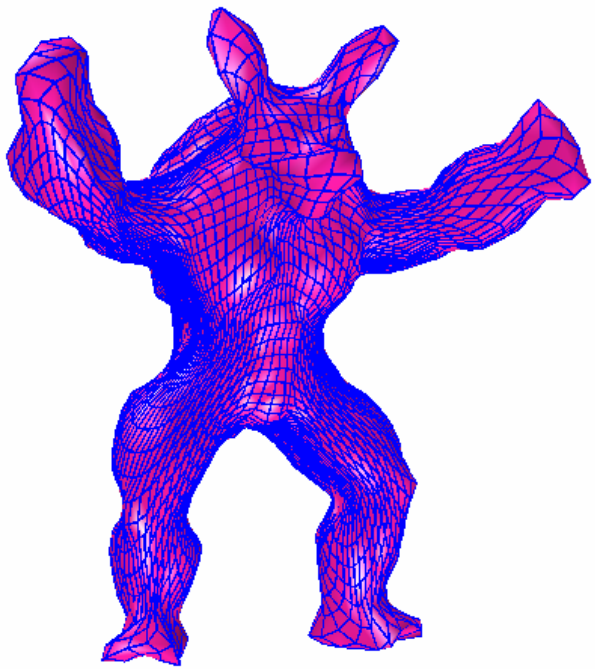


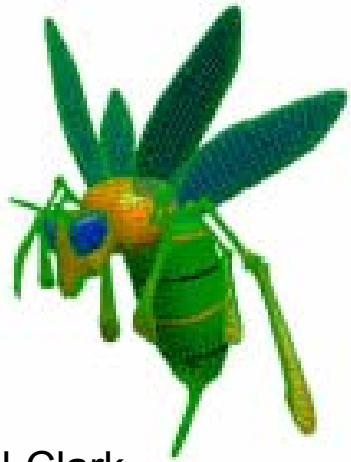




Covers both polygon form and surface form

(Uniformity of representation)





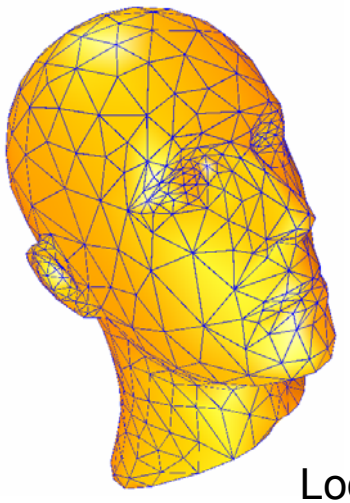
Catmull-Clark

Quadrilateral

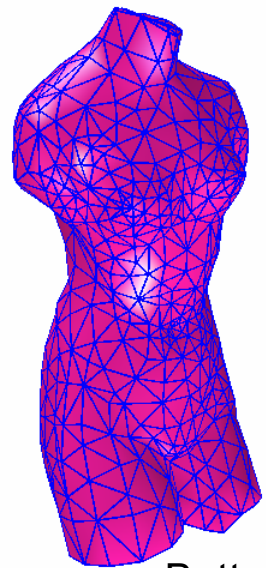
Doo-Sabin

So, just what is a subdivision surface?

Triangular



Loop

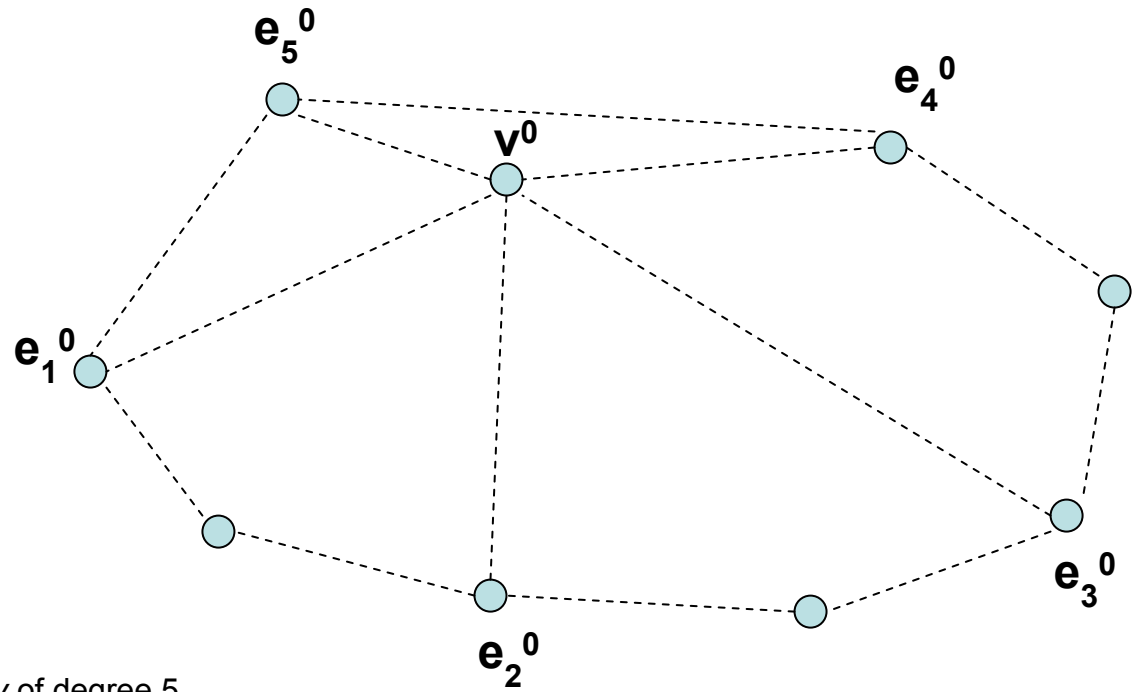


Butterfly

Basic Concept (Catmull-Clark Scheme):

: vertices from mesh M^0

, , : vertices to be generated for M^1

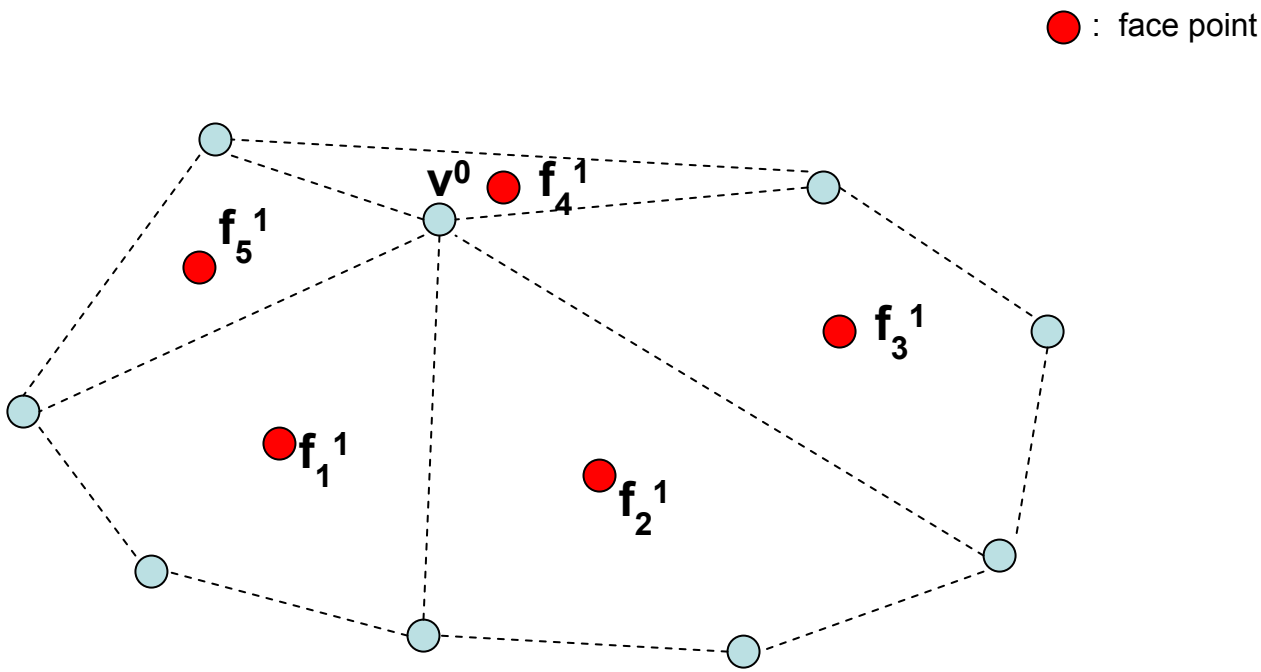


Around a vertex *v* of degree 5

Basic Concept (Catmull-Clark Scheme):

Generating new face points

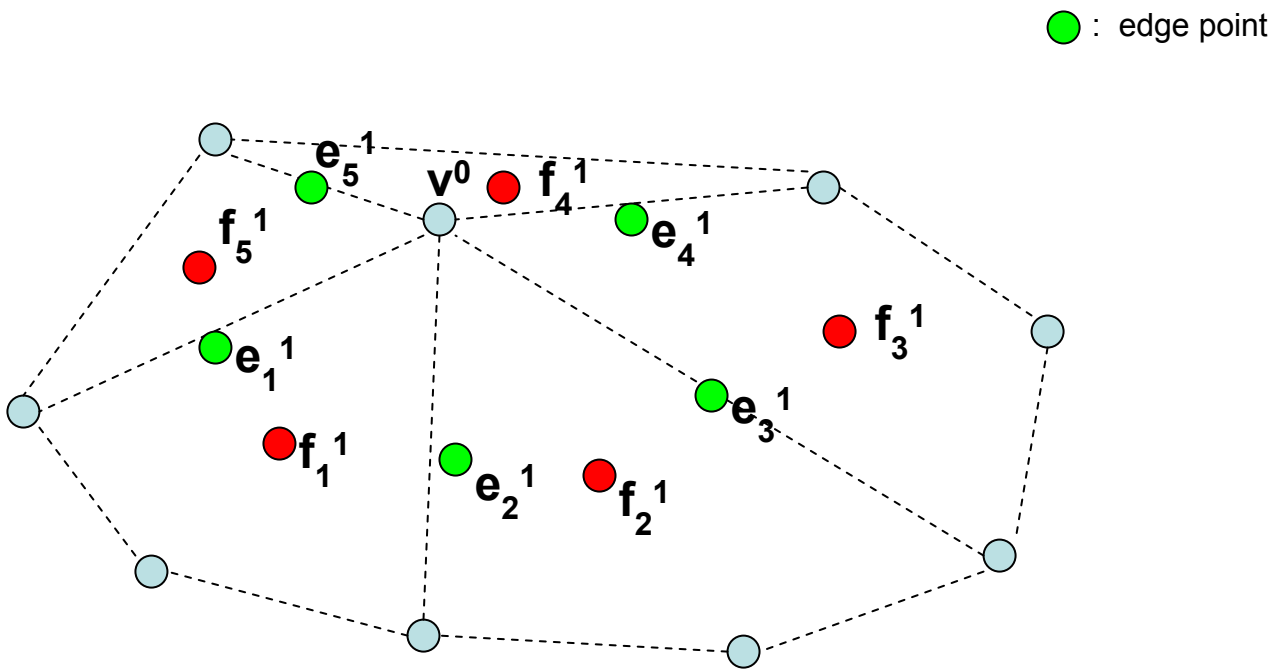
Face point: centroid of each face



Basic Concept (Catmull-Clark Scheme):

Generating new edge points

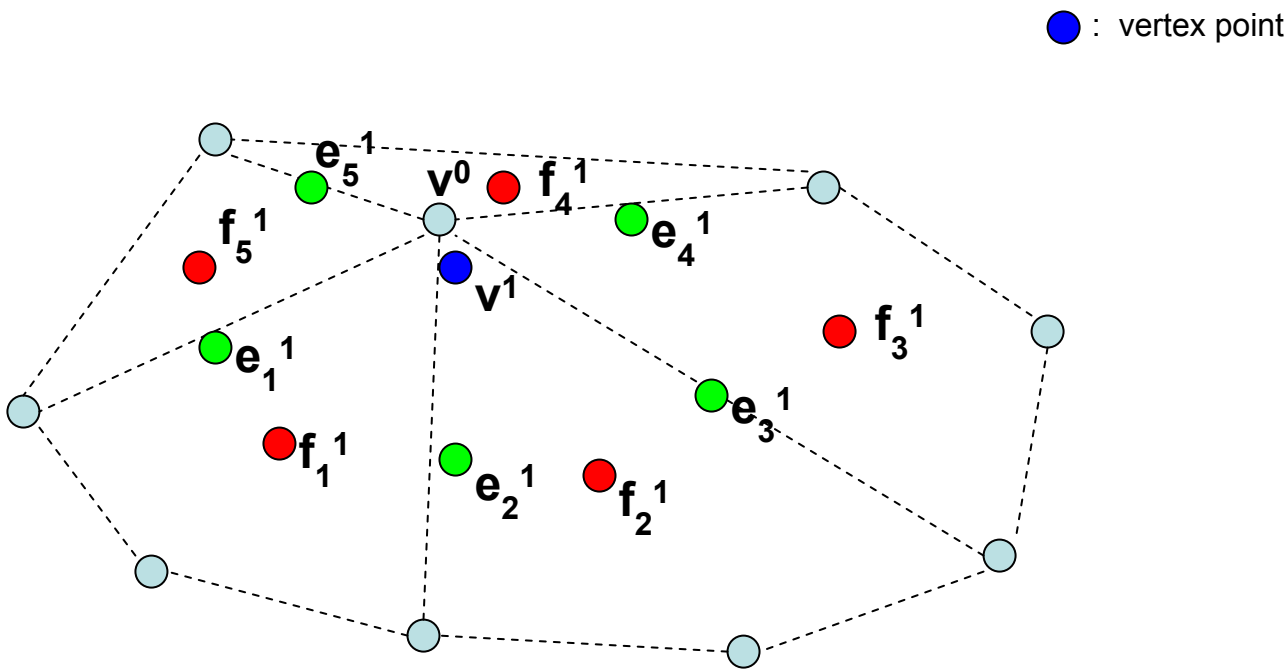
$$e_i^1 = \frac{v^0 + e_i^0 + f_{i-1}^0 + f_i^0}{4}$$



Basic Concept (Catmull-Clark Scheme):

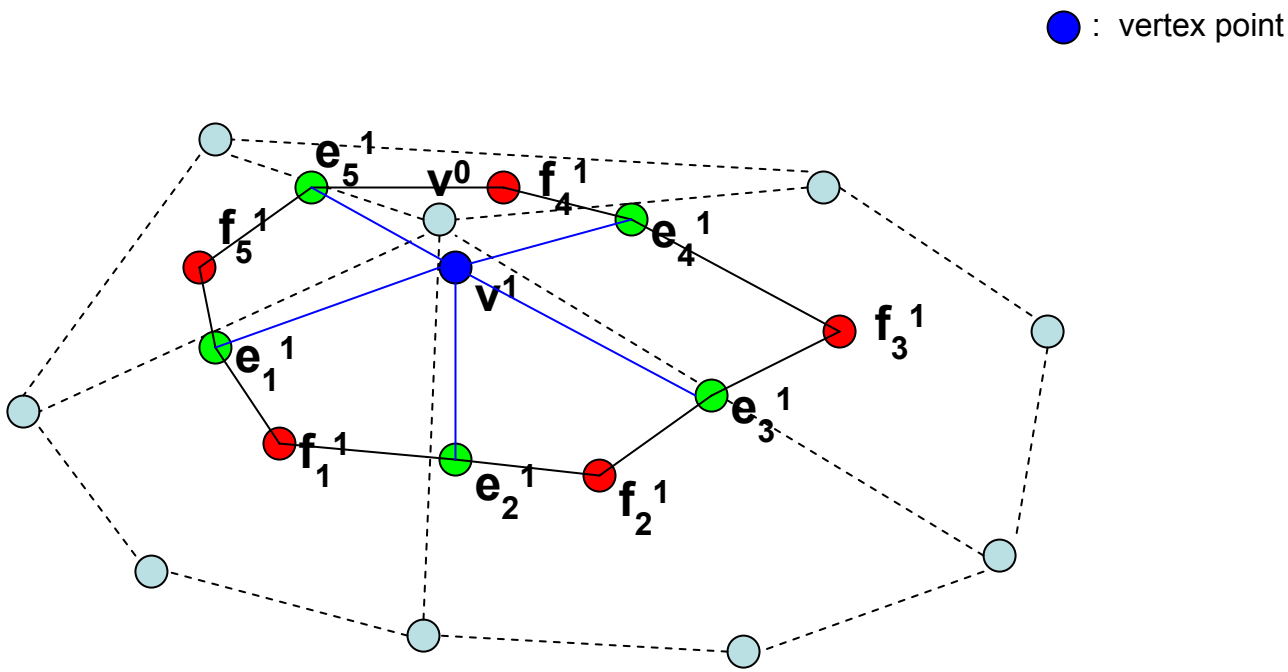
Generating new vertex points

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

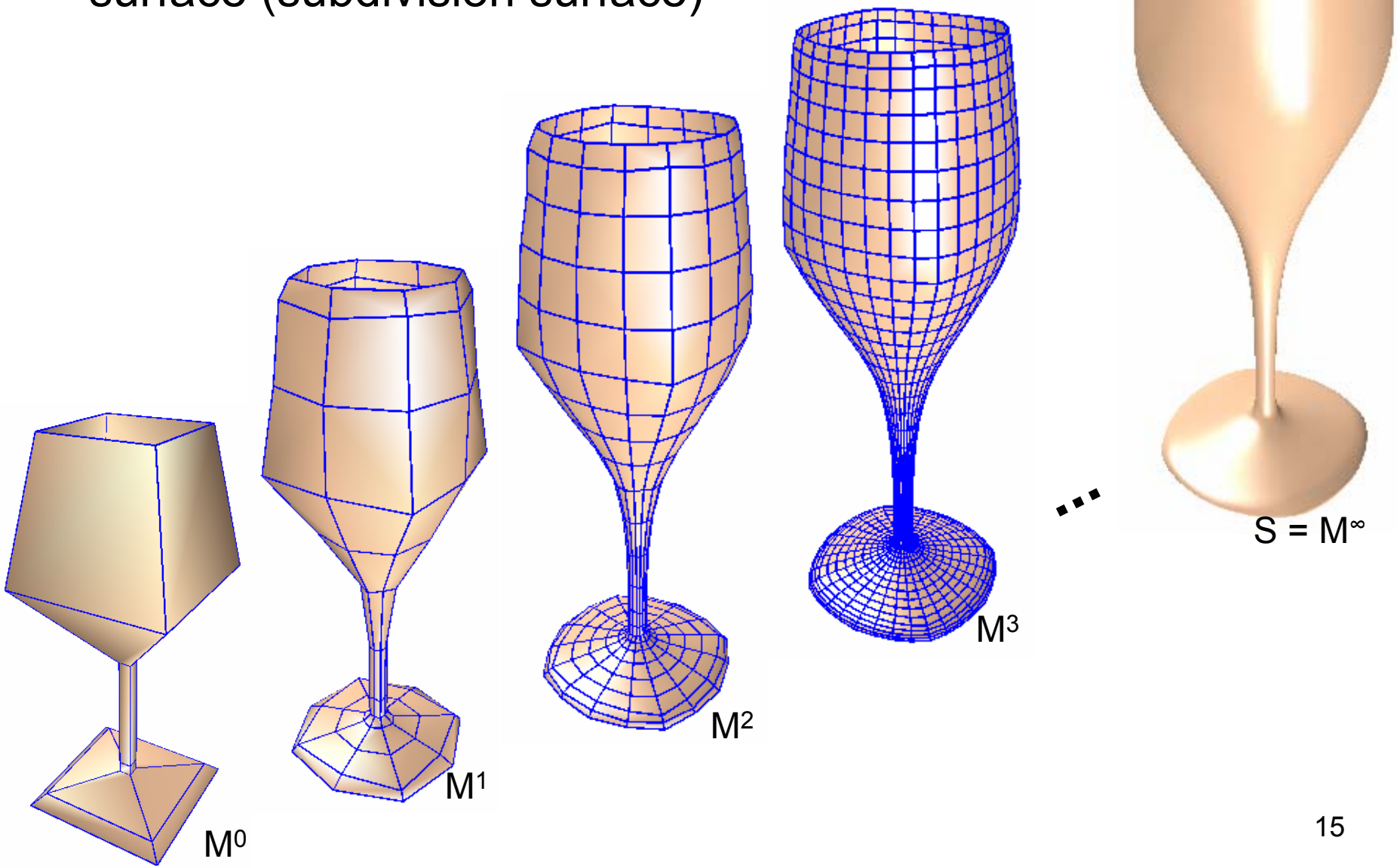


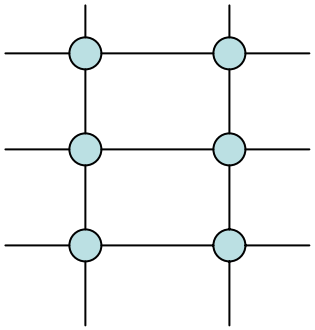
Basic Concept (Catmull-Clark Scheme):

Forming new edges

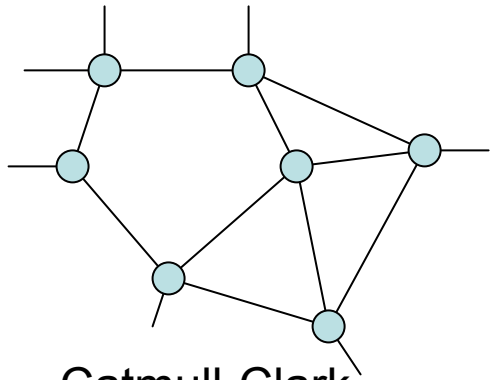


- Repeatedly refining the control meshes, one gets $M^0, M^1, M^2, M^3, \cdots \longrightarrow$ limit surface (subdivision surface)





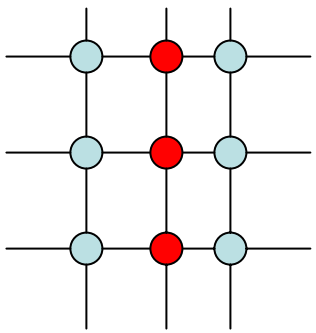
NURBS



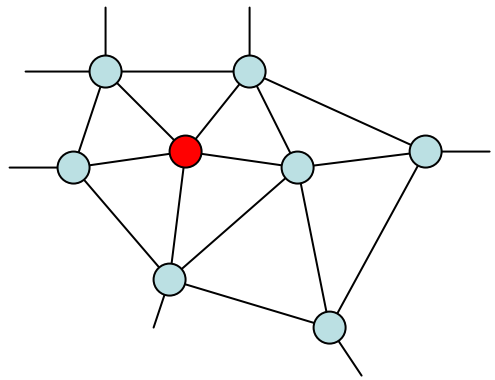
Catmull-Clark

Modeling made much easier. Why?

- No restrictions on the topology of the control points
- Local refinement is possible

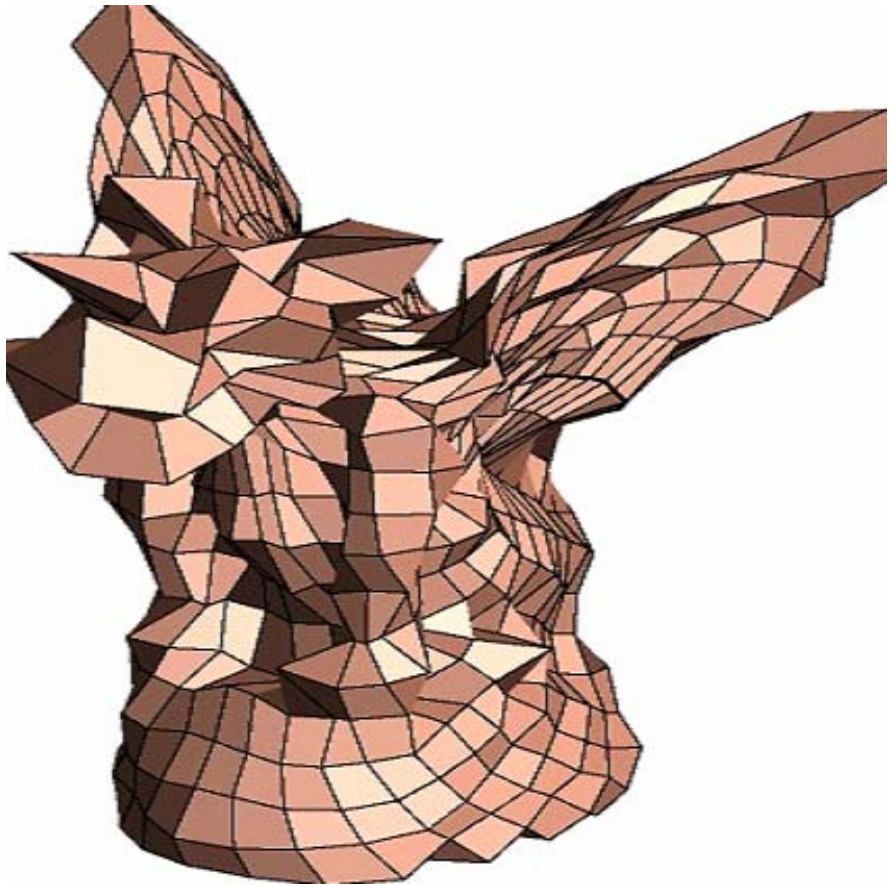


NURBS

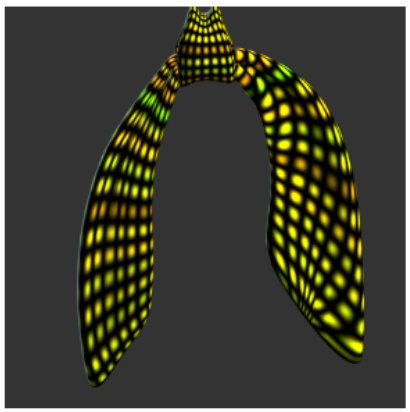


Catmull-Clark

Example of control meshes of Catmull-Clark subdivision surfaces

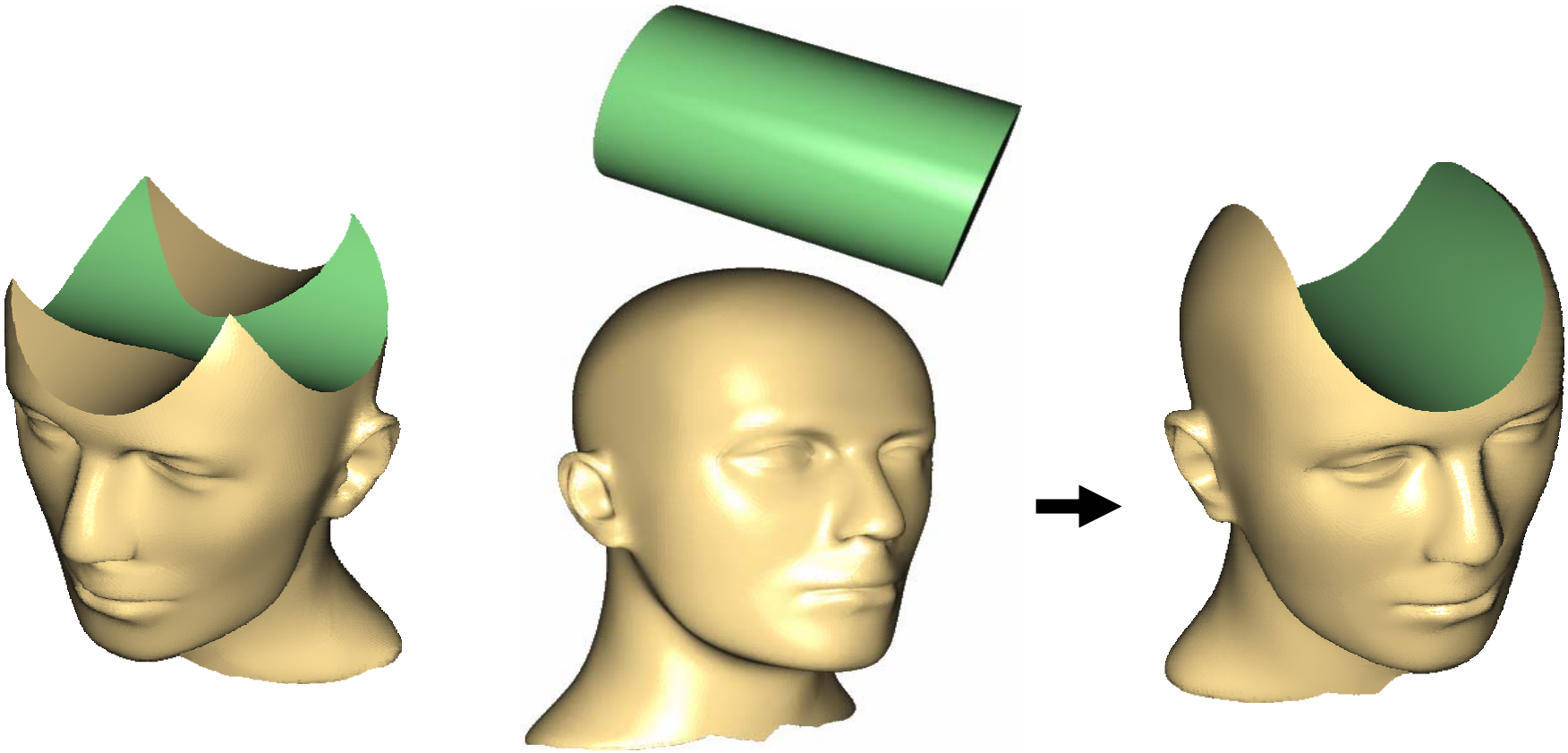


Can model any kind of special features
(by modifying the subdivision rules)



Most importantly, can represent any shape with just one surface

(one piece representation ™)



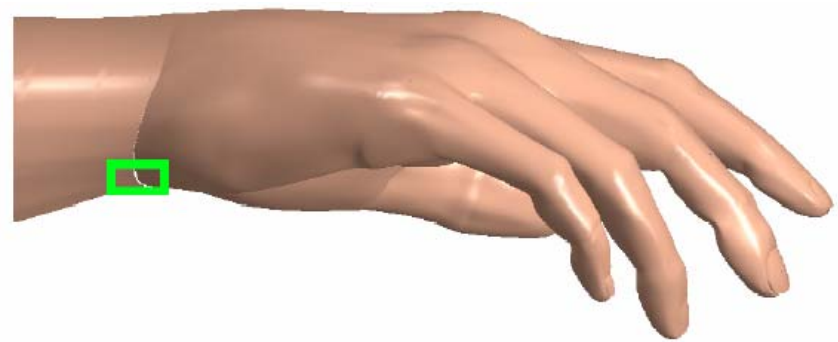
One Piece

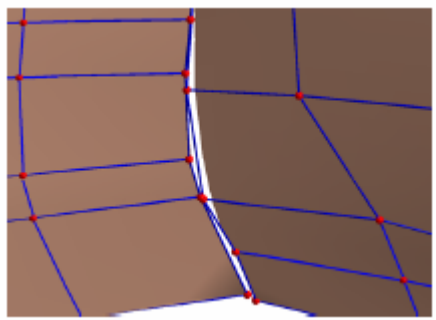
Solid Modeling

Multi-Piece

Is One Piece Representation™ Good?

Data Management:	Simpler
Rendering:	More efficient
Machining:	More precise
Animation:	Crack free





One Piece Representation is good

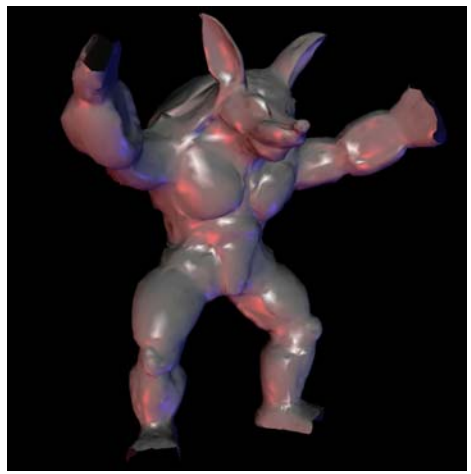
ONLY IF

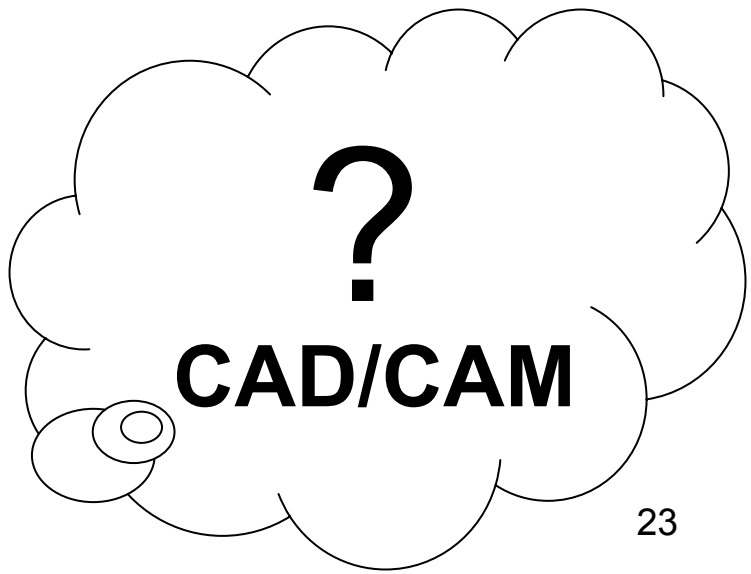
the representation is precise

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

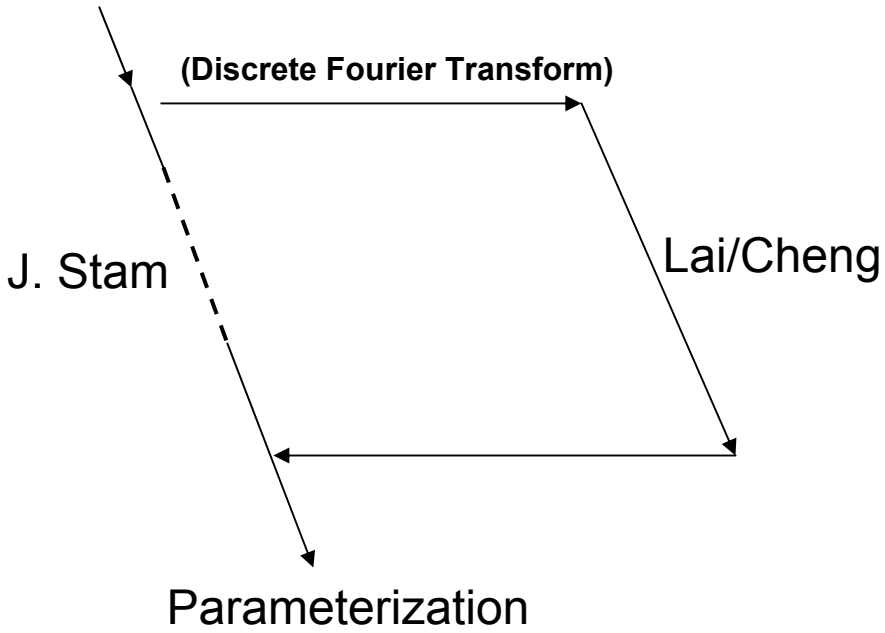
- Without parameterization
  - Difficult to perform picking, rendering, texture mapping
- Without error control
  - No CAD/CAM applications
- Without adaptive tessellation
  - Too expensive to use

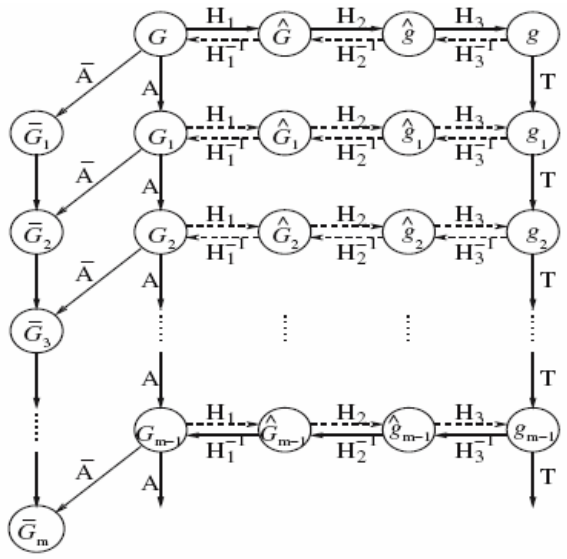
A major breakthrough happened in 1998

- Jos Stam
- Parameterization of Catmull-Clark Subdivision Surfaces
- 1998

Work on Subdivision Surface Parameterization

1. J. Stam (1998)
2. D. Zorin, D. Kristjansson (2002)
3. S. Lai, F. Cheng (2005)



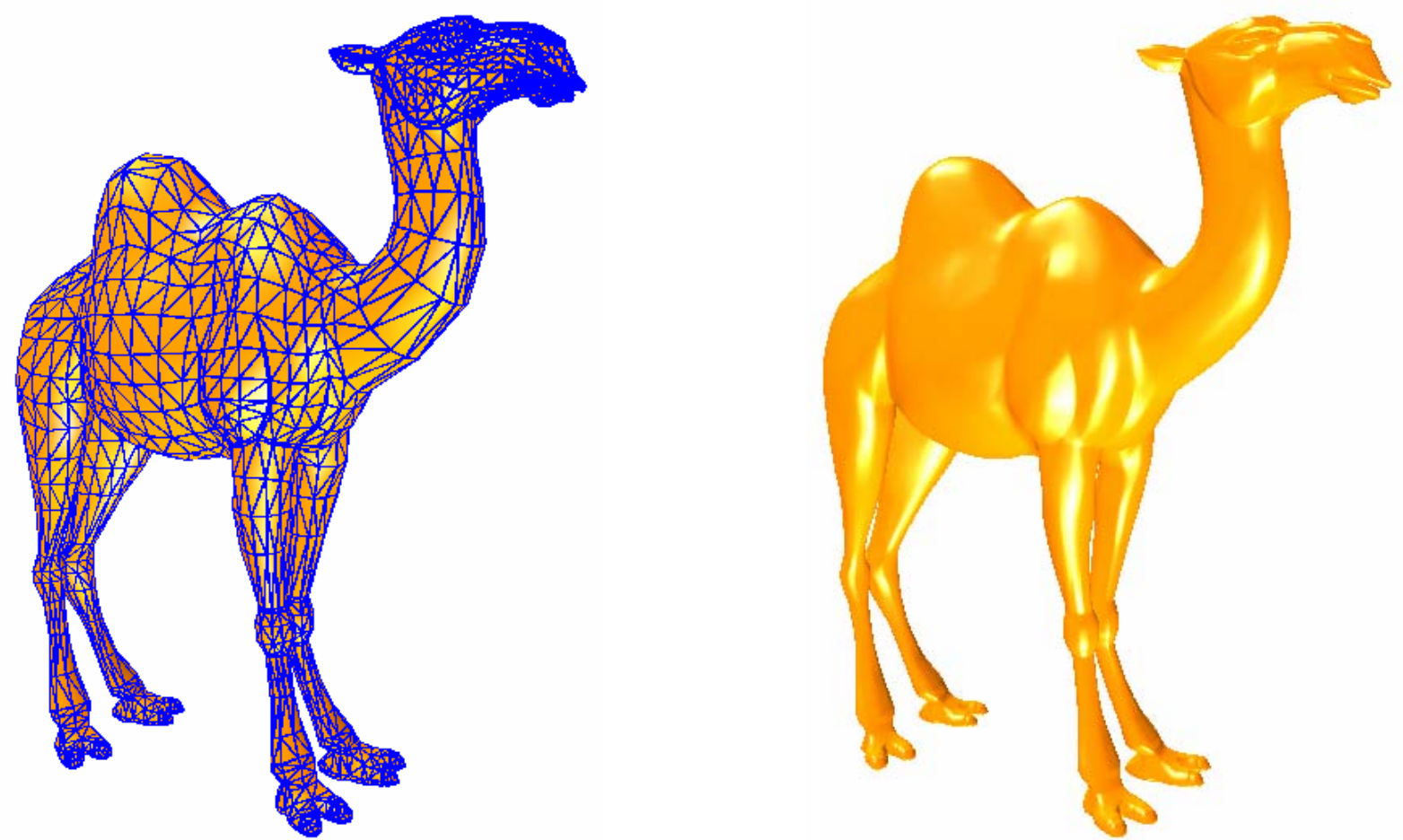


The Extended Subdivision Diagram

Applications of the new parameterization technique

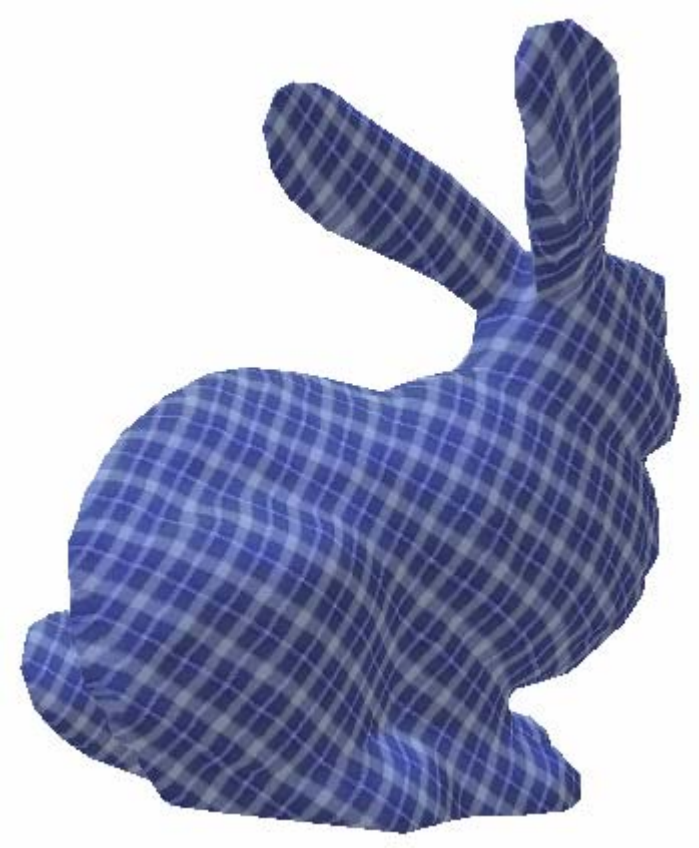
- Surface Evaluation
- Texture Mapping
- Boolean Operations
- Surface Trimming
- Adaptive Tessellation
- Animation

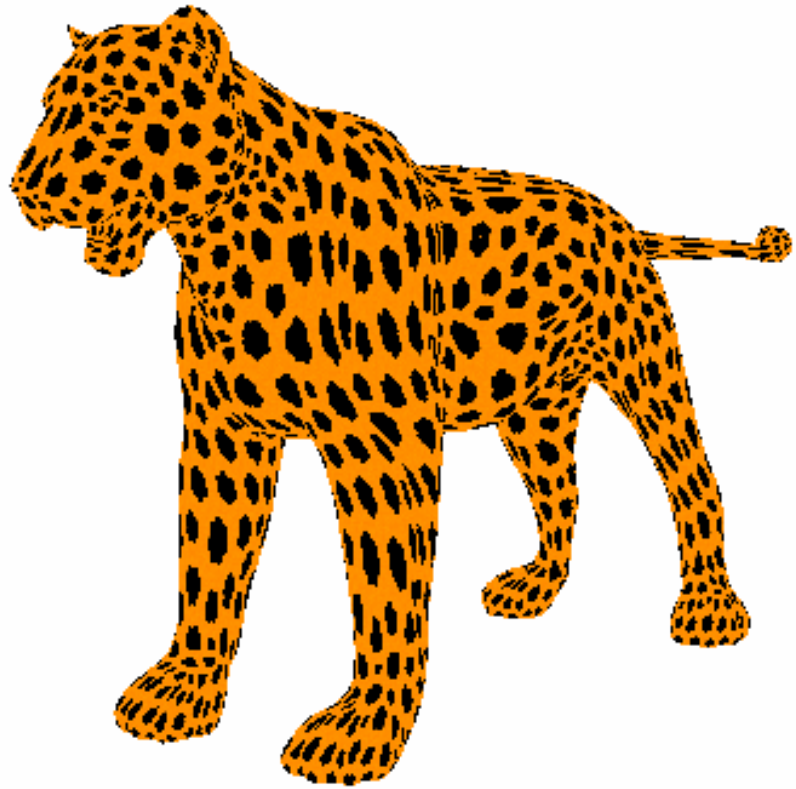
Surface Evaluation



Fast, Exact Rendering

Texture Mapping[1]



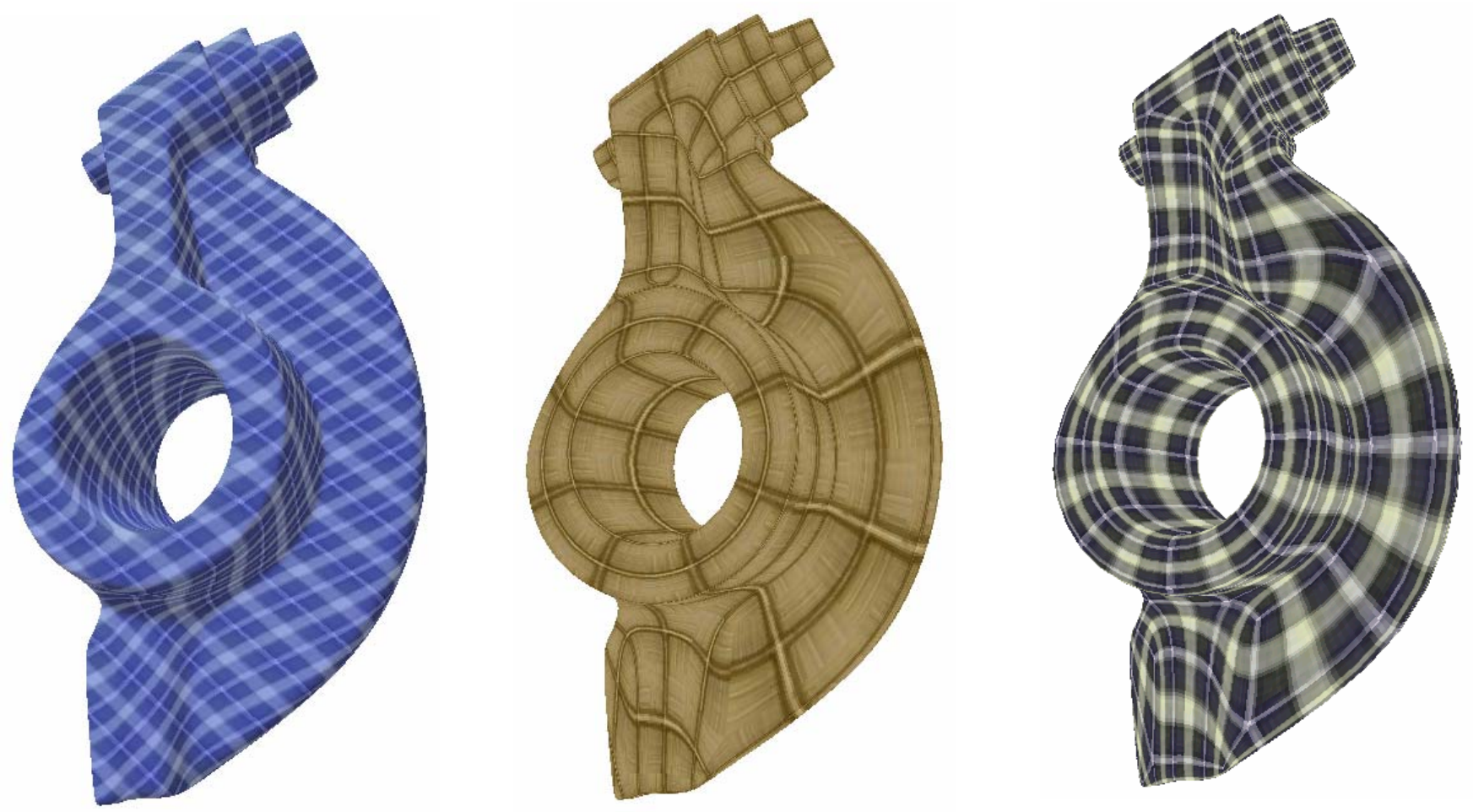


1: Lai and Cheng, 2005

Texture Mapping[1]

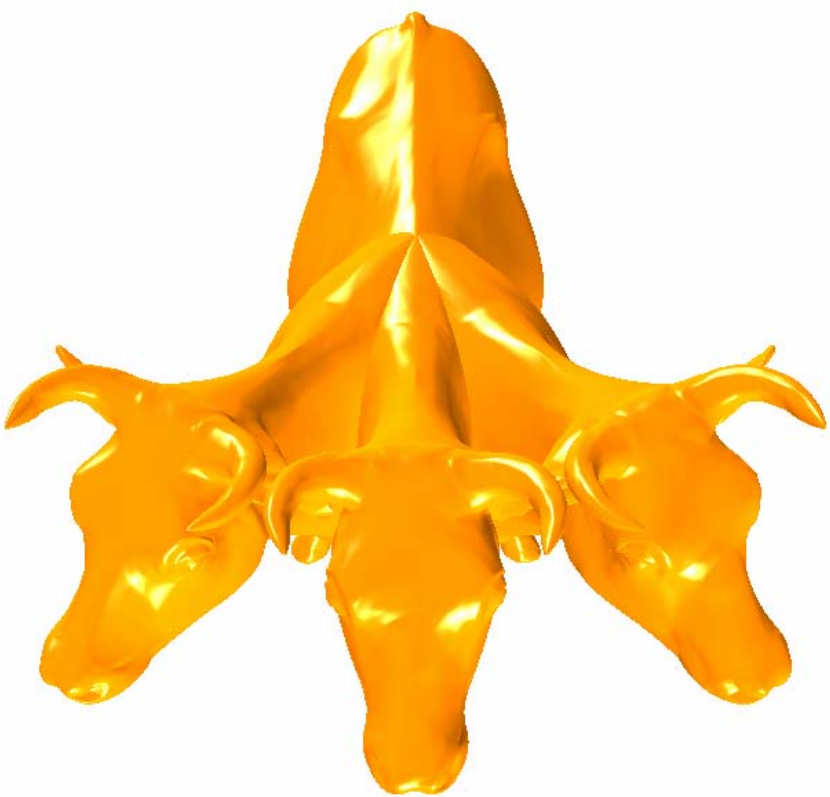
1: Lai and Cheng, 2005

Texture Mapping[1]



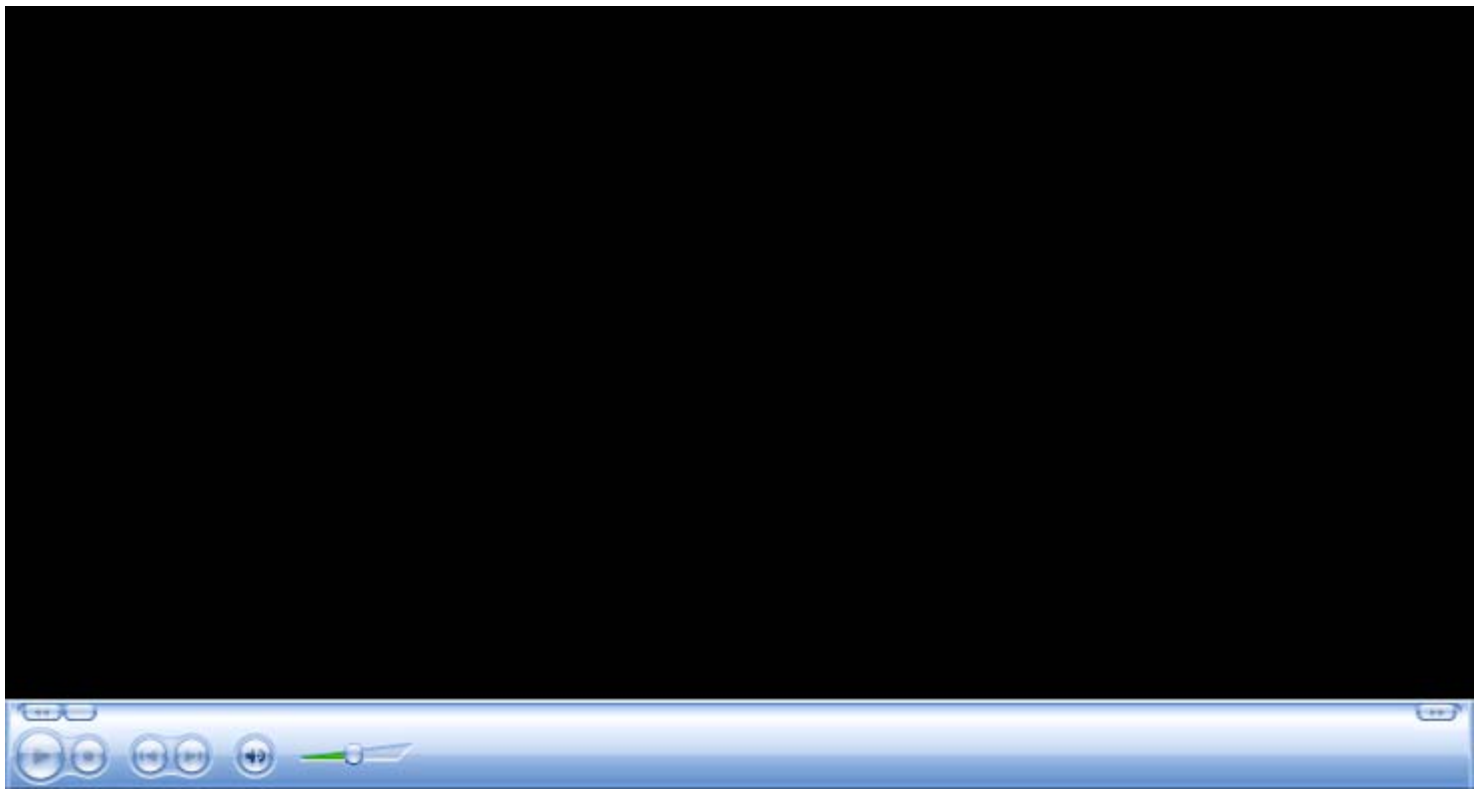
1: Lai and Cheng, 2005

Boolean Operations[2]

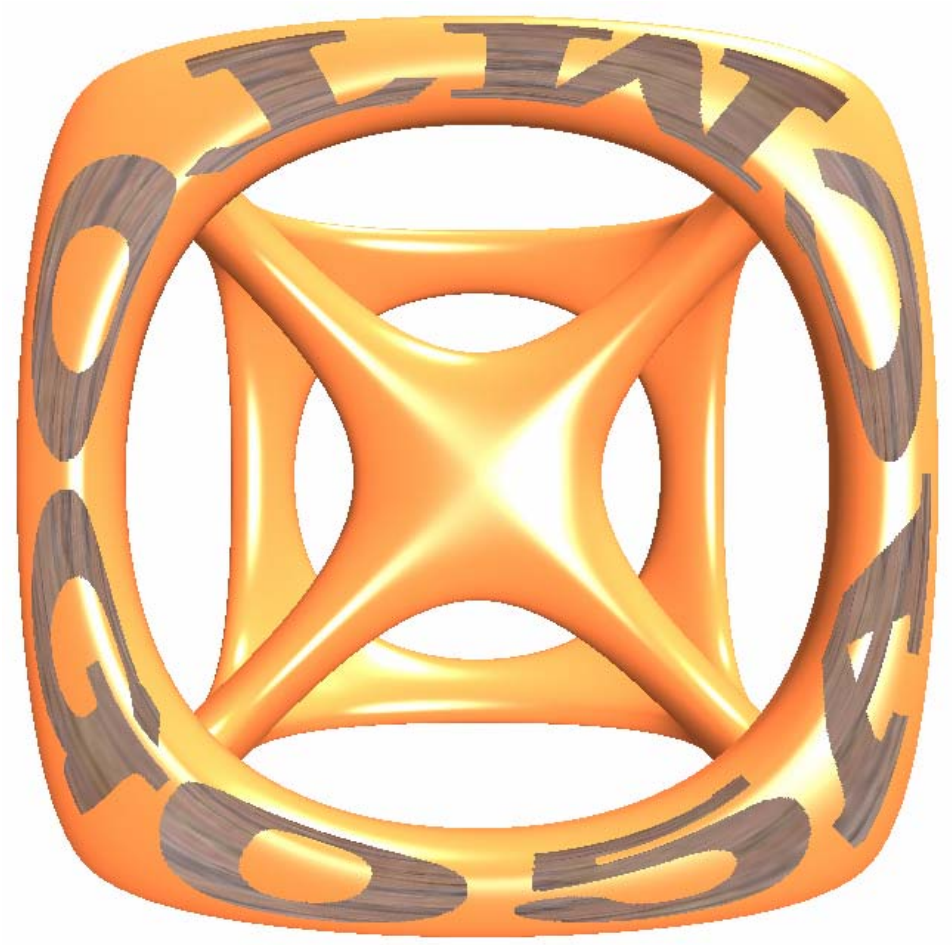


2: Lai and Cheng, 2005

Real time Boolean Operations

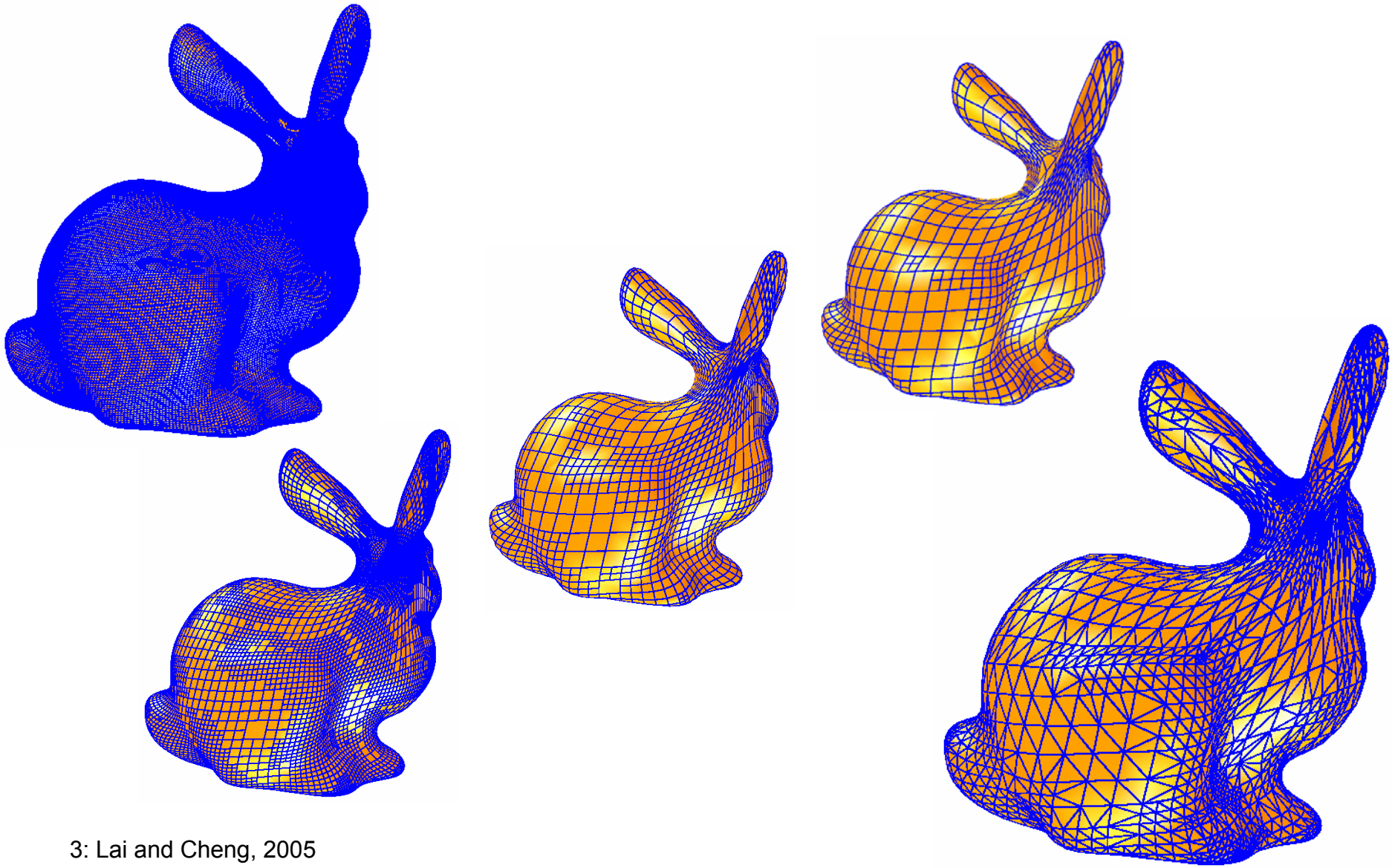


Surface Trimming[2]



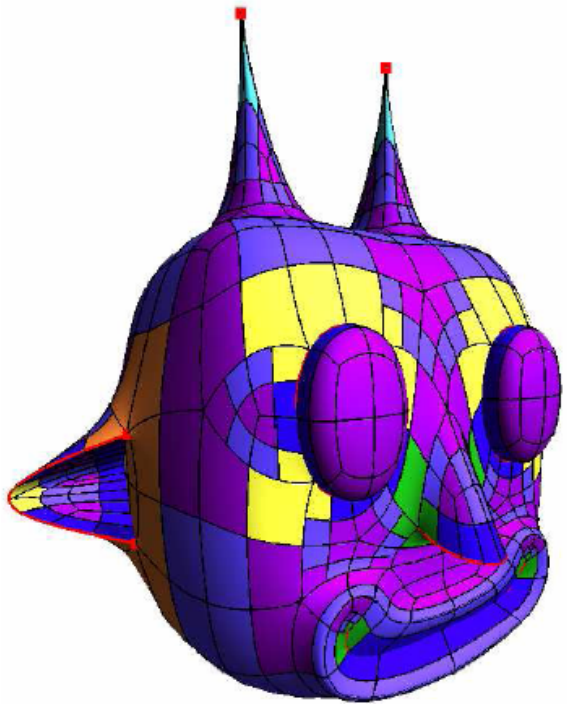
2: Lai and Cheng, 2005

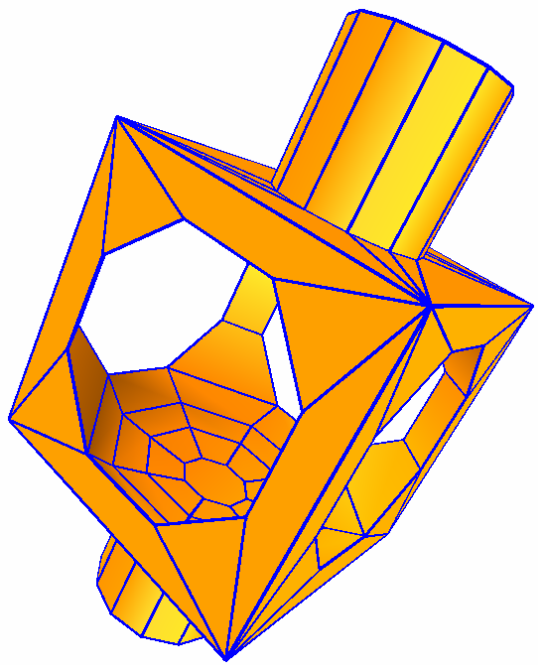
Adaptive Tessellation[3]



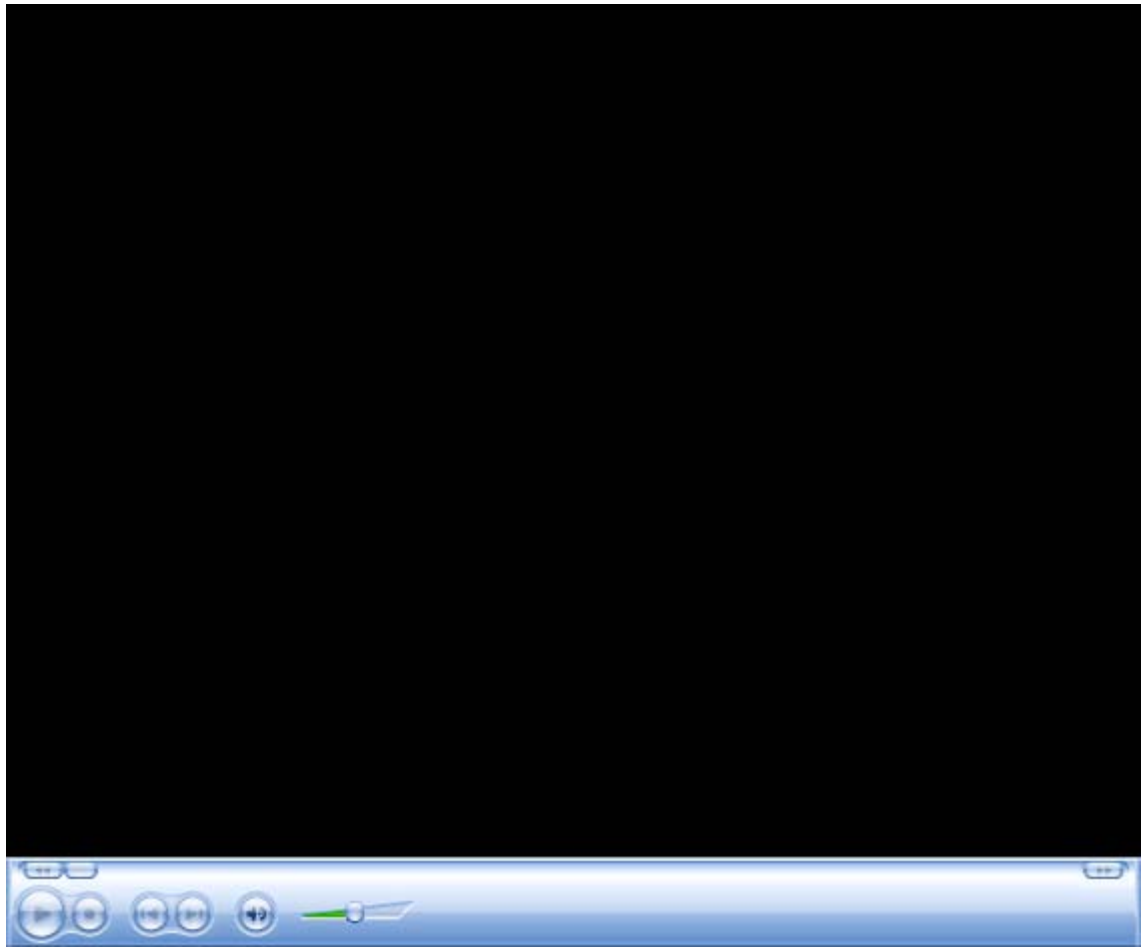
3: Lai and Cheng, 2005

Special Features: Corners, Creases, Darts, Edges



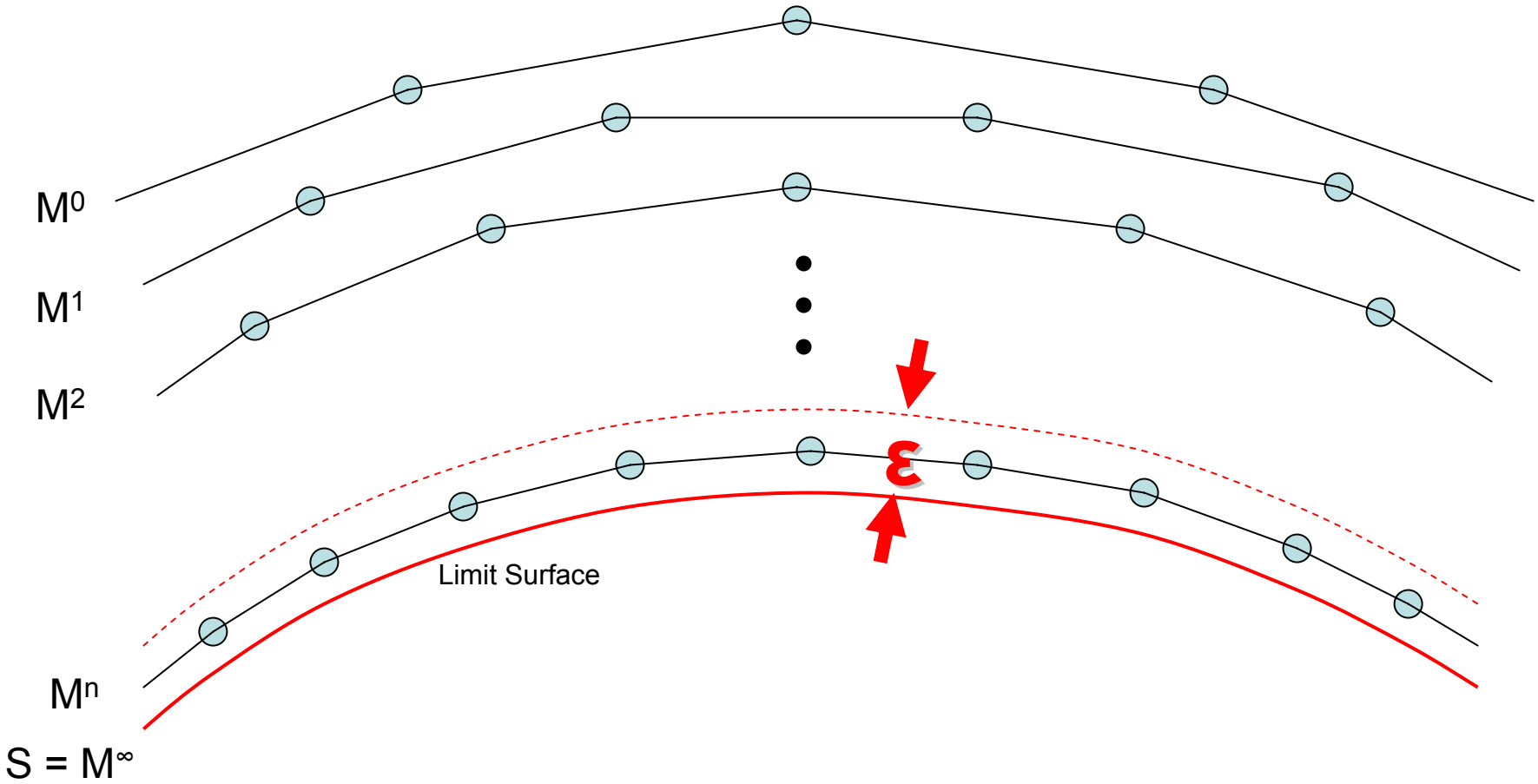


Animation



What is error control?

Error Control: Given $\varepsilon > 0$, when would $\|M^n - S\| < \varepsilon$?

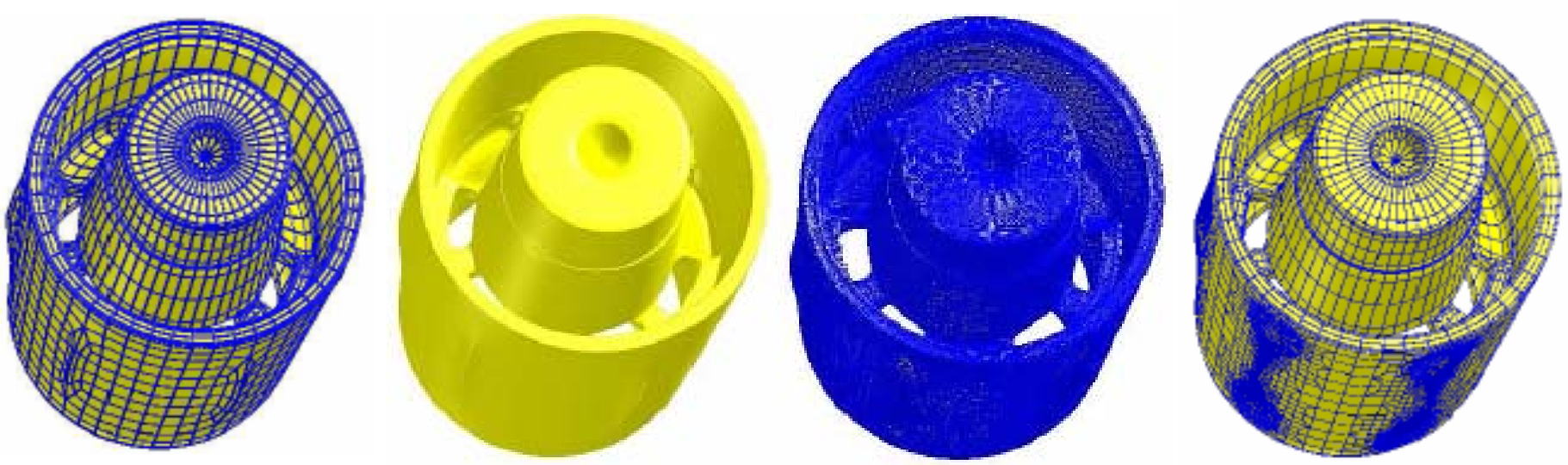


Cross-Sectional View

A solution is finally available…

- F. Cheng, G. Chen, J. Yong
- Subdivision Depth Computation for Catmull-Clark Subdivision Surfaces
- 2005

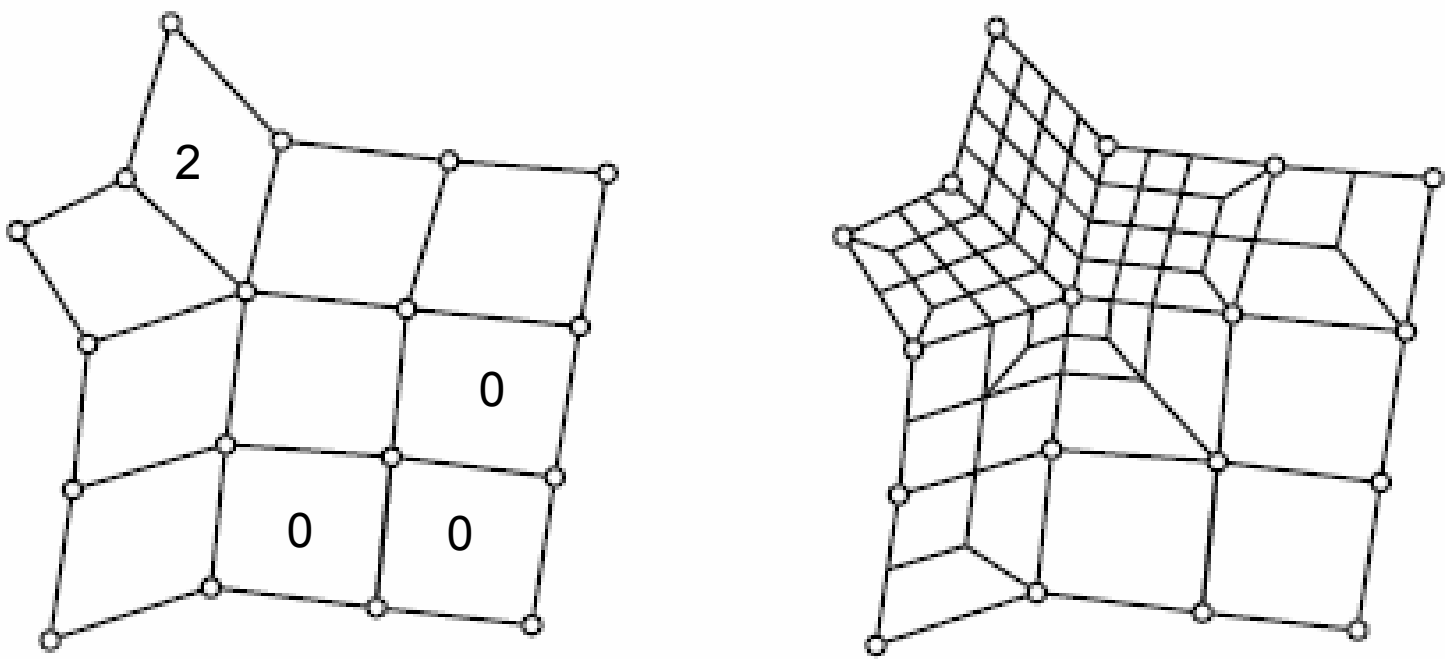
This work is also important for adaptive subdivision[5].



Control Mesh | Limit Surface | Uniform Subdivision | Adaptive Subdivision

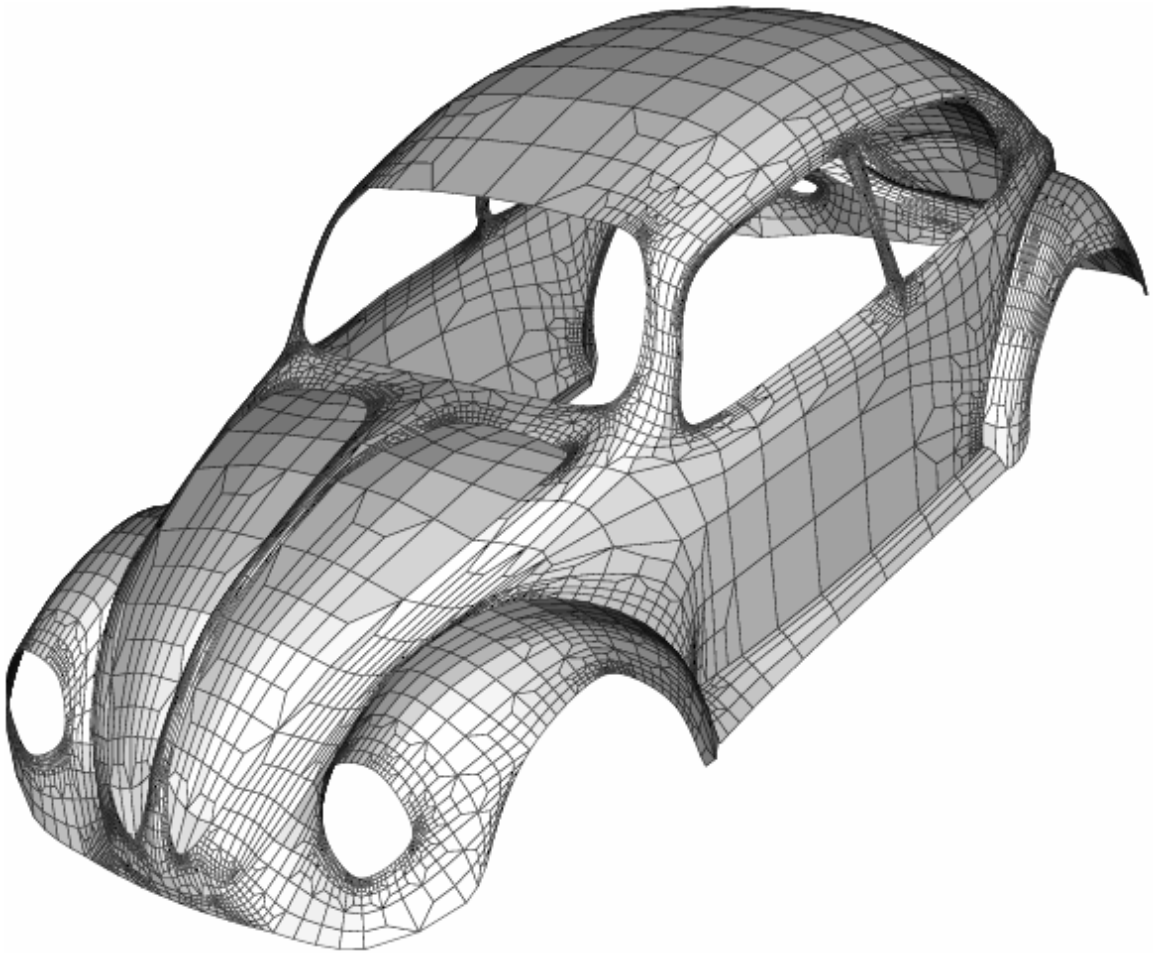
5: J. Yong, F. Cheng, (2004)

Basic Idea: Use unbalanced subdivision[6] to provide smooth transition between areas with different densities



6: F. Cheng, J. Jaromczyk et al (1989)

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?”

Acknowledgement:

- Research work presented here is supported by NSF (DMS-0310645, DMI-0422126).
- Some datasets are taken from P. Schroeder, D. Zorin, L. Kobbelt, H. Hoppe.
- S. Lai helped prepare the PPT file.

The End