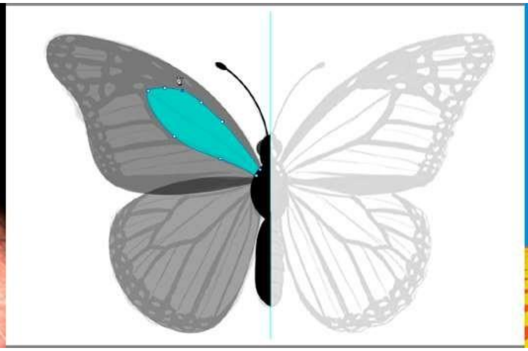
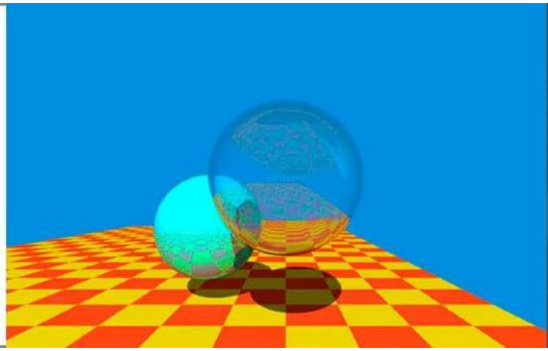
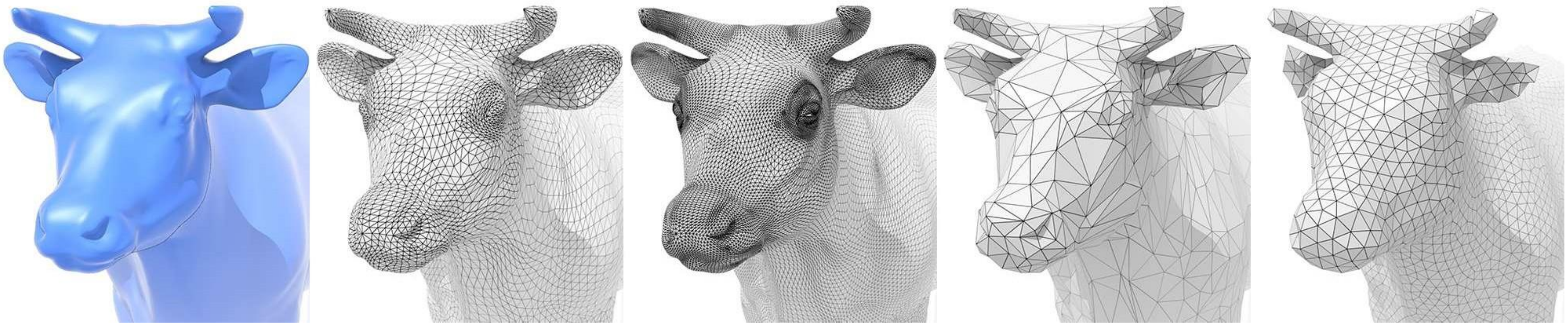
Computer Graphics

# Geometry 3 (Mesh Processing)

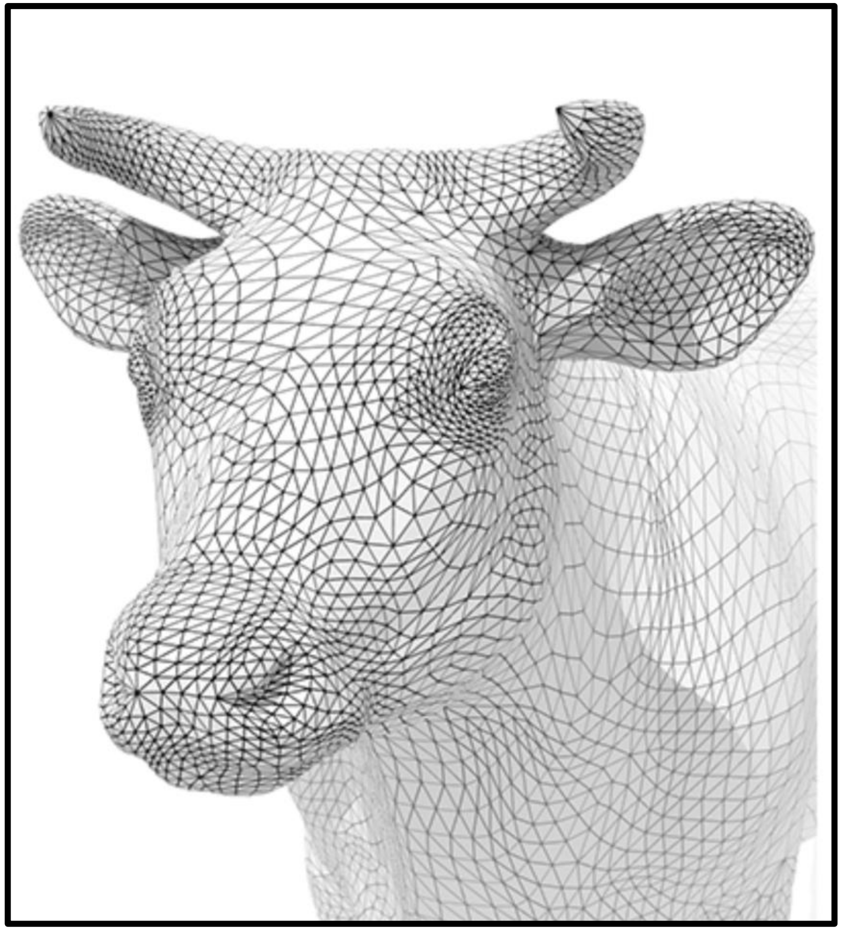




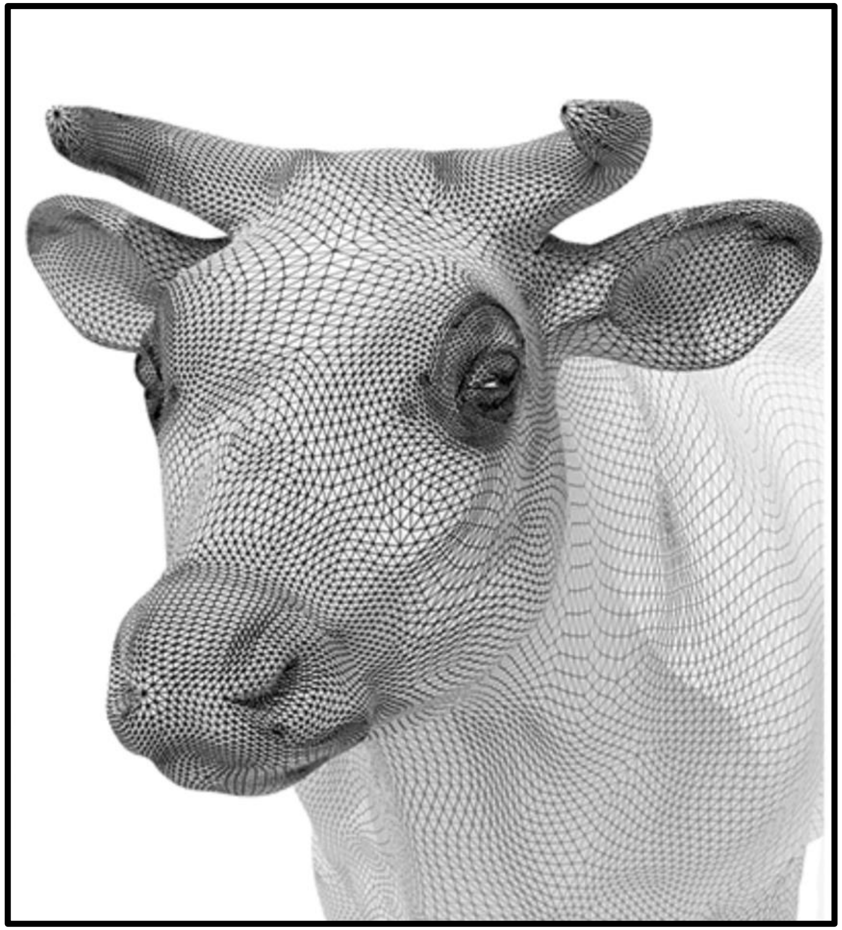

# Mesh Operations: Geometry Processing

- Mesh subdivision (网格细分)
- Mesh simplification （网格简化）
- Mesh regularization（网格正则化）



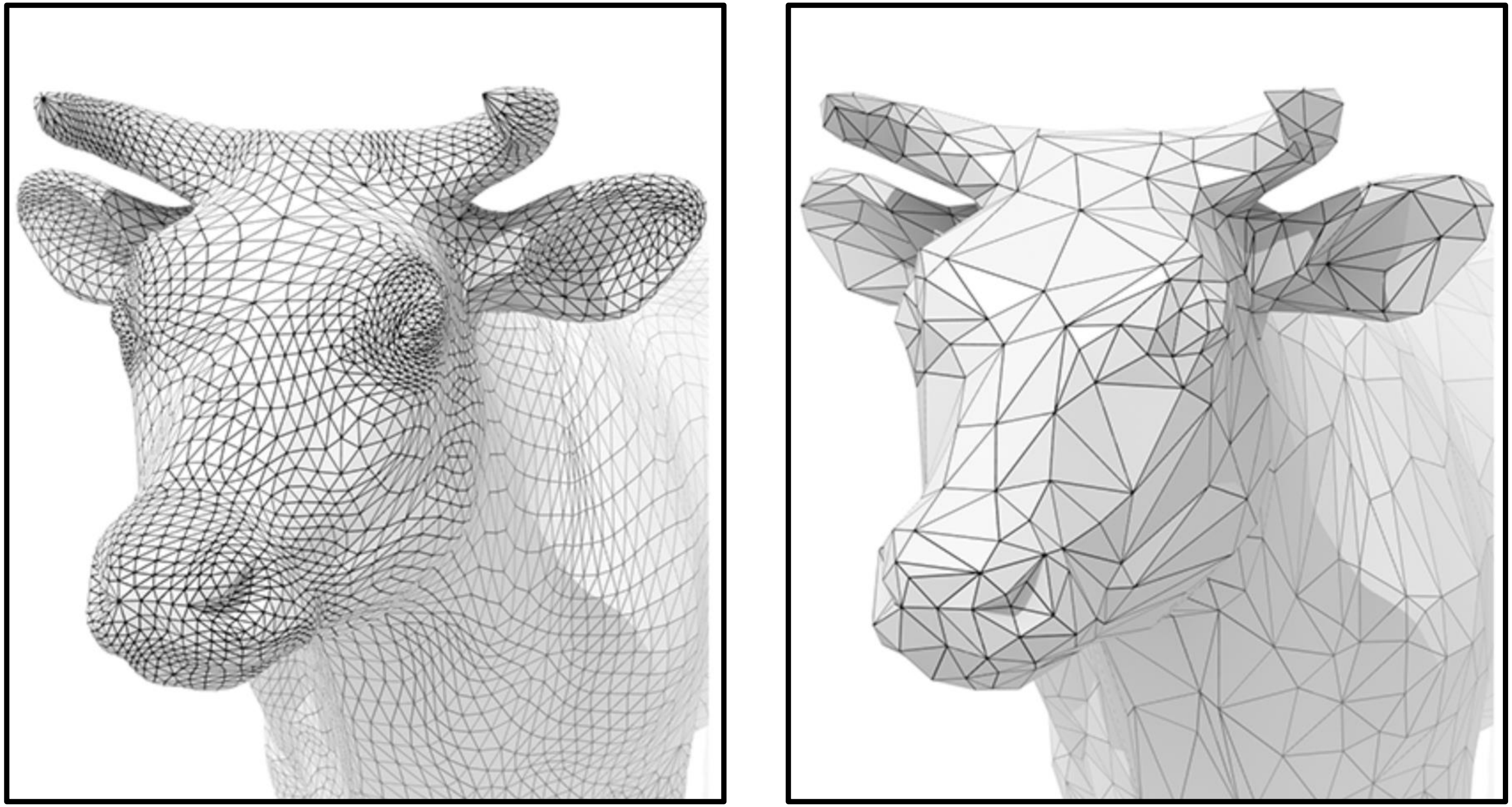
# Mesh Subdivision (upsampling)





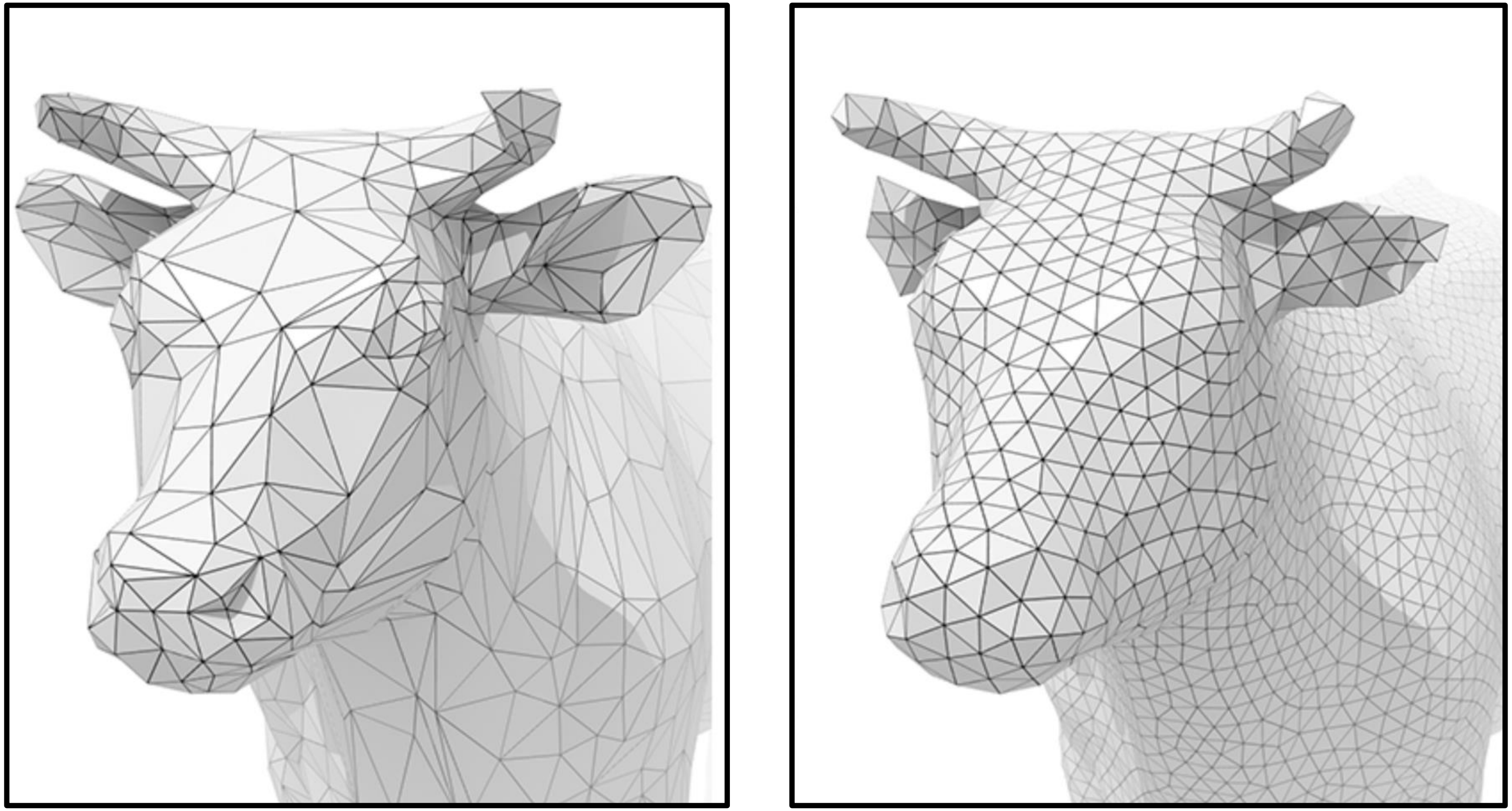
Increase resolution

# Mesh Simplification (downsampling)



Decrease resolution; try to preserve shape/appearance

# Mesh Regularization (same #triangles)



Modify sample distribution to improve quality

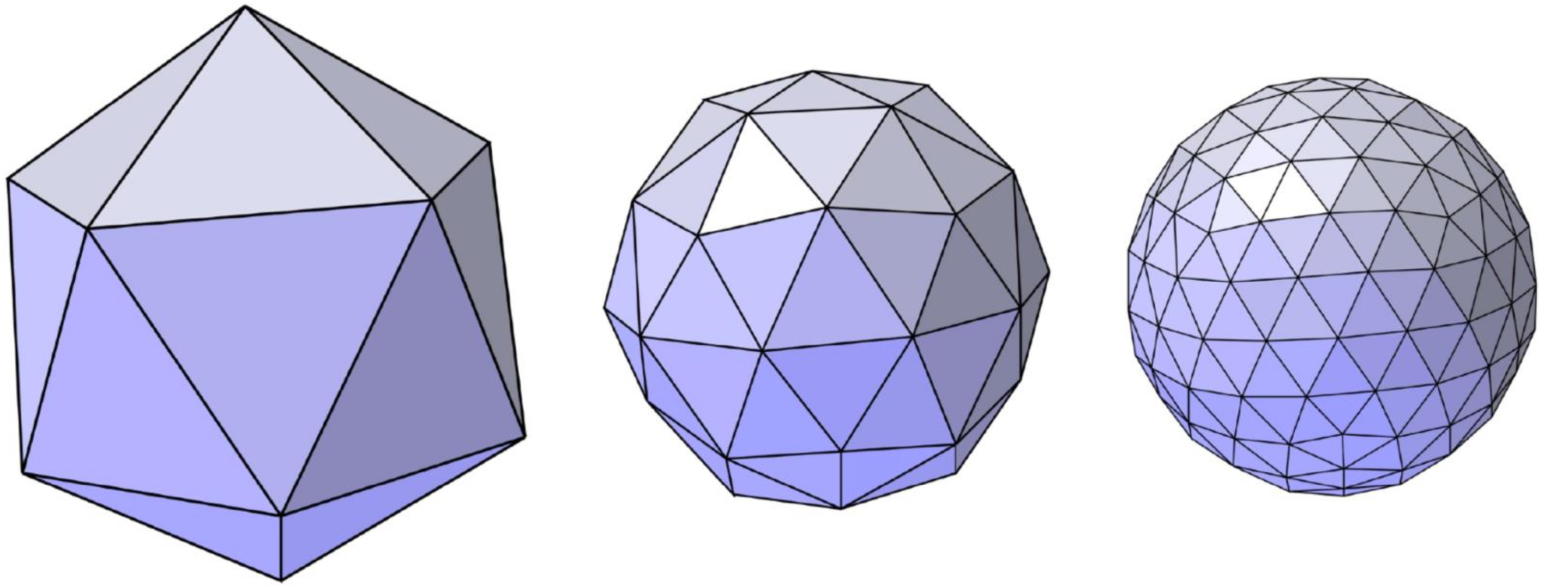
# Subdivision

# Loop Subdivision

Common subdivision rule for triangle meshes

First, create more triangles (vertices)

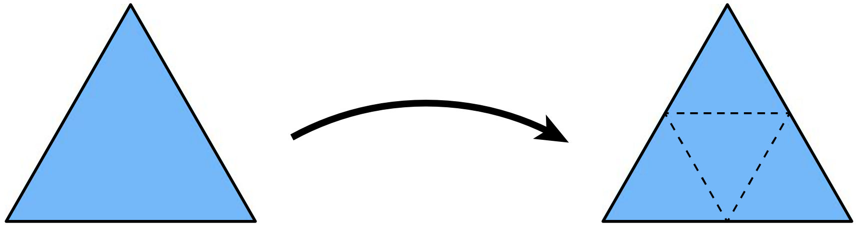
Second, tune their positions



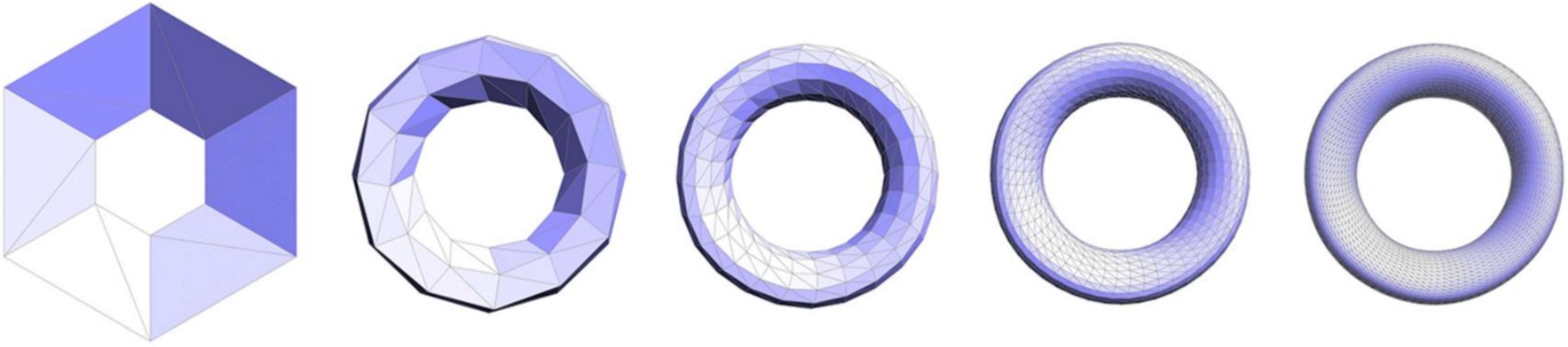
Simon Fuhrman

# Loop Subdivision

- Split each triangle into four

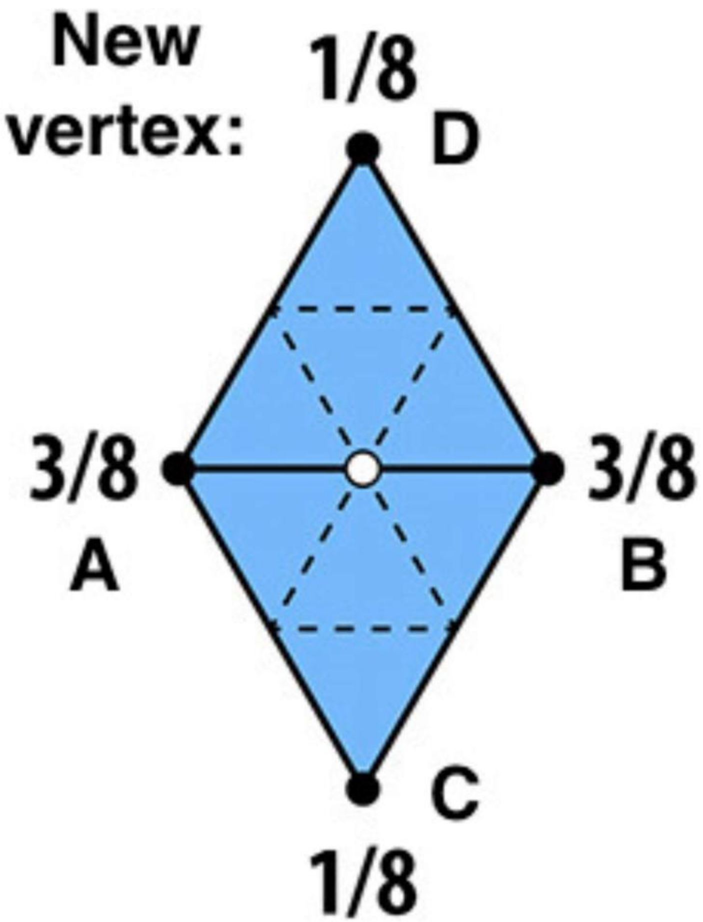


- Assign new vertex positions according to weights
  - New / old vertices updated differently



# Loop Subdivision — Update

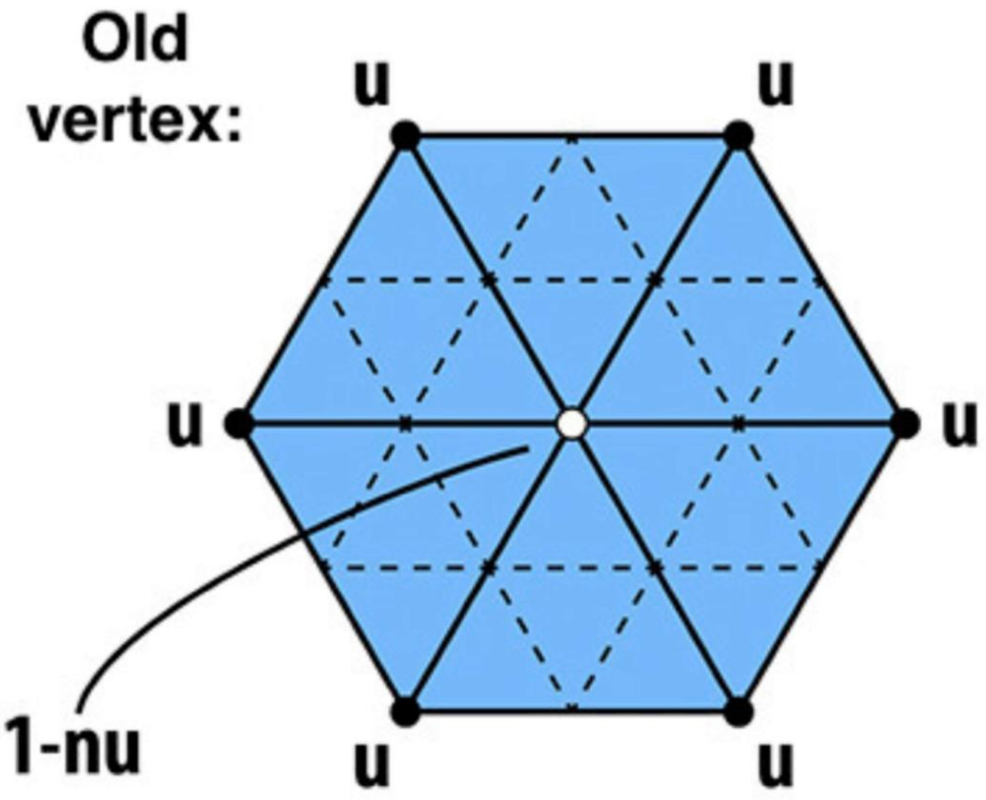
For new vertices:




Update to:
3/8 * (A + B) + 1/8 * (C + D)

# Loop Subdivision — Update

For old vertices (e.g. degree 6 vertices here):

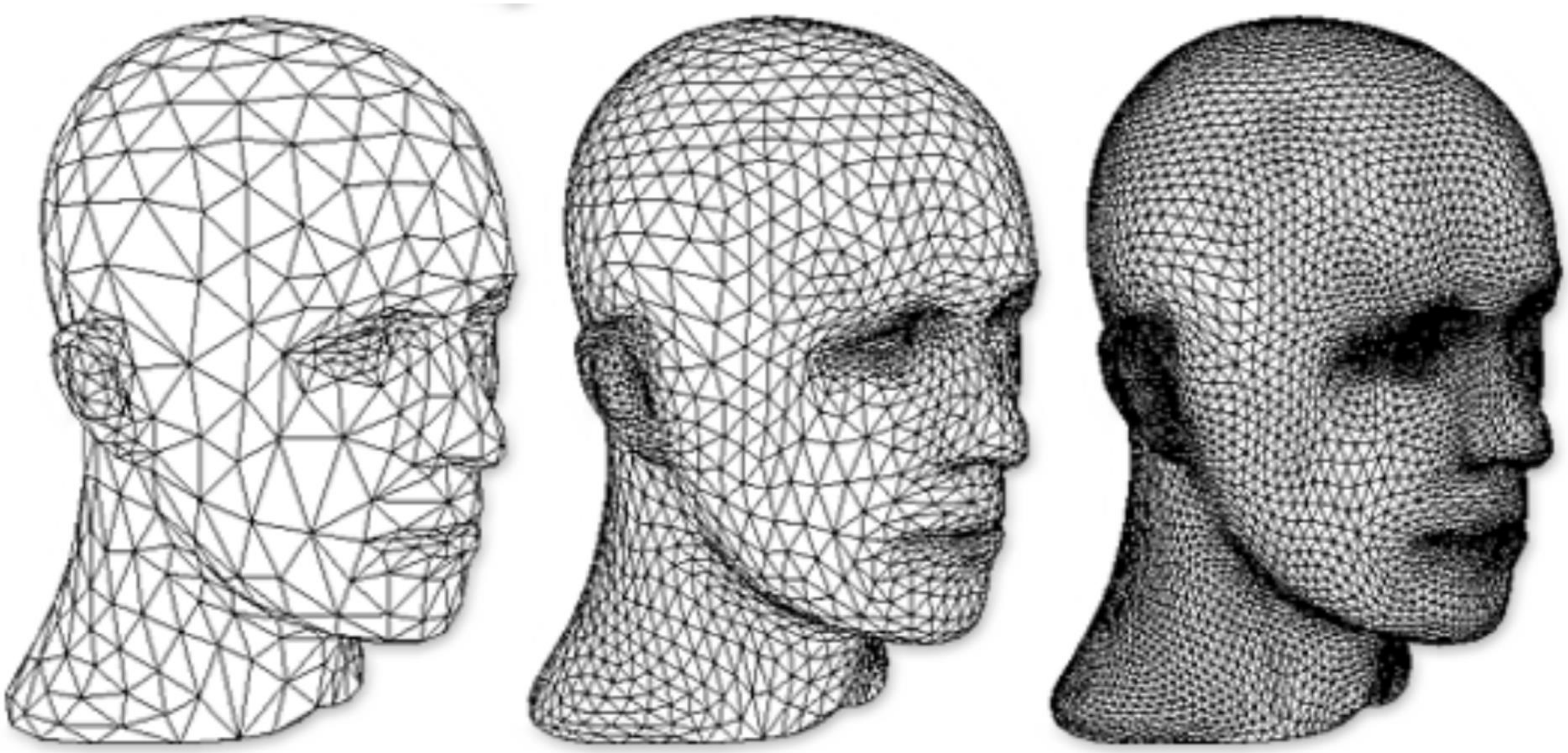



Update to:
(1 - n*u) * original_position +
u * neighbor_position_sum

**n: vertex degree**

**u: 3/16 if n=3, 3/(8n) otherwise**

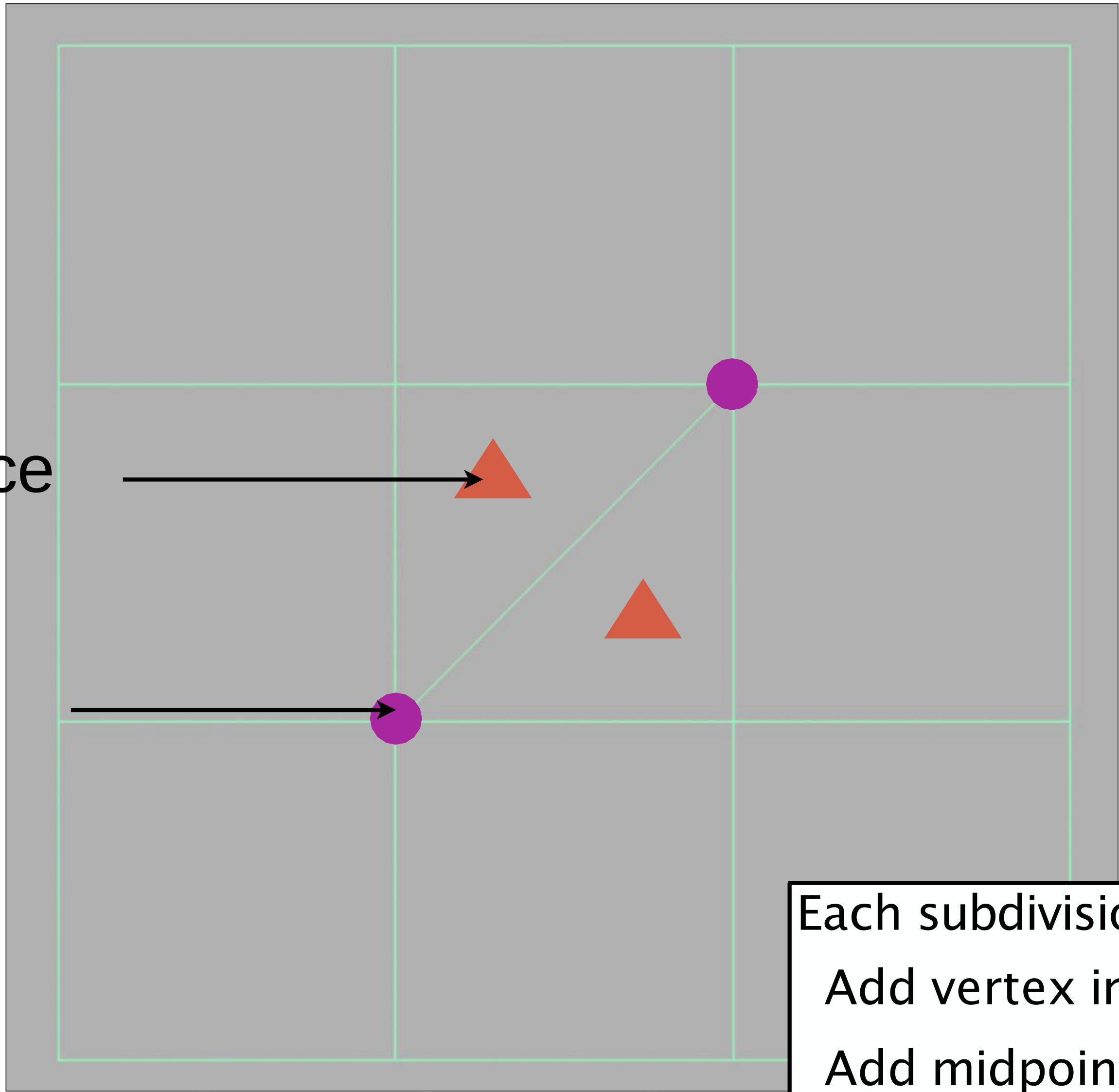
# Loop Subdivision Results



# Catmull-Clark Subdivision (General Mesh)

Non-quad face

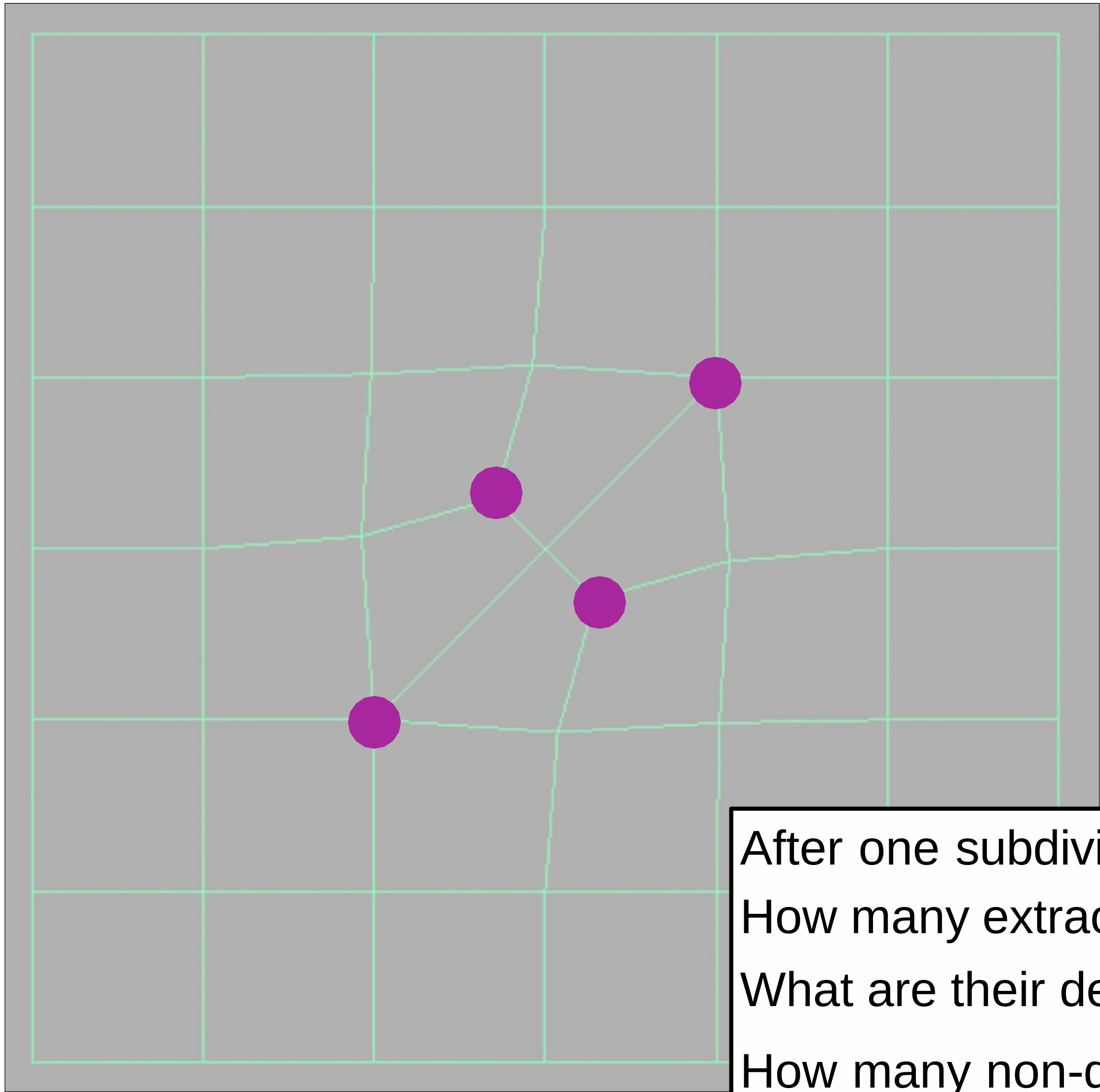
Extraordinary vertex (奇异点) (degree != 4)



Each subdivision step:

- Add vertex in each face
- Add midpoint on each edge
- Connect all new vertices

# Catmull-Clark Subdivision (General Mesh)



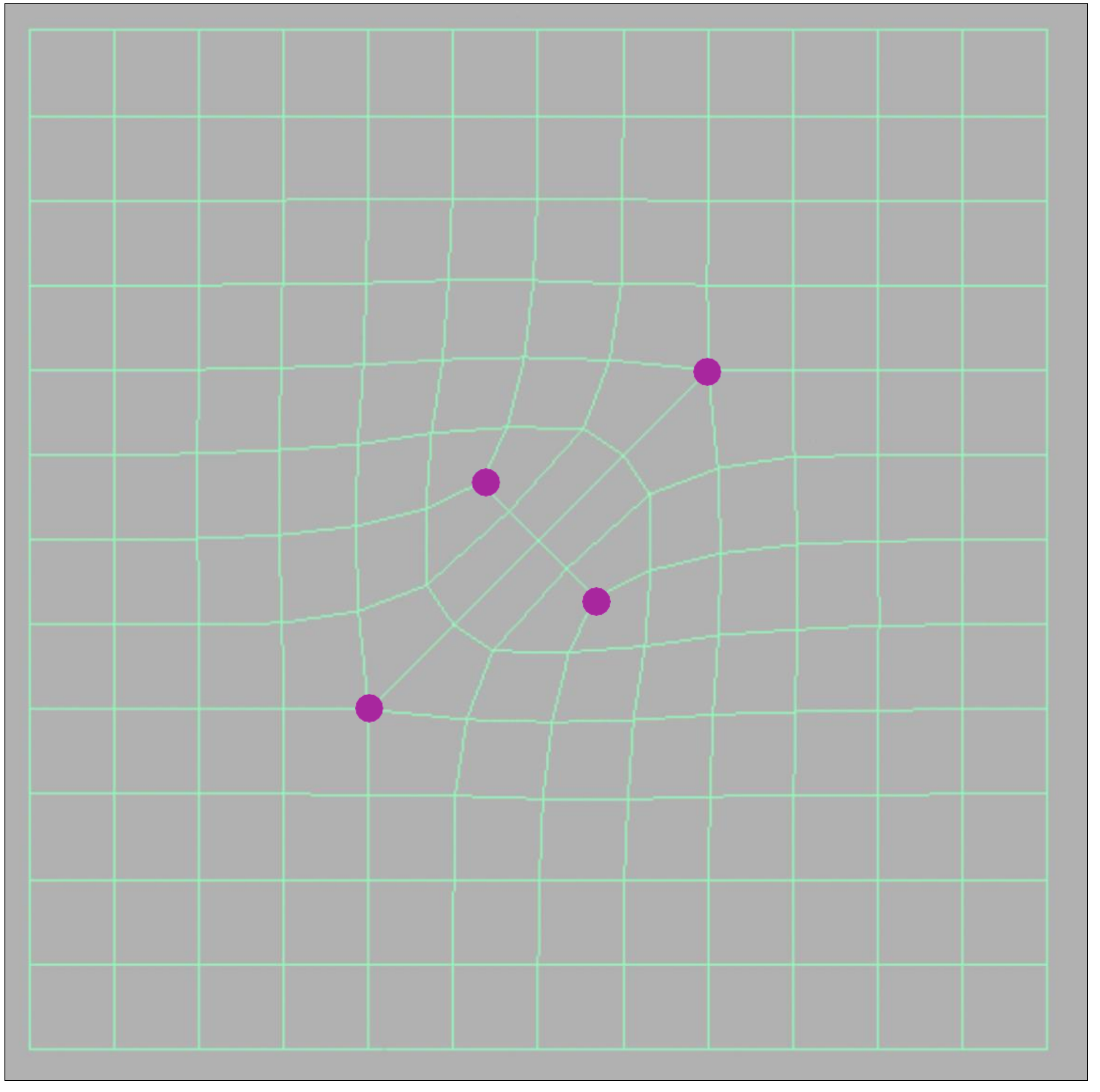
After one subdivision:

How many extraordinary vertices?

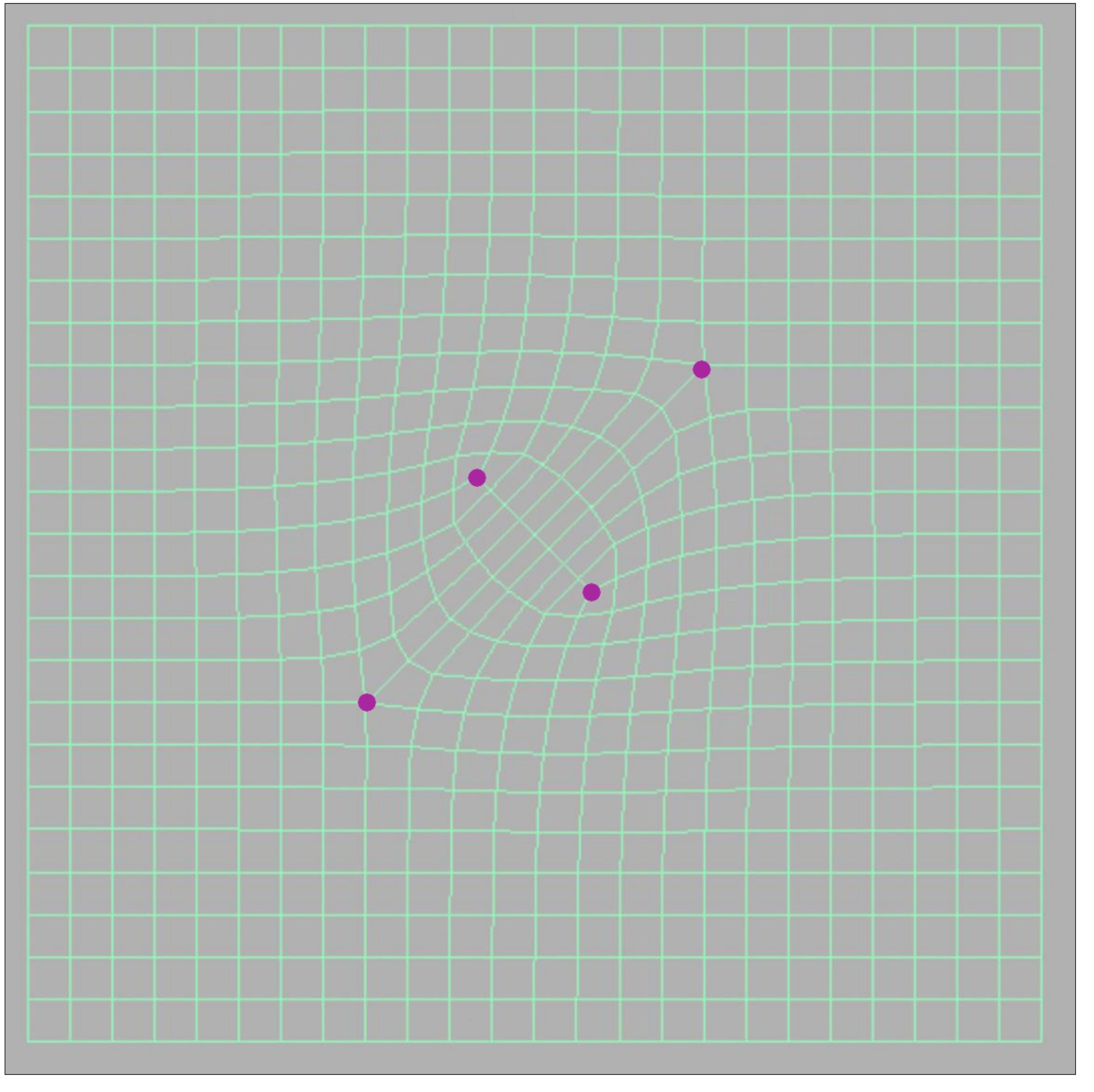
What are their degrees?

How many non-quad faces?

# Catmull-Clark Subdivision (General Mesh)

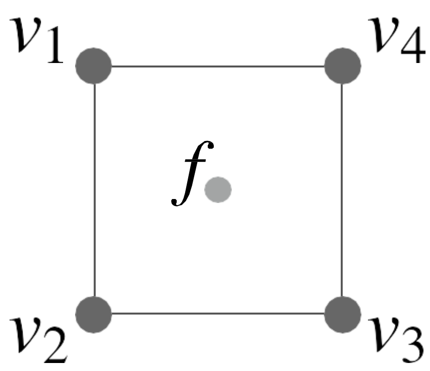


# Catmull-Clark Subdivision (General Mesh)



# FYI: Catmull-Clark Vertex Update Rules (Quad Mesh)

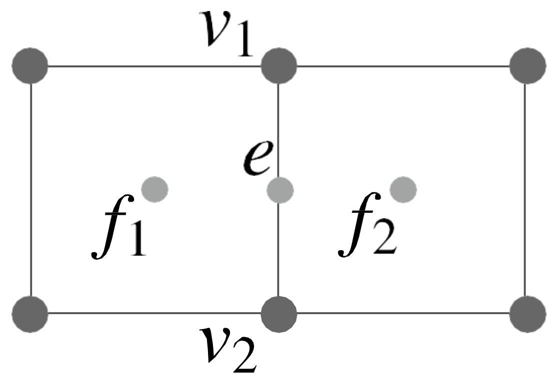
Face point

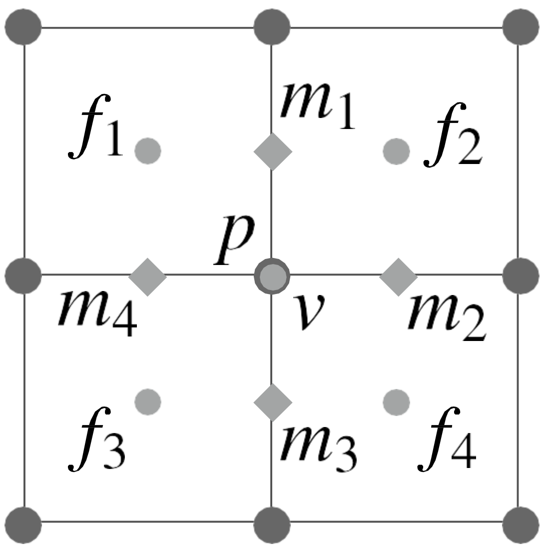



$$f = \frac{v_1 + v_2 + v_3 + v_4}{4}$$

$$e = \frac{v_1 + v_2 + f_1 + f_2}{4}$$

Edge point




Vertex point

$$v = \frac{f_1 + f_2 + f_3 + f_4 + 2(m_1 + m_2 + m_3 + m_4) + 4p}{16}$$

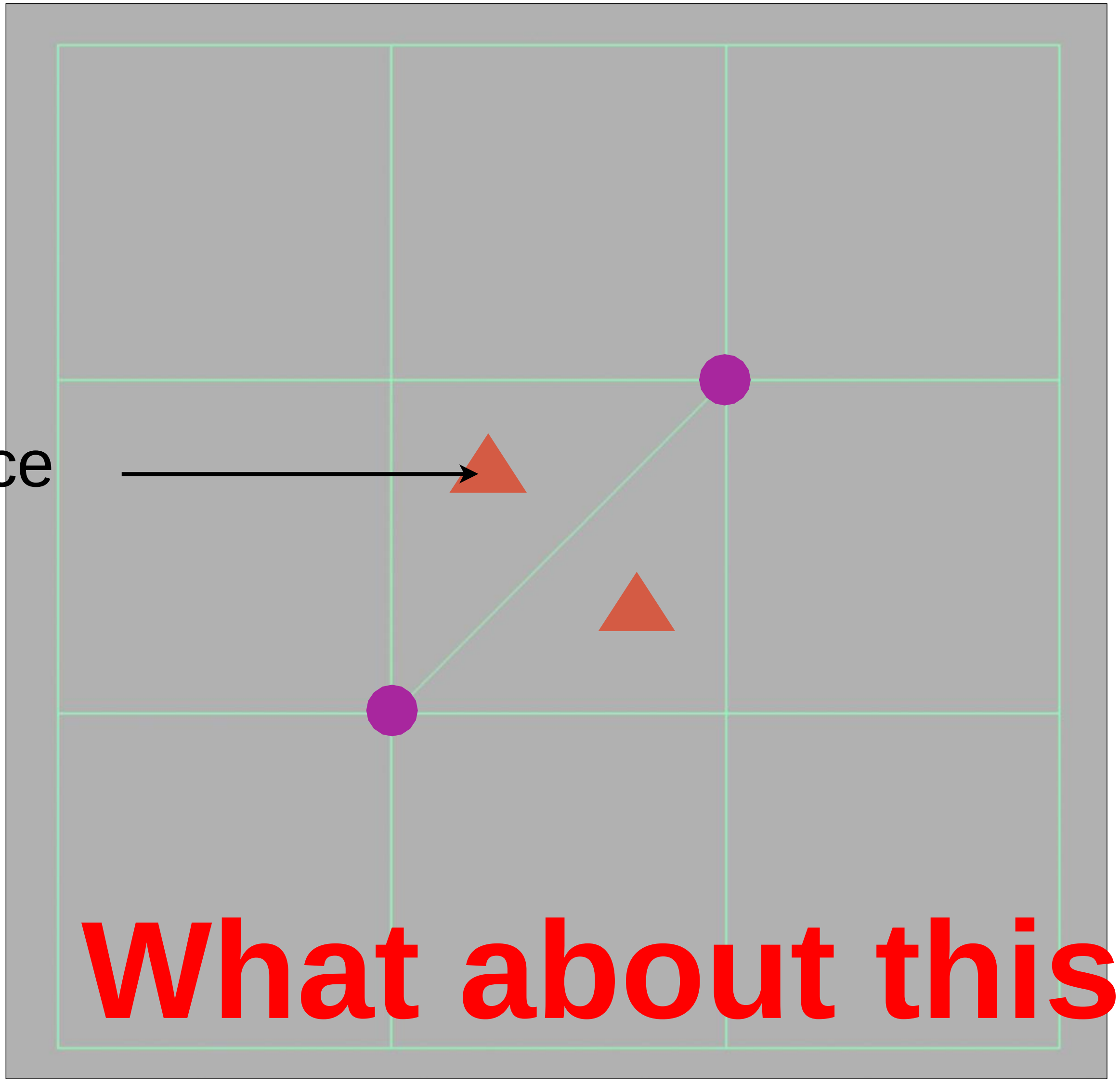
$m$ midpoint of edge

$p$ old "vertex point"

# FYI: Catmull-Clark Vertex Update Rules (Quad Mesh)

Non-quad face

Extraordinary vertex (奇异点) (degree != 4)



# Convergence: Overall Shape and Creases

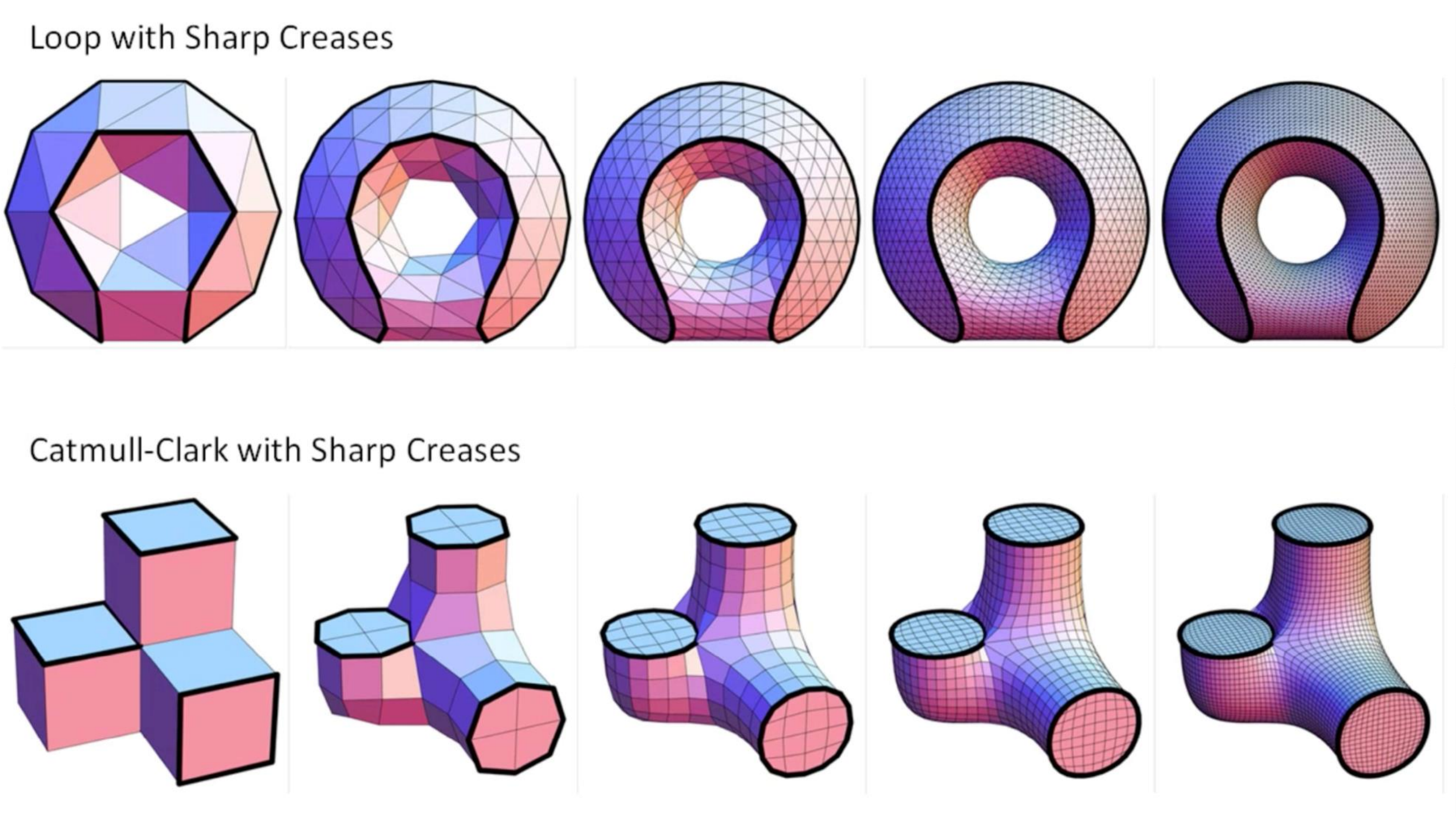
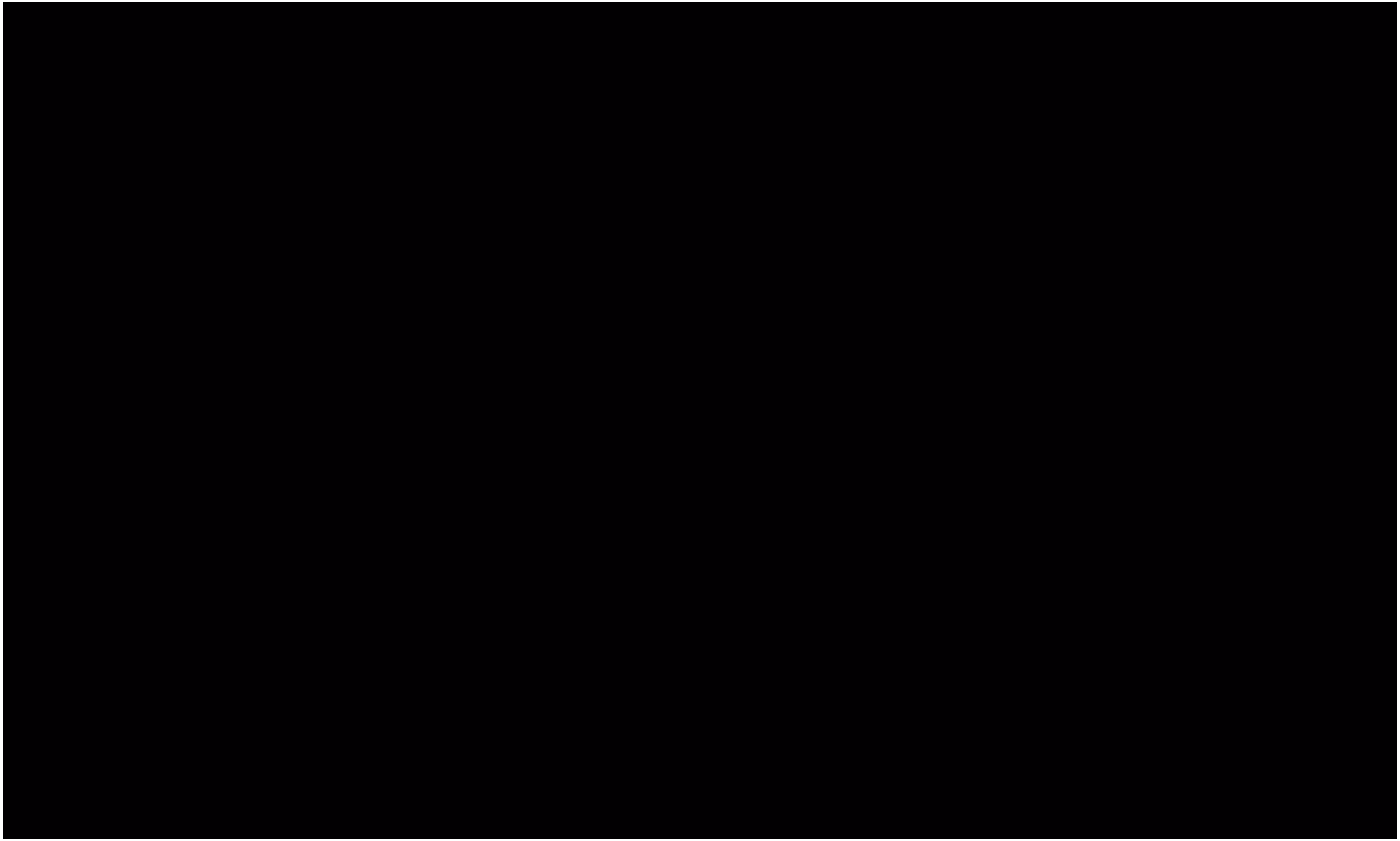



Figure from: Hakenberg et al. Volume Enclosed by Subdivision Surfaces with Sharp Creases

# Subdivision in Action (Pixar's "Geri's Game")



# Mesh Simplification

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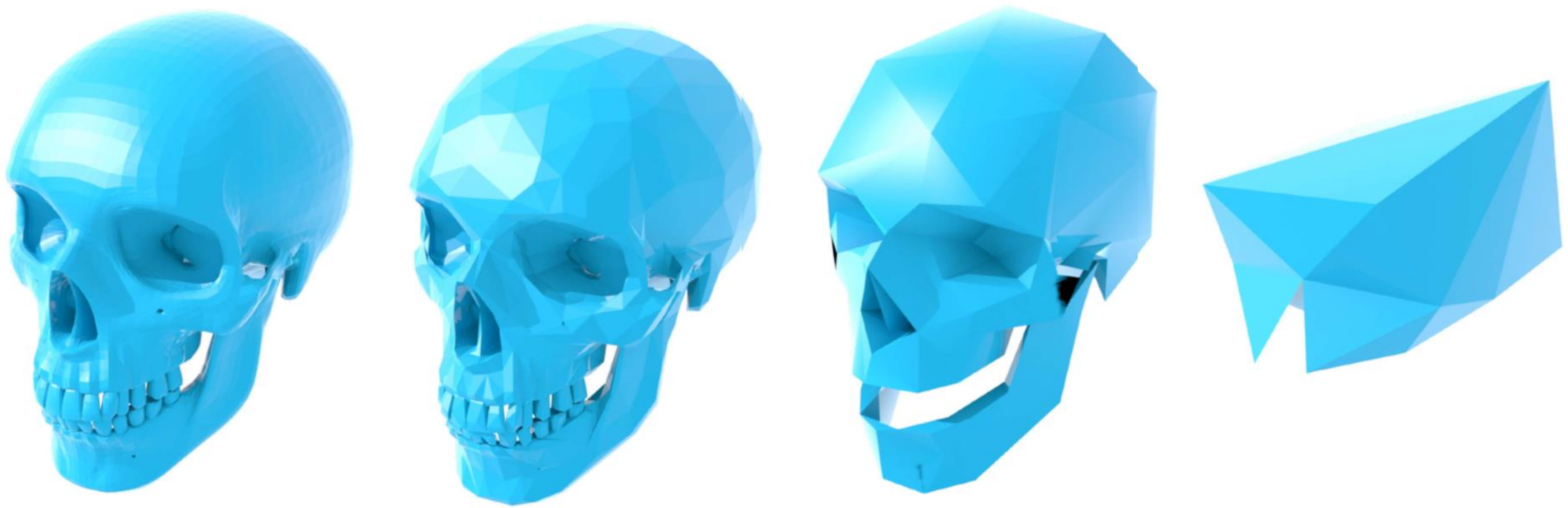
Goal: reduce number of mesh elements
while maintaining the overall shape

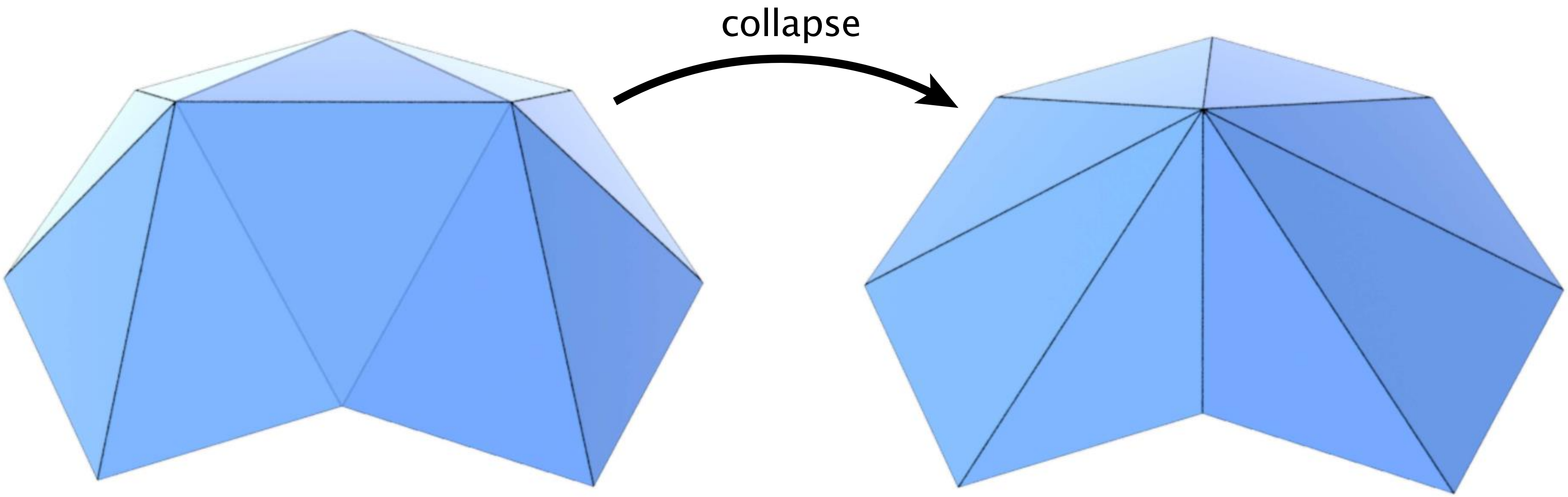


30,000 triangles | 3,000 | 300 | 30

How to compute?

# Collapsing An Edge

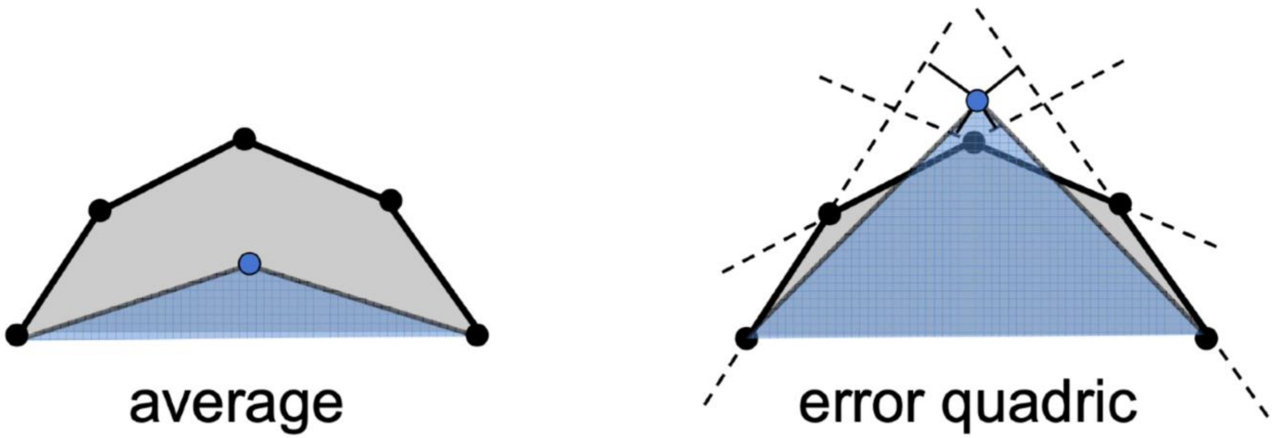
- Suppose we simplify a mesh using edge collapsing



# Quadric Error Metrics

（二次误差度量）

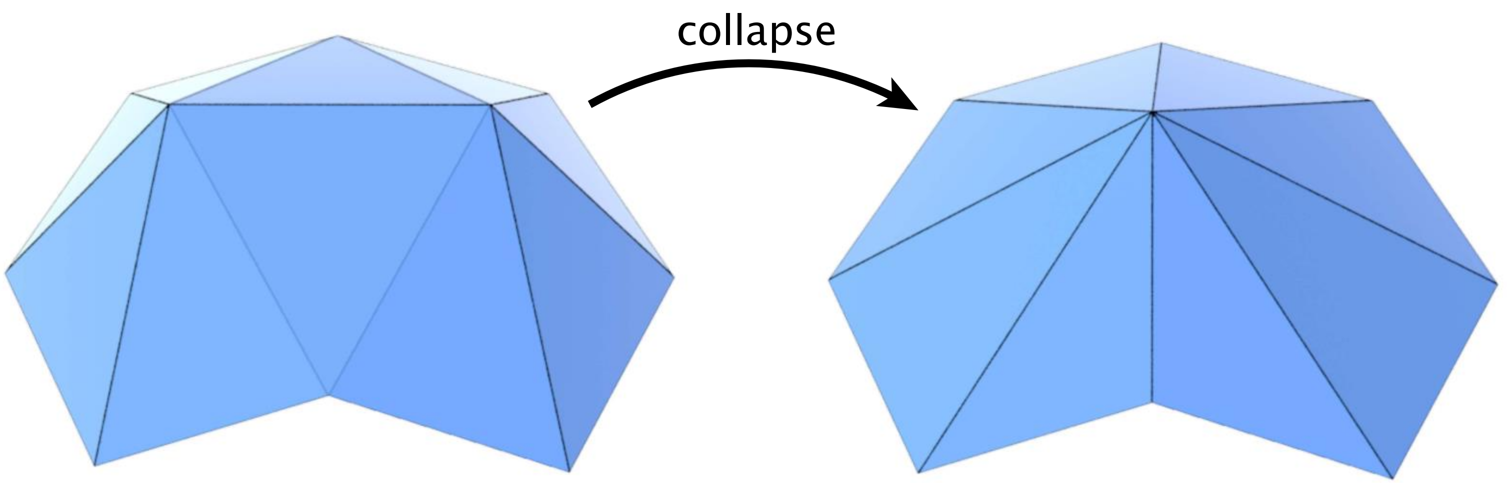
- How much geometric error is introduced by simplification?
- Not a good idea to perform local averaging of vertices
- Quadric error: new vertex should minimize its sum of square distance (L2 distance) to previously related triangle planes!




http://graphics.stanford.edu/courses/cs468-10-fall/LectureSlides/08_Simplification.pdf

# Quadric Error of Edge Collapse

- How much does it cost to collapse an edge?
- Idea: compute edge midpoint, measure quadric error




- Better idea: choose point that minimizes quadric error
- More details: Garland & Heckbert 1997.

# Simplification via Quadric Error

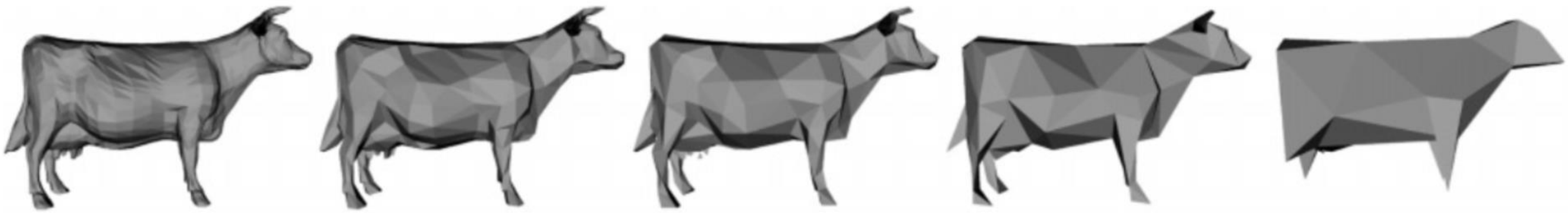
Iteratively collapse edges

Which edges?  Assign score with quadric error metric*

- approximate distance to surface as sum of distances to planes containing triangles
- iteratively collapse edge with smallest score
- greedy algorithm... great results!

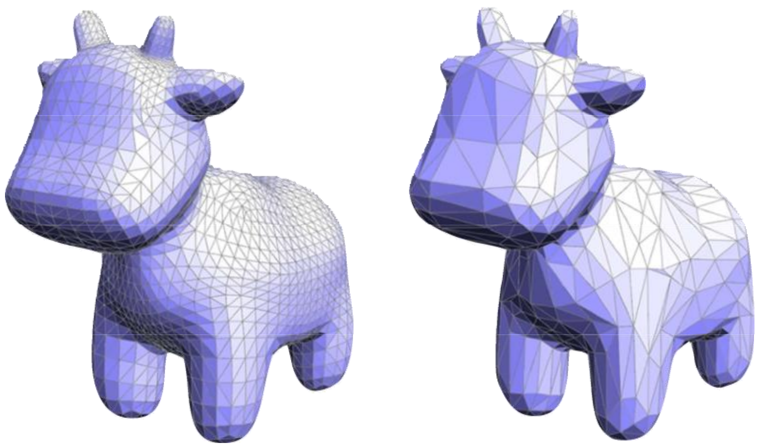
* (Garland & Heckbert 1997)

# Quadric Error Mesh Simplification

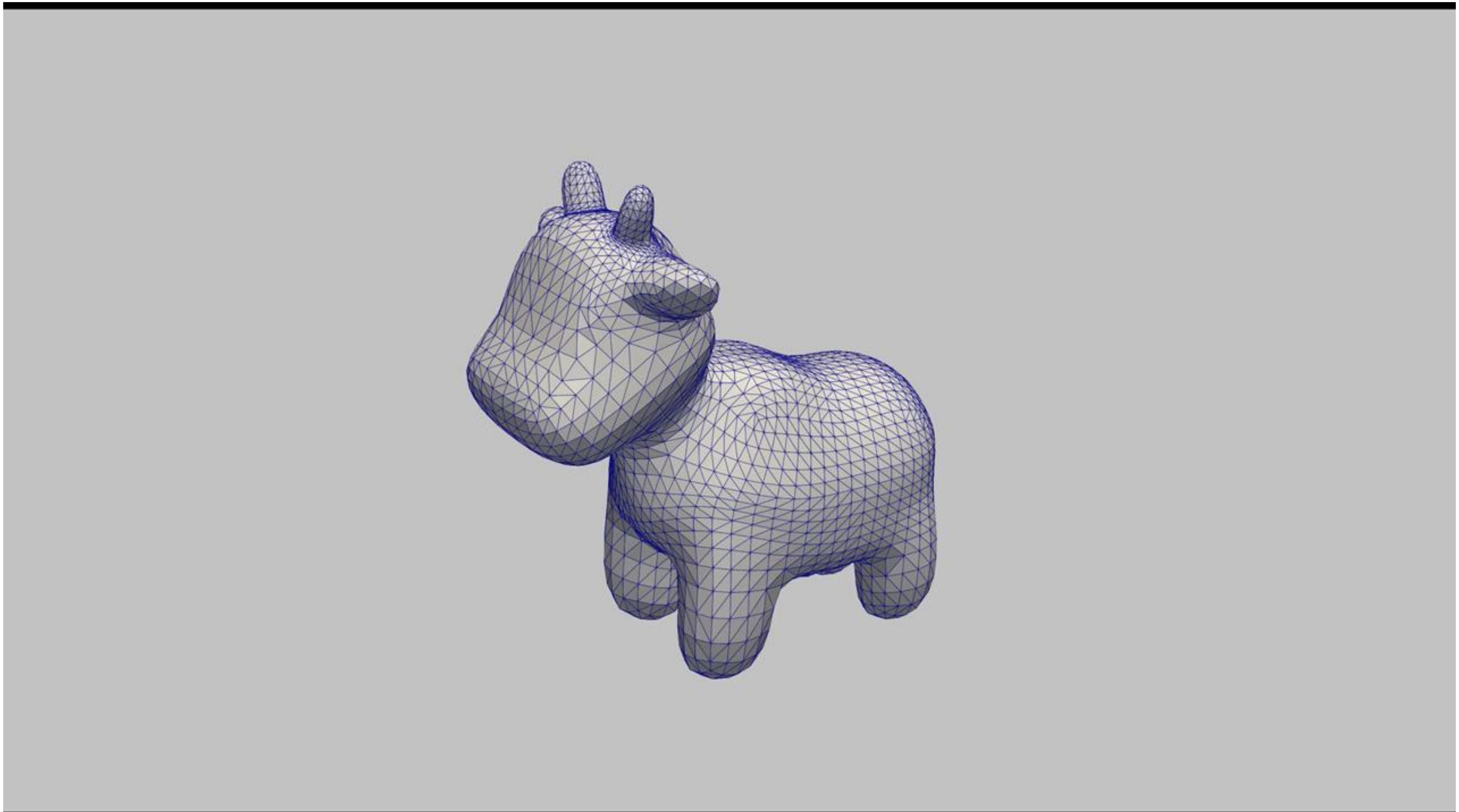


5,804 994 532 248 64

Garland and Heckbert '97



# Quadric Error Mesh Simplification



# Thank you!