CS354R

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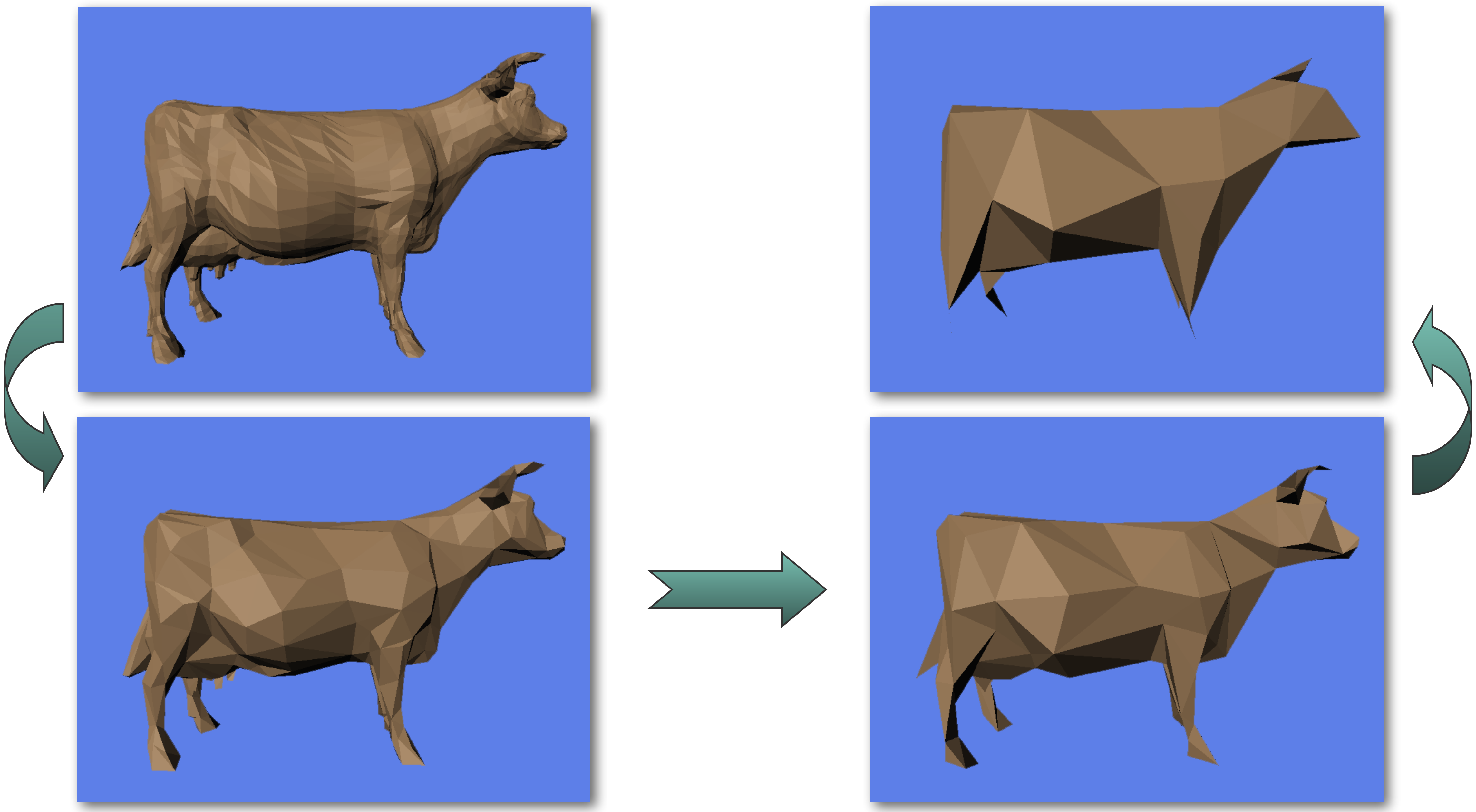
LEVEL OF DETAIL

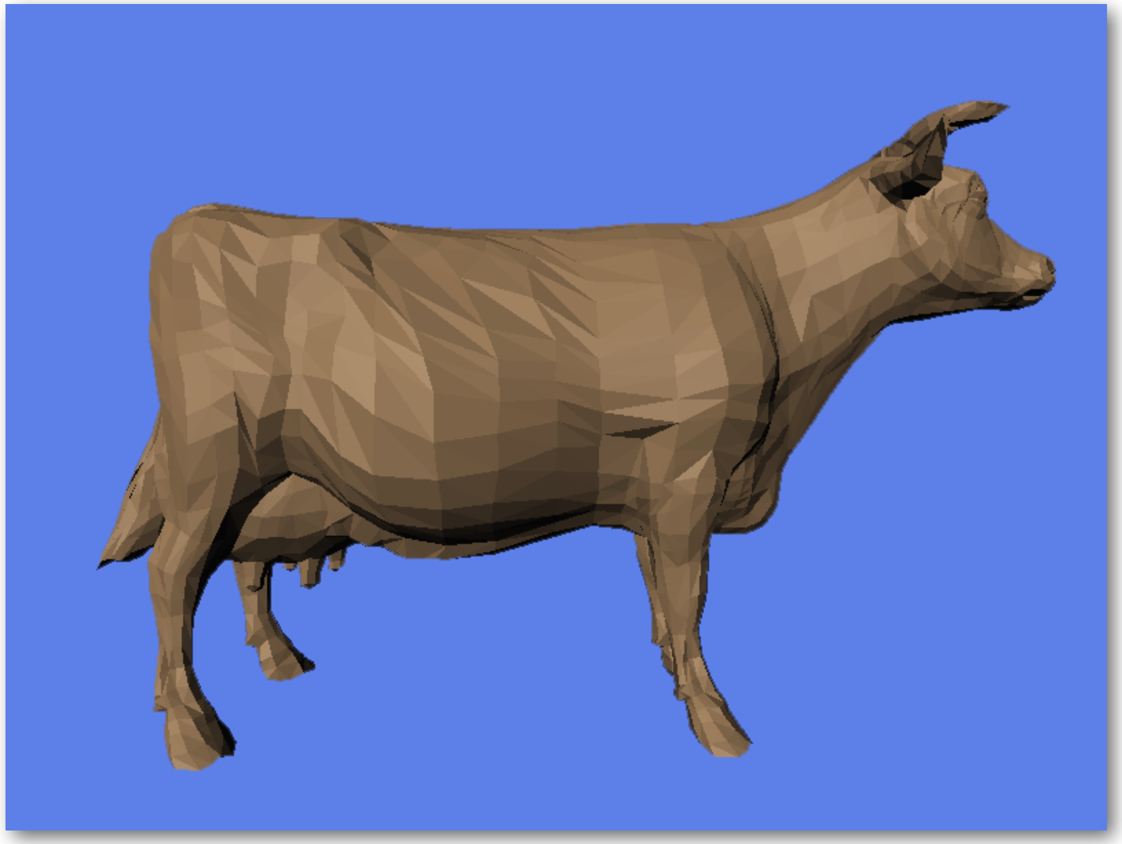
LEVEL OF DETAIL (LOD)

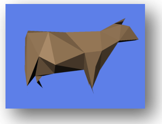
- When an object is close to the viewer, we want a high resolution model
  - Thousands of polygons in high-res textures
- When an object is a long way away, it maps to relatively few screen pixels, so we want a low resolution model
  - Maybe only a single polygon, or tens of polygons
- Level of Detail (LOD) techniques draw models at different resolutions depending on their relevance to the viewer
  - Covers both the generation of the models and how they are displayed
  - Deep topic, this is just an overview

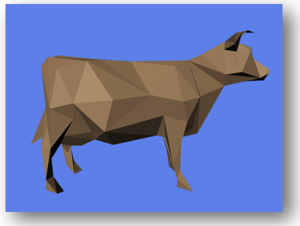
LOD MODELS AT FULL RESOLUTION

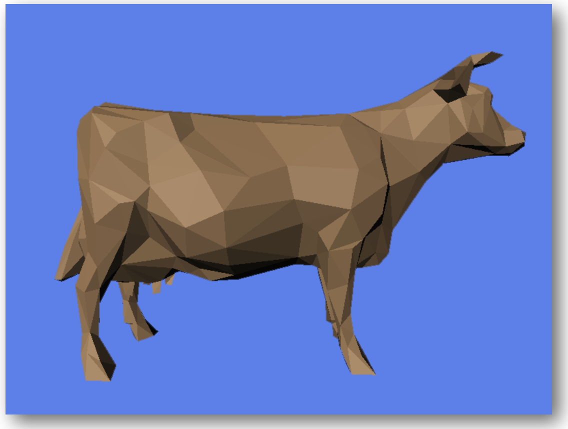


LOD MODELS AT SCALE









STANDARD LOD

- The current standard for LOD in games is to use a finite set of models
  - Typically aim for models with n, n/2, n/4, … polygons
  - Models may be hand generated or come from automatic decimation of the base mesh (highest resolution)
- Models are switched based on the distance from the object to the viewer, or projected screen size
  - Better metric is visual importance, but it is harder to implement
  - Objects that the viewer is likely to be looking at have higher resolution, objects at periphery have lower resolution

EXAMPLES

- No Man’s Sky <https://youtu.be/WrsLdwm_40k?t=209>
- Final Fantasy XV <https://youtu.be/TbKkJKfy6Cg?t=30>

MESH DECIMATION

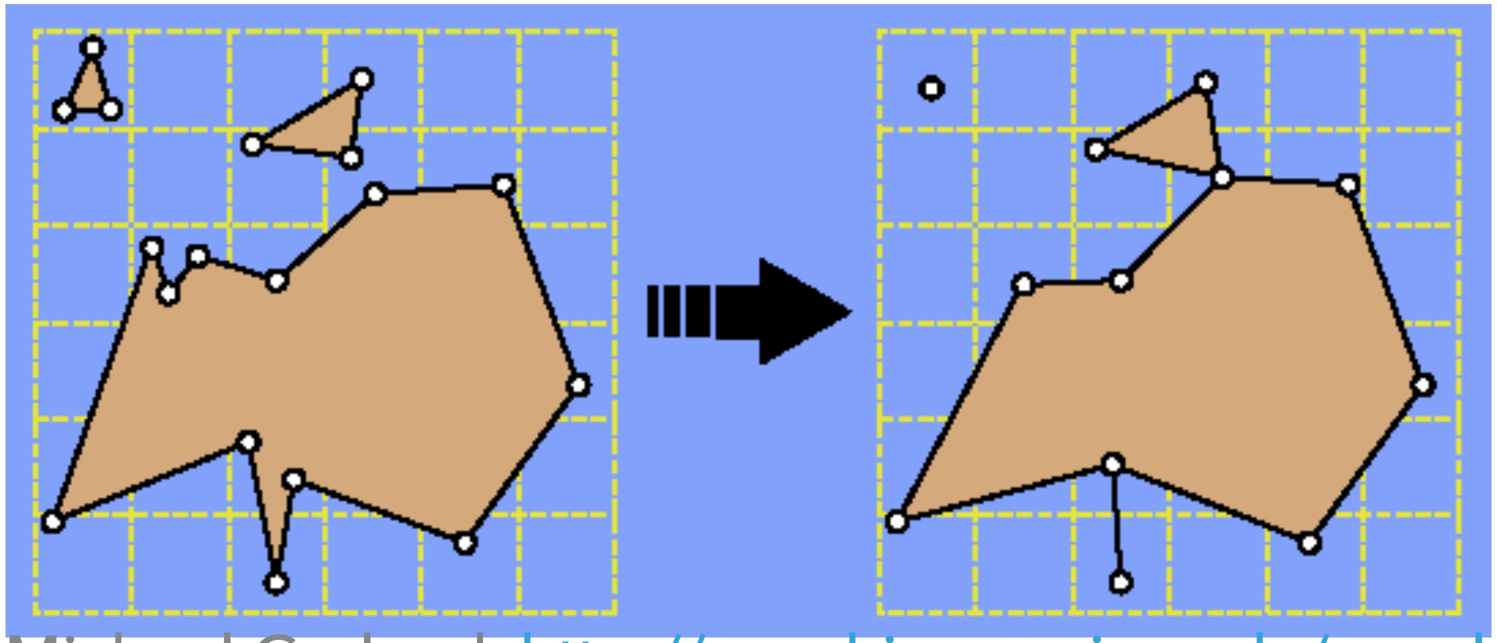
- Take a high resolution base mesh and approximate it while retaining its visual appearance
- Desirable properties:
  - Fast (although not real-time)
  - Generates "good" approximations
  - Handles wide variety of input meshes
  - Allows for geomorphs (geometric blending from one mesh to another)
- Two essential questions:
  - What operations are used to reduce the mesh complexity?
  - How is "good" measured and used to guide the approximation?

MESH OPERATIONS

- Operations seek to eliminate triangles while maintaining appearance. Key questions:
- What does the operation do?
  - Can it connect previously unconnected parts of the mesh?
  - Does it change the mesh topology?
- How much does it assume about the mesh structure?
  - Must the mesh be manifold (locally isomorphic to a disc)?
  - Can it handle, or does it produce, degenerate meshes?
- Can it be construed as a morph?
  - Can it be animated smoothly?

VERTEX CLUSTERING

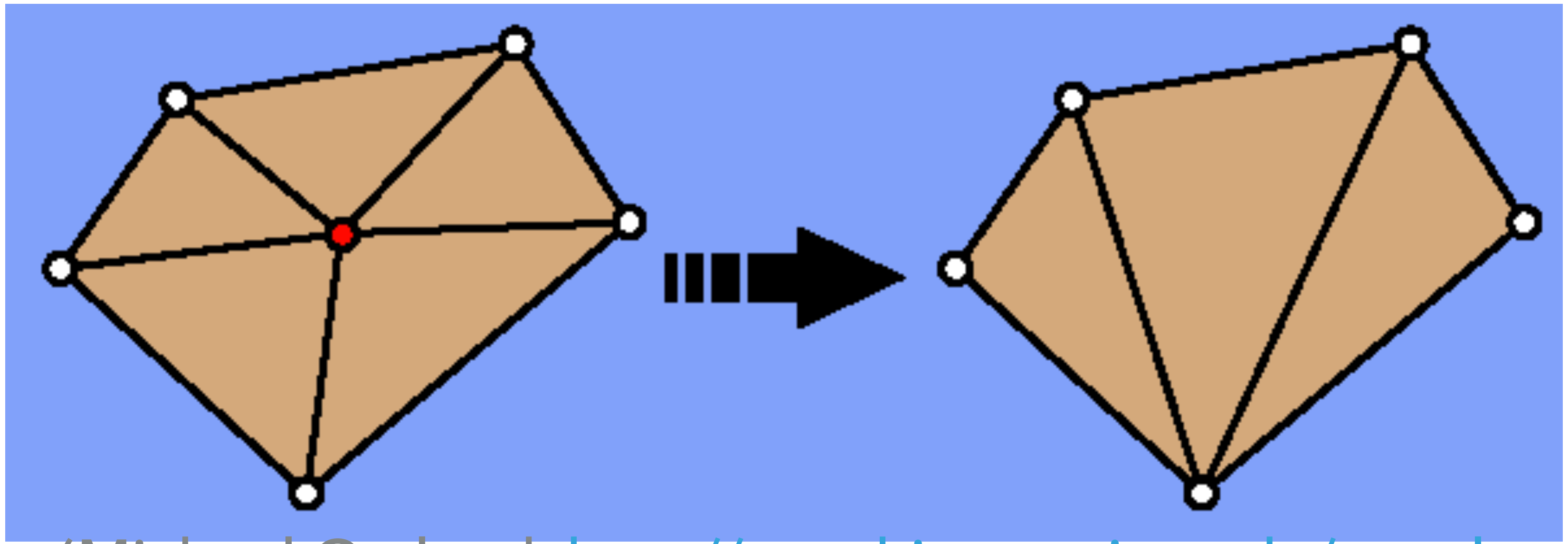
- Partition space into cells
  - Grids [Rossignac-Borrel], spheres [Low-Tan], octrees, etc
- Merge all vertices within the same cell
  - Triangles with multiple corners in one cell will degenerate



(Michael Garland, http://graphics.cs.uiuc.edu/~garland)

VERTEX DECIMATION

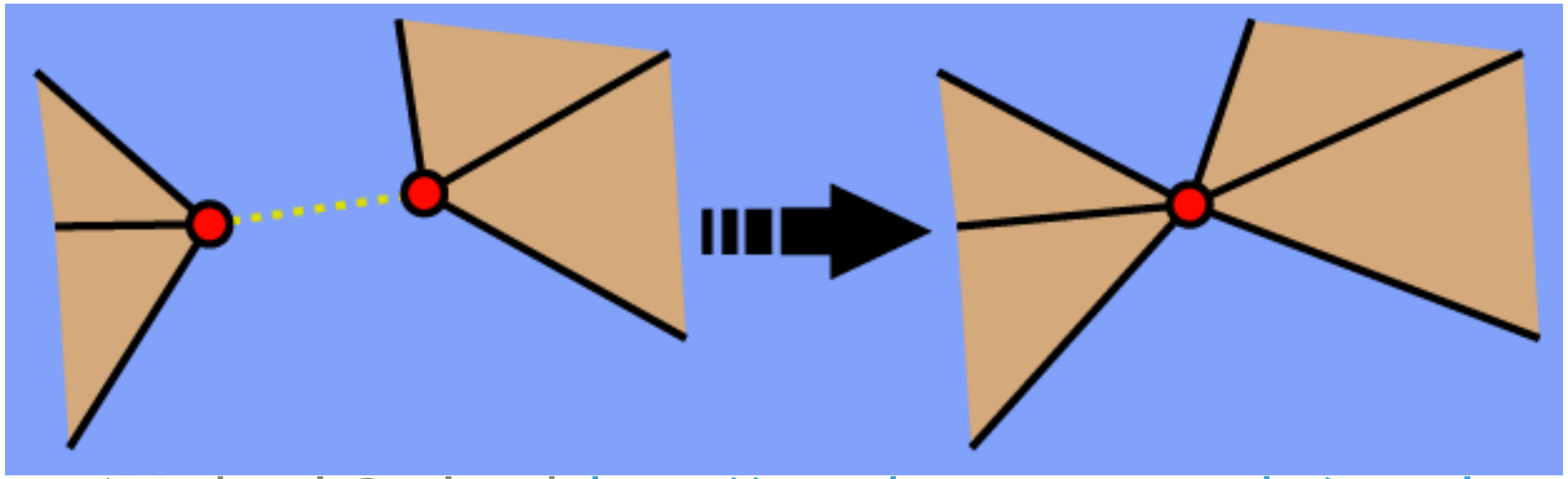
- Iteratively on original model:
    1. Rank vertices according to their importance
    2. Select unimportant vertex, remove it, re-triangulate hole
- Fairly common technique
    - Schroeder et al, Soucy et al, Klein et al, Ciampalini et al



(Michael Garland, http://graphics.cs.uiuc.edu/~garland)

VERTEX PAIR CONTRACTION

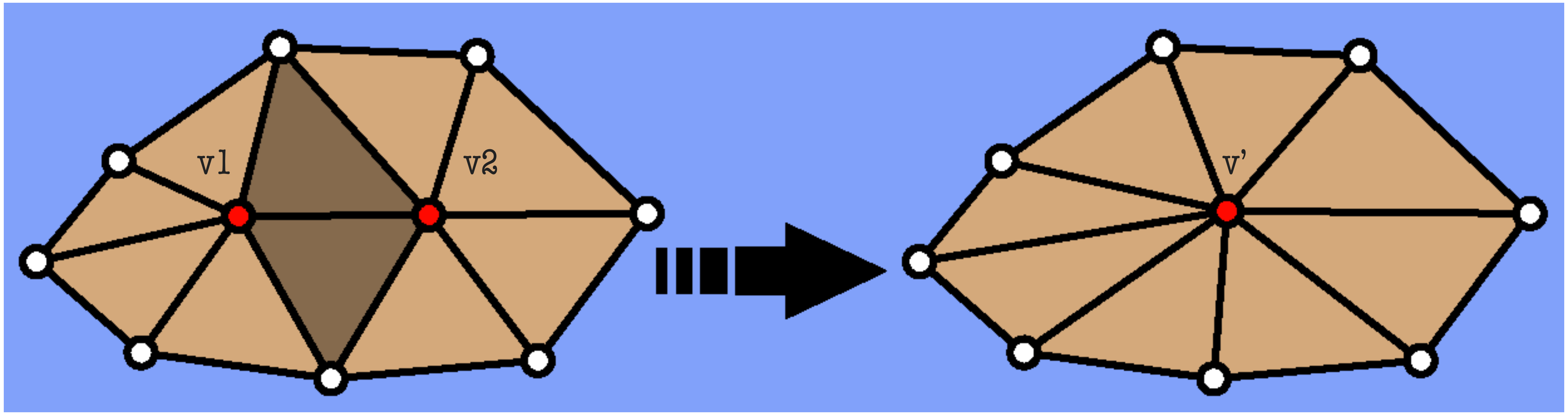
- Can contract any pair of vertices
  - Fundamental operation is exactly the same
  - Joins previously unconnected areas
  - Achieves topological simplification



(Michael Garland, http://graphics.cs.uiuc.edu/~garland)

EDGE CONTRACTION

- Single edge contraction (v1,v2) → v′ is performed by
  1. Move v1 and v2 to position v′
  2. Replace all occurrences of v2 with v1
  3. Remove v2 and all degenerate triangles



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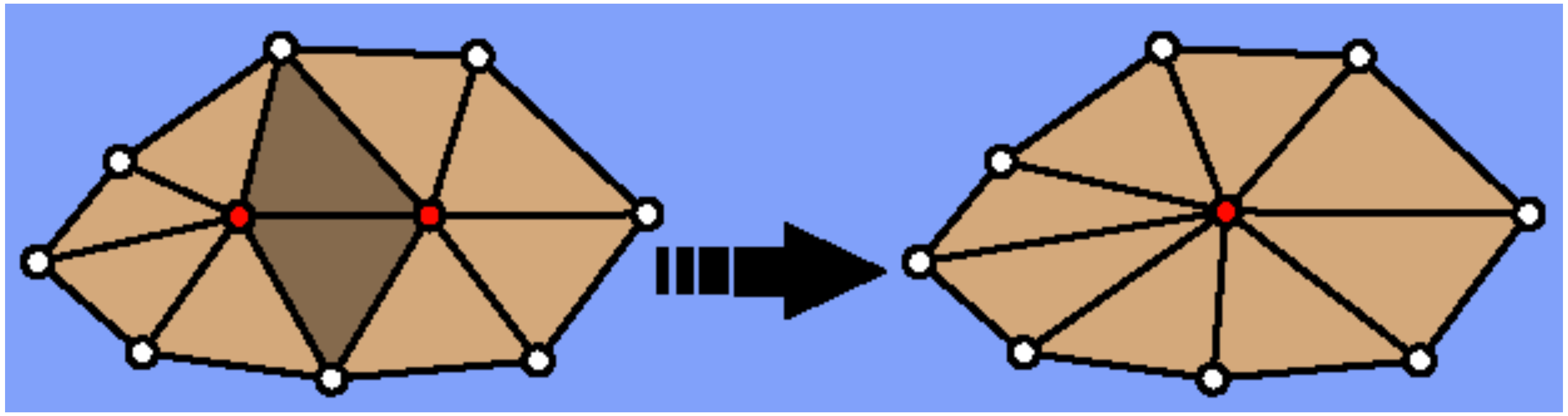
ITERATIVE CONTRACTION

- Contraction can operate on any set of vertices
  - Edges (or vertex pairs) are most common, faces also used
- Iterate on original model:
  1. Rank all edges with some cost metric
  2. Contract minimum cost edge
  3. Update edge costs



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OPERATIONS TO ALGORITHMS

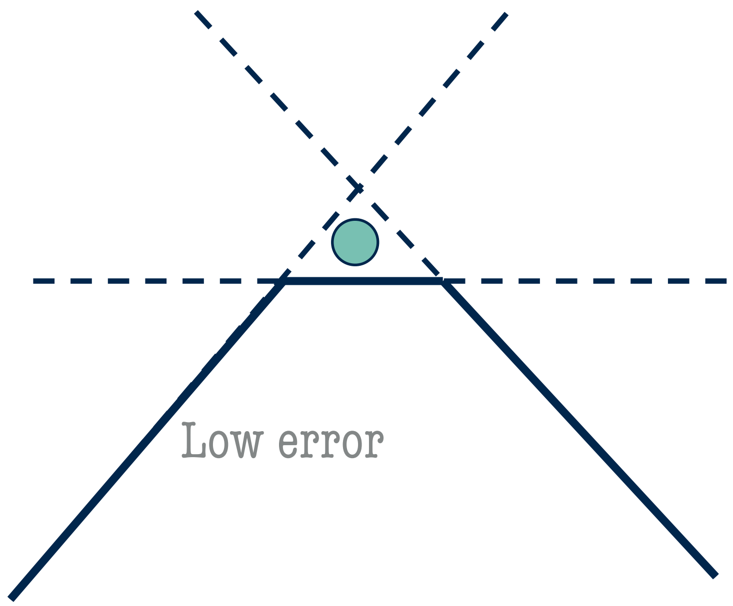
- A single operation doesn't reduce a mesh!
- Most common approach is a greedy algorithm built on edge contractions (iterative edge contractions):
    1. Rank each possible edge contraction according to how much error it would introduce
    2. Contract edge that introduces the least error
    3. Repeat until done
- Does NOT produce optimal meshes
    - An optimal mesh for a given target number of triangles is the one with the lowest error with respect to the original mesh
    - Finding the optimal mesh is NP-hard (intractable)

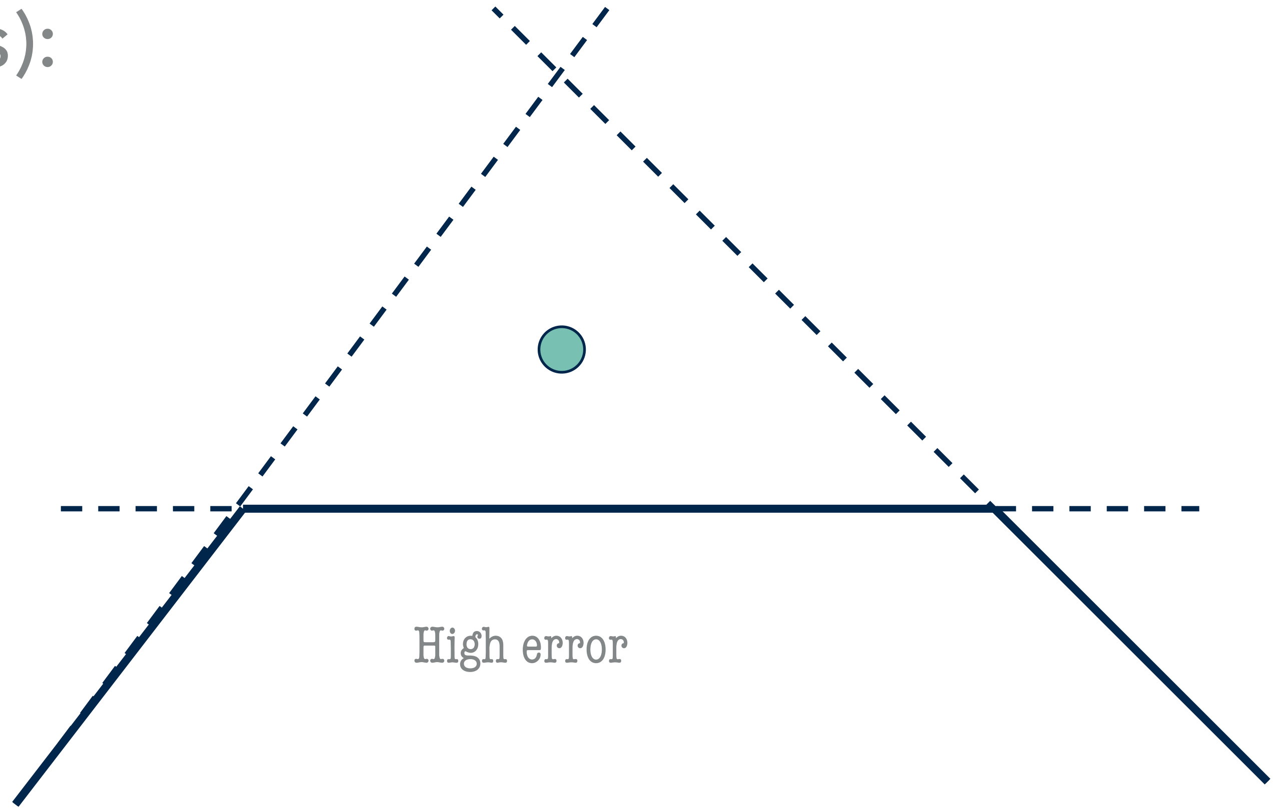
ERROR METRICS

- Error metric measures error introduced contracting an edge
    - Low for edges whose removal leaves mesh mostly unchanged
- Issues:
    - How well does it measure changes in appearance?
    - How easy is it to compute?
    - Can it handle color and other non-geometric attributes?
    - Error is measured with respect to original mesh

MEASURING ERROR WITH PLANES

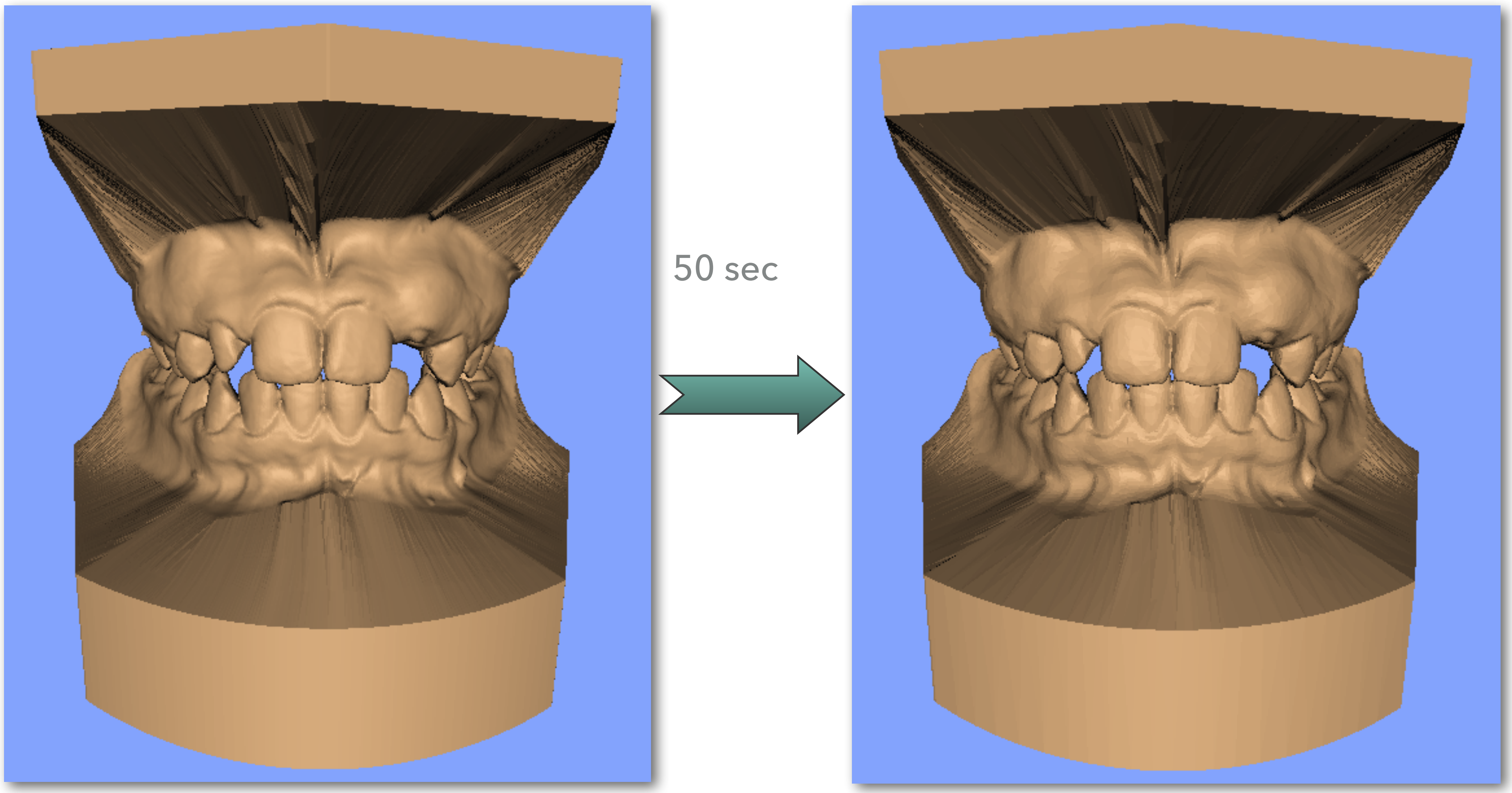
- An edge contraction moves two vertices to a single new location
- Measure how far this location is from the planes of the original faces
- 2D examples (planes are lines):





- Error ≡ sum of squared distances to planes associated with vertex

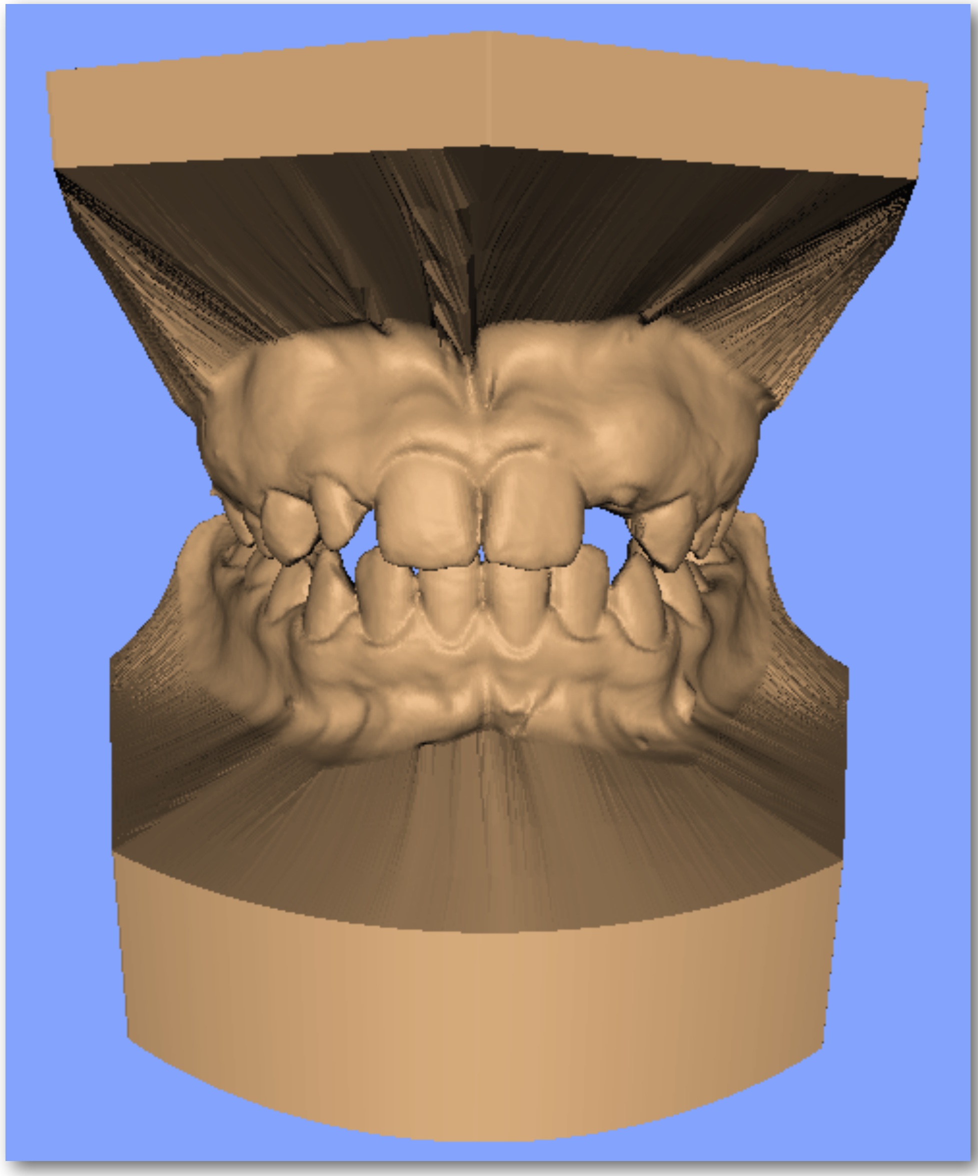
SAMPLE MODEL: DENTAL MOLD



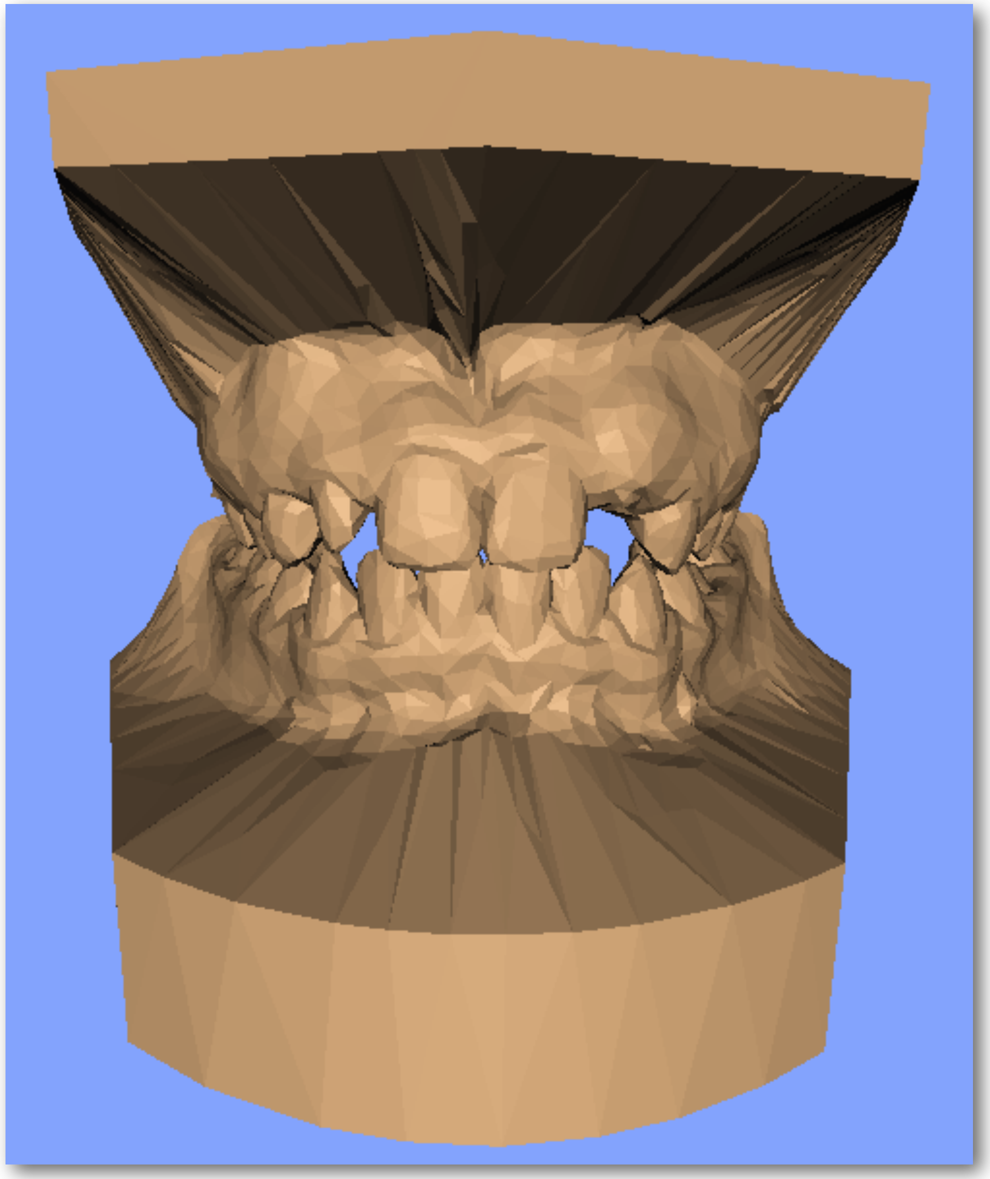
424,376 faces

60,000 faces

SAMPLE MODEL: DENTAL MOLD



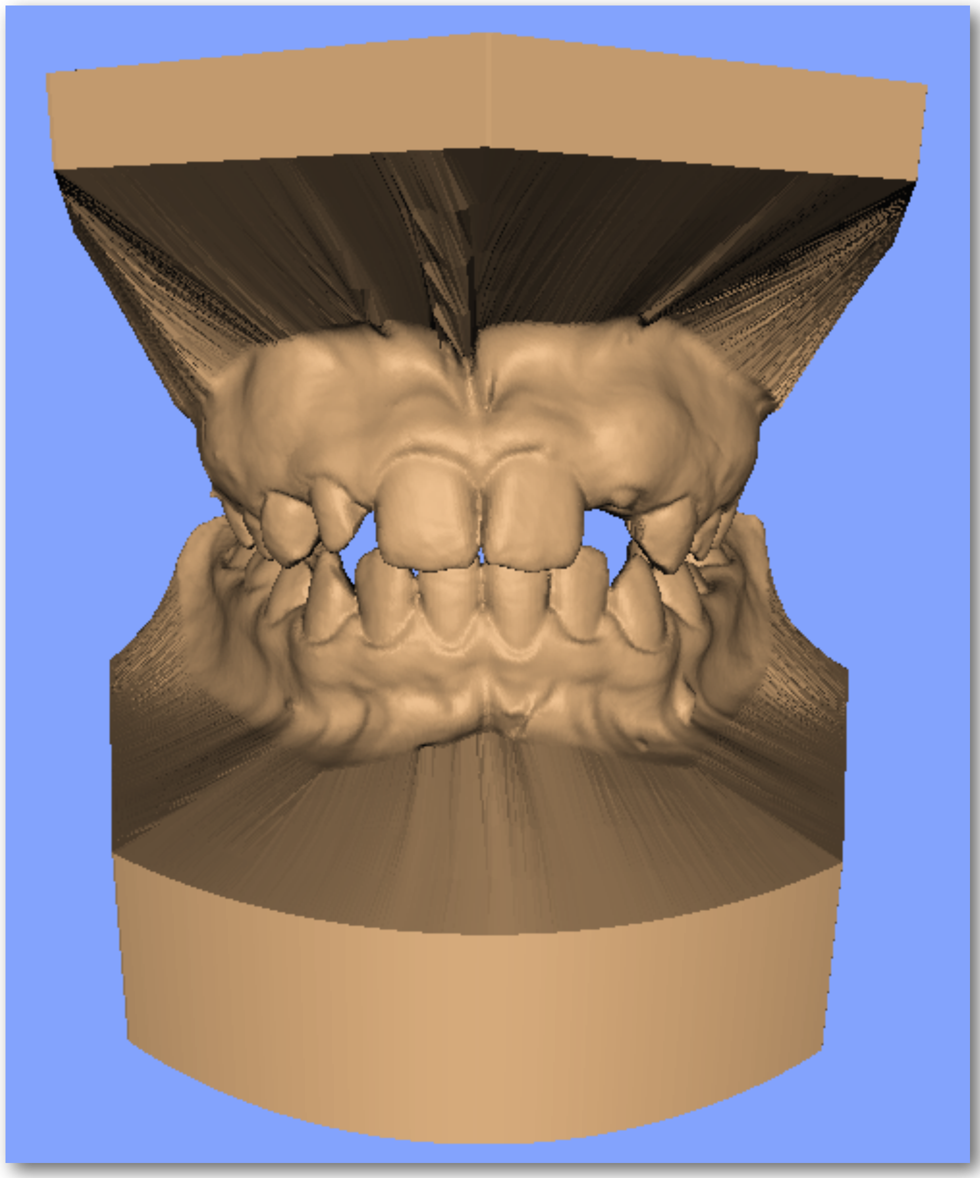
55 sec



424,376 faces

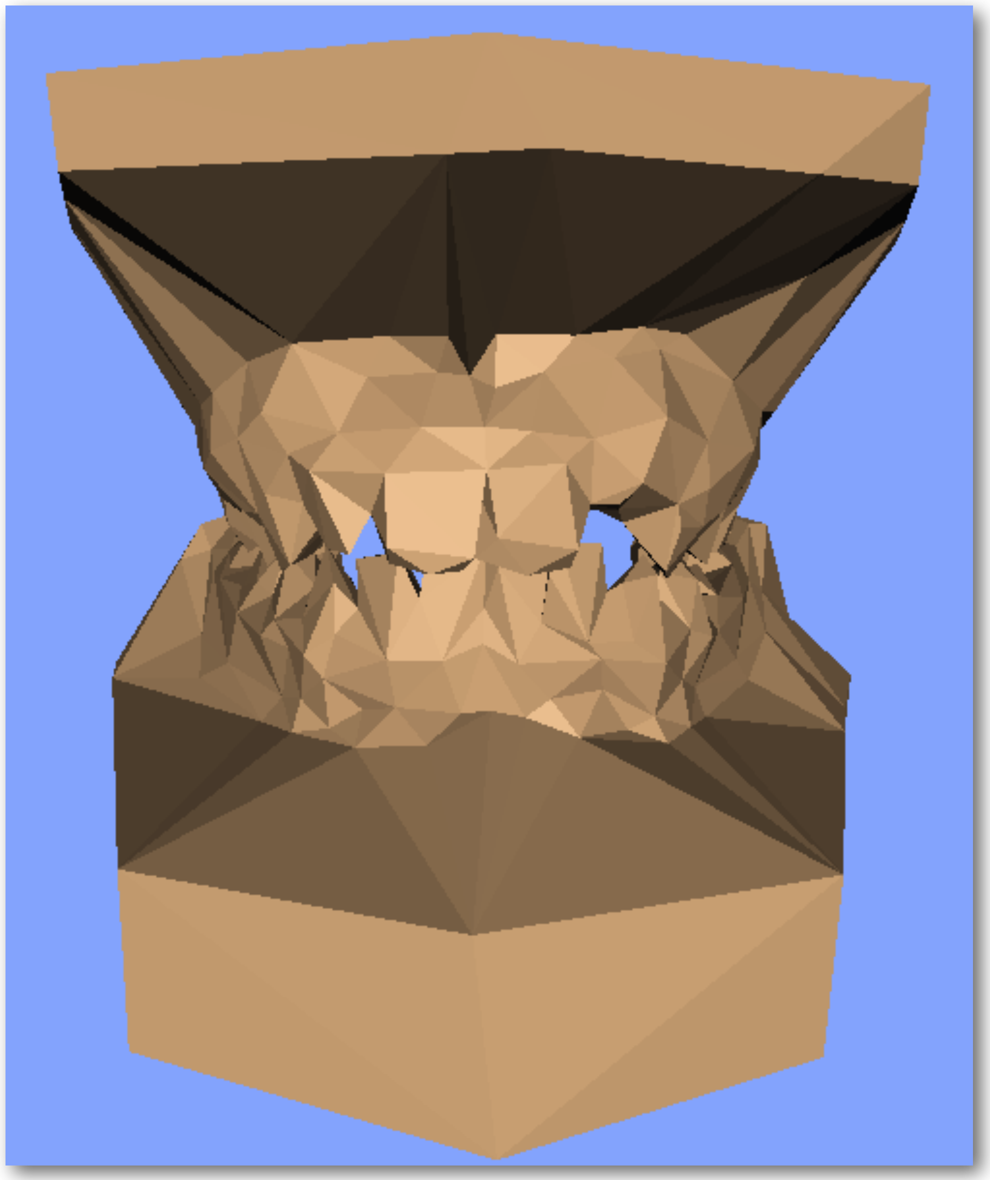
8000 faces

SAMPLE MODEL: DENTAL MOLD



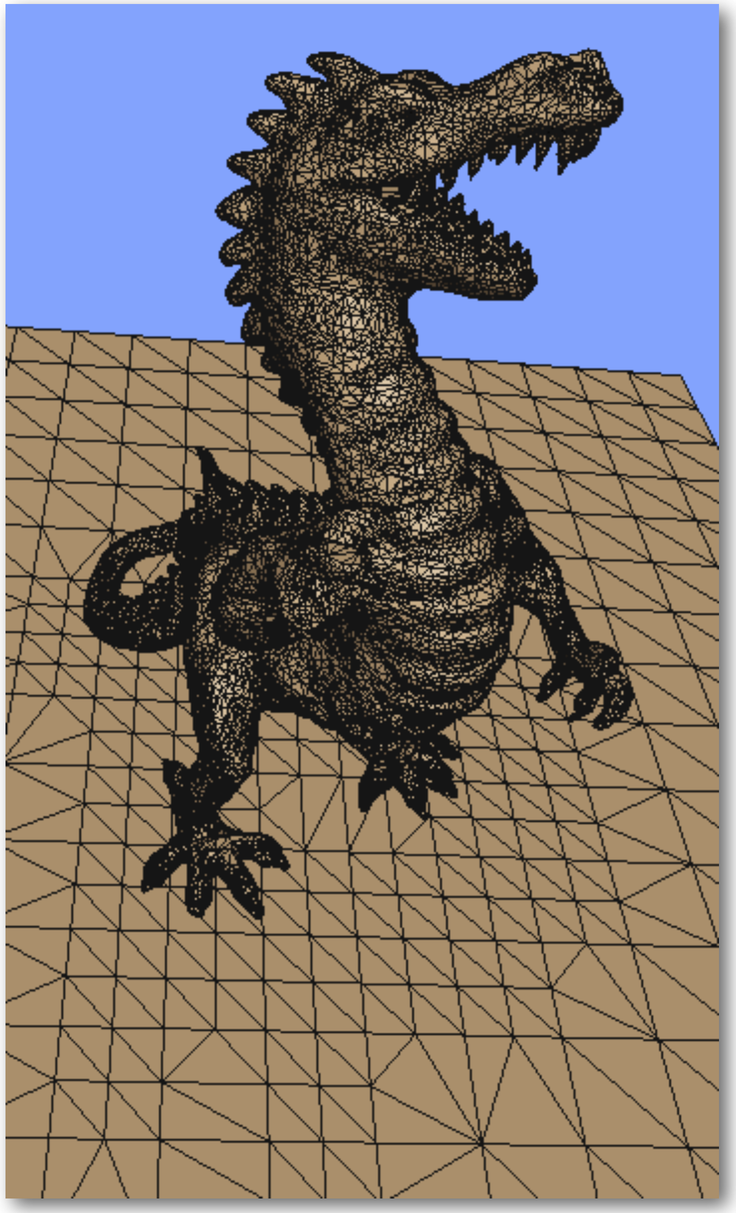
424,376 faces

56 sec



1000 faces

SHOULD ALSO CONSIDER MESH ATTRIBUTES

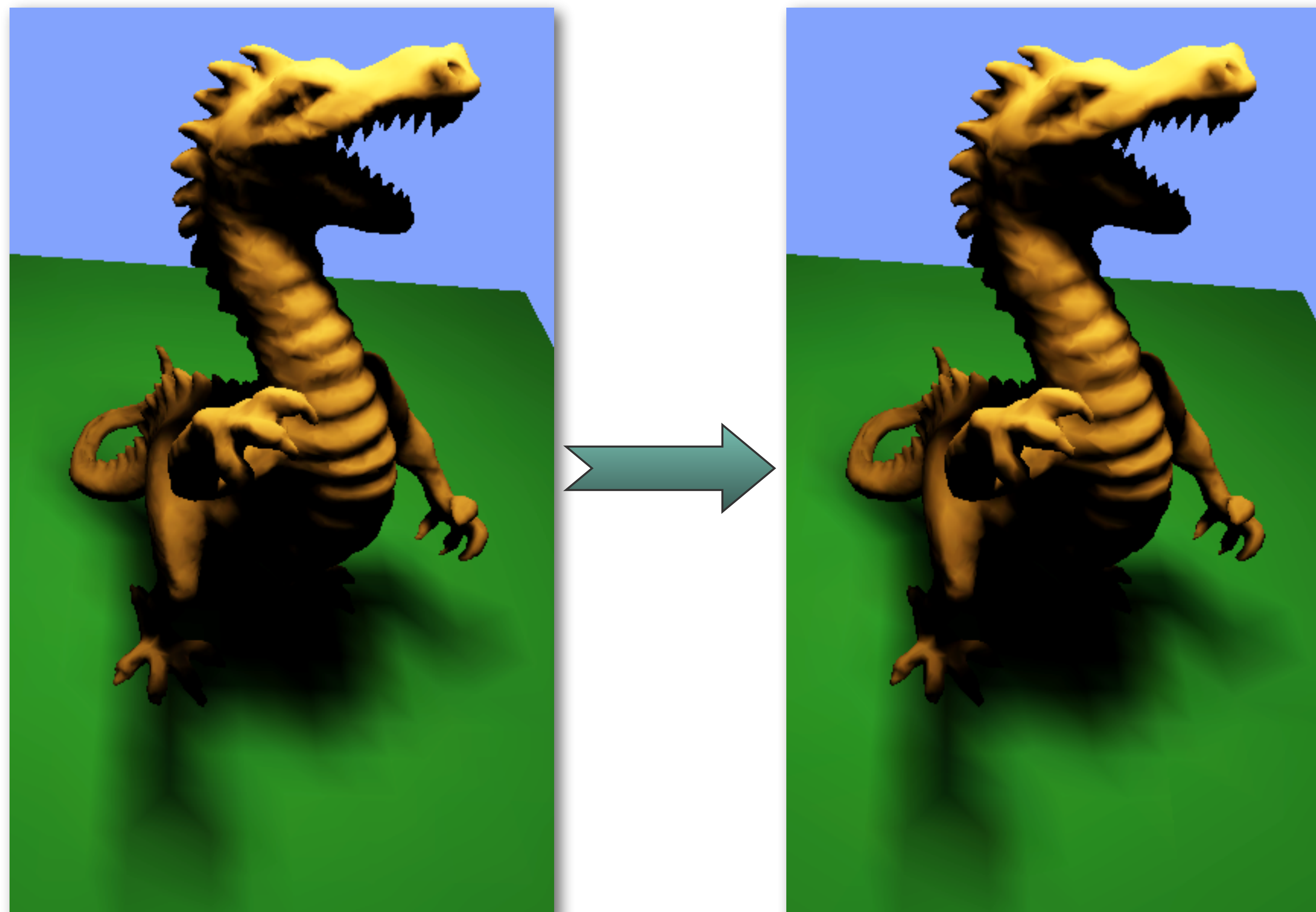


Mesh for solution

Radiosity solution

MUST ALSO CONSIDER ATTRIBUTES

- Add extra terms to plane equations for color information (or texture coords)
- Makes matrices and vectors bigger, but doesn't change overall approach



50,761 faces

10,000 faces

LOD SWITCHING

- When should we switch between LODs?
- How should we switch between LODs?

LOD SWITCHING

- Popping
  - Sudden change in appearance as models are swapped
  - If the object is at the switching distance, may flicker
- Popping Example:
  - Black Desert Online <https://www.youtube.com/watch?v=0ShwKAuRxbc>

HOW TO HANDLE POPPING?

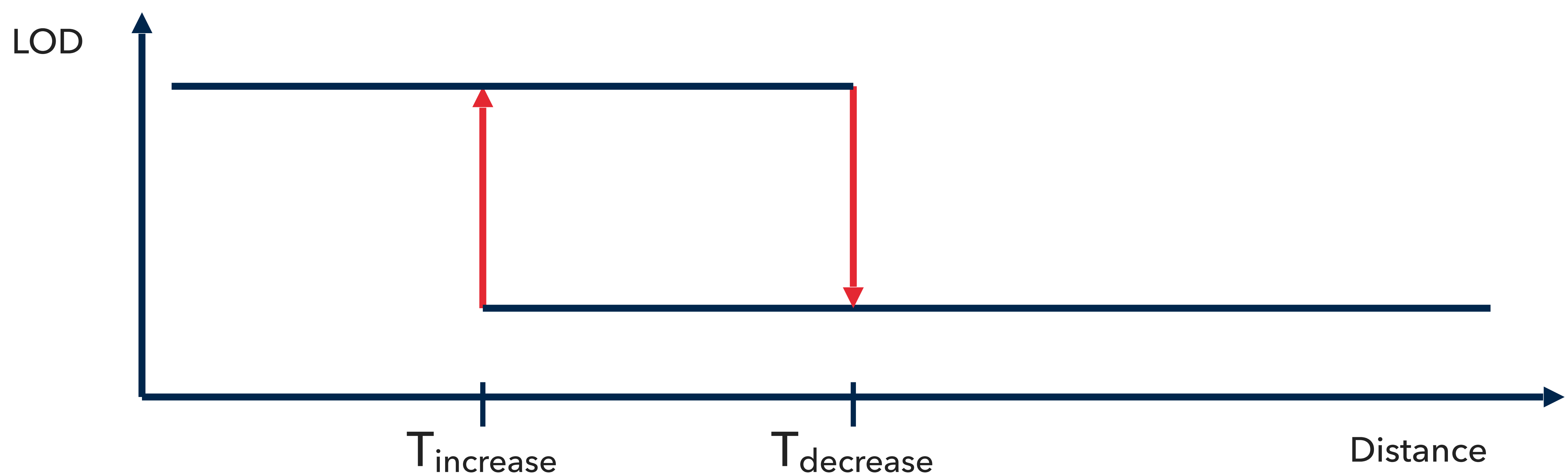
- Leave popping but try to avoid flicker
- Show a blended combination of two models, based on the distance between the switching points
  - Image blend – render two models at alpha 0.5 each
  - Geometric blend – define a way to geometrically morph from one model to the next, and blend the models
- Have more models that are so similar that the popping is not evident

HYSTERESIS THRESHOLDS

- Avoid rapid popping if the object straddles the threshold for switching
- Define two thresholds for each switch, distance as the metric
  - One determines when to improve the quality of the model
  - Other determines when to reduce it
  - Reduction threshold should be at a greater distance than the increase threshold
  - If the object is between the thresholds, use the same LOD as on the previous frame

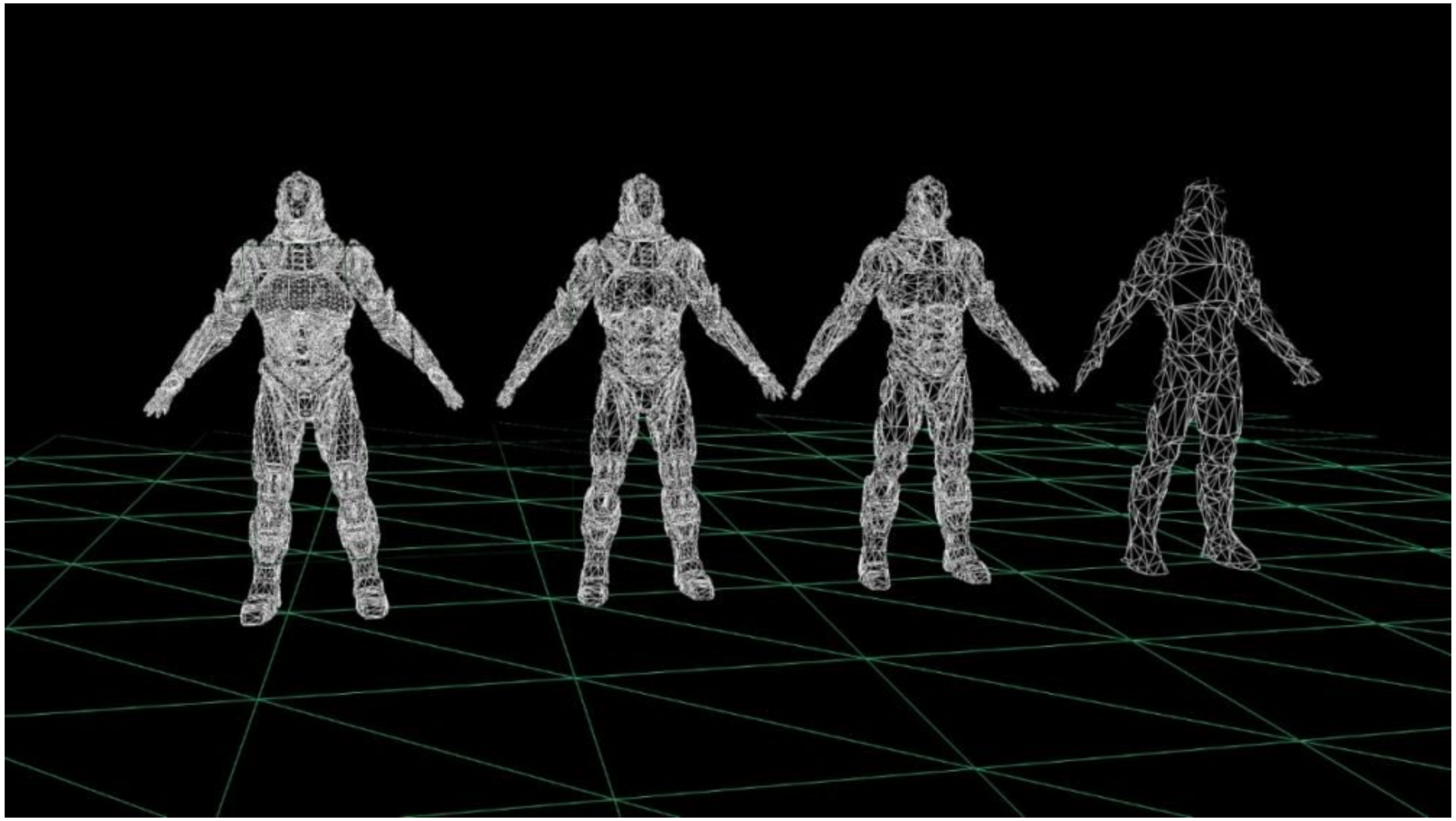
HYSTERESIS ILLUSTRATION

- Imagine an object repeatedly jumps from one position to a nearer one and then back again
    - How far must it jump to exhibit popping?
- One way to think about it: If you're on one level, you can only ride the arrows to the next level



INDUSTRY LOD TOOL: SIMPLYGON

- Widely used automatic 3D optimization tool



- http://www.gdcvault.com/play/1020666/Optimize-your-3D-Assets-with
- https://www.youtube.com/watch?v=Tzvw6Df5pnI