Automatic Shader Level of Detail

Marc Olano – UMBC
Bob Kuehne – SGI
Maryann Simmons – SGI

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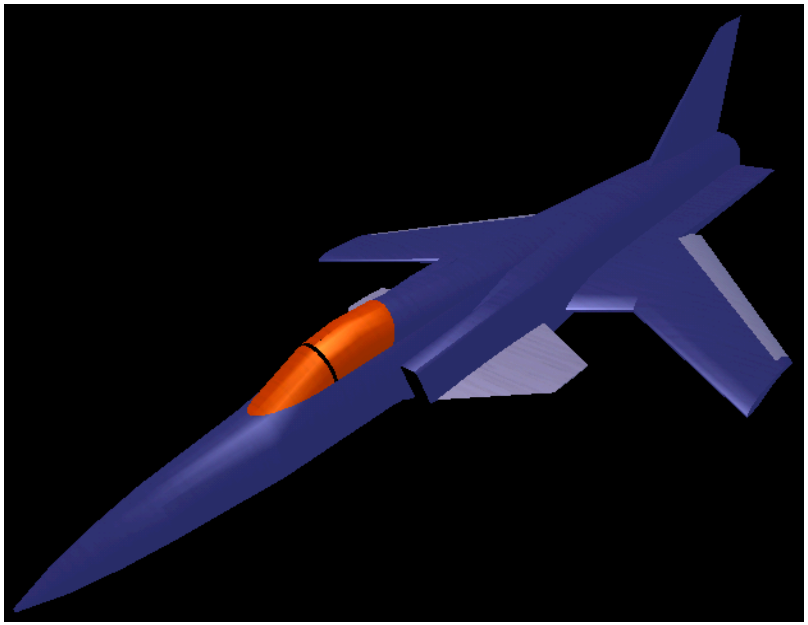
What is Shading

- Ultimate control of appearance
- Programmable
  - Arbitrary computation
- Procedural
  - Simple procedures
  - High-level language

Interactive Rendering

- Illusion of Presence
  - 10 – 30 – 60 frames per second
  - Immediate response
  - Simple appearance
- Shading HW
  - ISL, GLslang, Cg, HLSL



Uses for Real-Time Shading

- More realistic appearance
  - Automotive styling
- Visualization
  - Data fields on surfaces
- Non-realistic appearance
  - Games, Illustration

Non-Real Time / Real Time

- Not Real-Time
  - General CPU
  - Seconds to hours per frame
  - Thousand line shaders
  - “Unlimited” computation, texture, memory, …
  - [Cook84] [Perlin85] [Hanrahan90]
- Real-Time
  - Graphics HW
  - Tens of frames per second
  - Thousand instruction shaders
  - Limited computation, texture, memory, …
  - [Rhoades92] [Olano98] [Peercy00] [Proudfoot01] [Mark02]

Stretching the Limits

- Want for shading
  - Expensive shaders: good up close
  - Real-time performance
  - Lots of objects
- Similar to geometric models
  - Detailed models: good up close
  - Real-time performance
  - Lots of objects

Geometric Level of Detail

- Multiple representations of object
- Differing complexity
- Choose based on distance, screen size, rendering budget, …
  - [Clark76] [Funkhouser93]

Image Removed: Figure 3.3
Thomas Funkhouser, *Database and Display Algorithms for Interactive Visualization of Large Architectural Models*, PhD Thesis
Computer Science Division, UC Berkeley
September 1993

Shader Level of Detail

- Multiple representations for shader
  - [Goldman97] [Apodaca00] [Olano02]
- Differing rendering cost
- Similar considerations for level

Geometric Simplification

- Start with complex model

Geometric Simplification

- **Automatically** create new models
  - Collapse, merge, volumetric, …
- Separate models or progressive mesh [Hoppe96]

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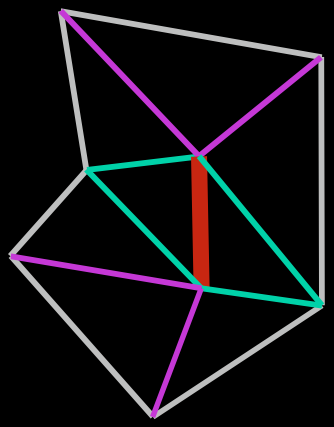
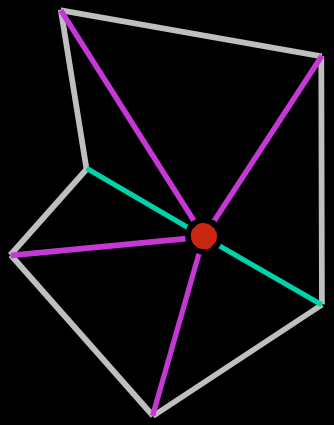
Hughes Hoppe, "Progressive Meshes," SIGGRAPH '96





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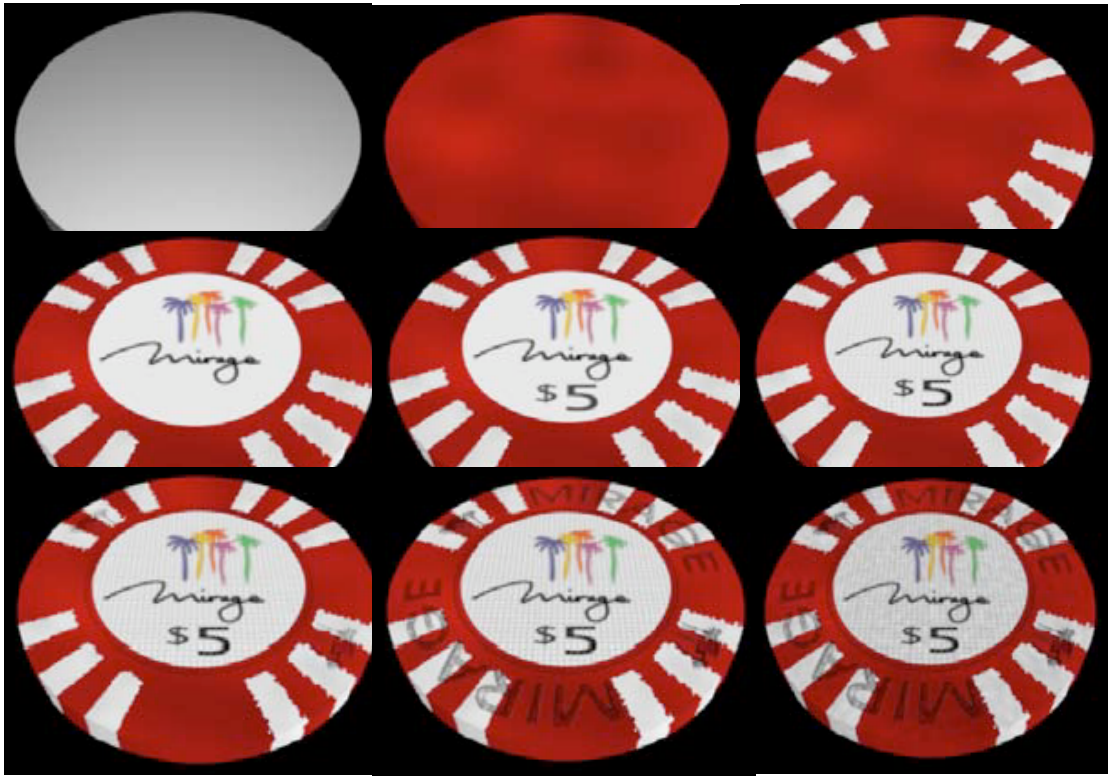
Geometric Simplification

- Evaluate possible collapse costs
- Choose least-cost remaining
  - Top of heap / full sort not necessary
- Re-evaluate changed costs
  - Usually local
  - Collapse moves monotonically toward goal, no backtracking

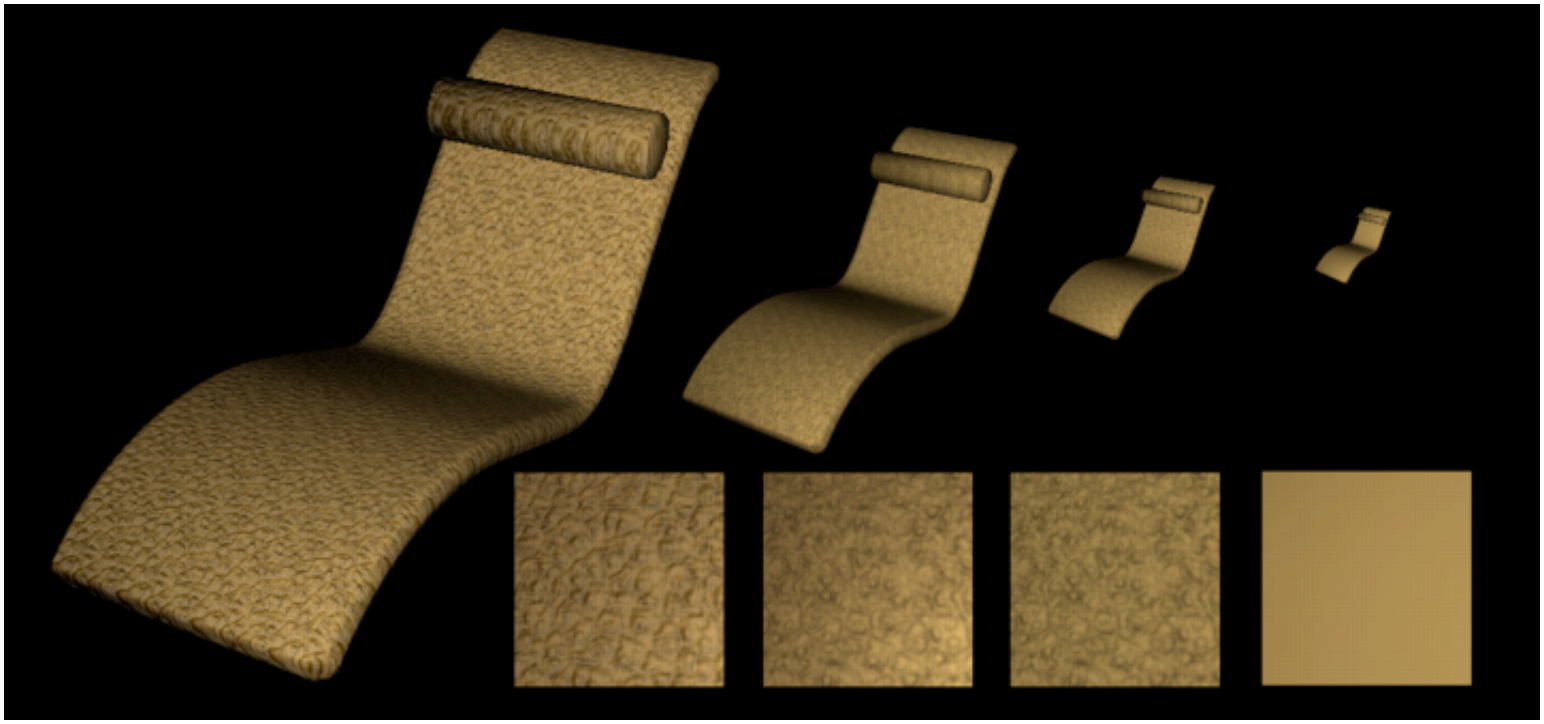
Shader Simplification

- Start with complex shader
  - Typically built in layers [Apodaca00]



Shader Simplification

- LOD building blocks [Olano01]
  - After [Cook84] [Abram90]
  - Bump, BRDF, Fresnel, …



Automatic Simplification

- Goal
- Simplification operation
  - Guaranteed convergence
- Cost function

Simplification Goal

- Reduce texture accesses
  - Direct benefit on most hardware
  - Indirectly reduces instruction count
  - Indirectly reduces active textures

Simplification vs Optimization

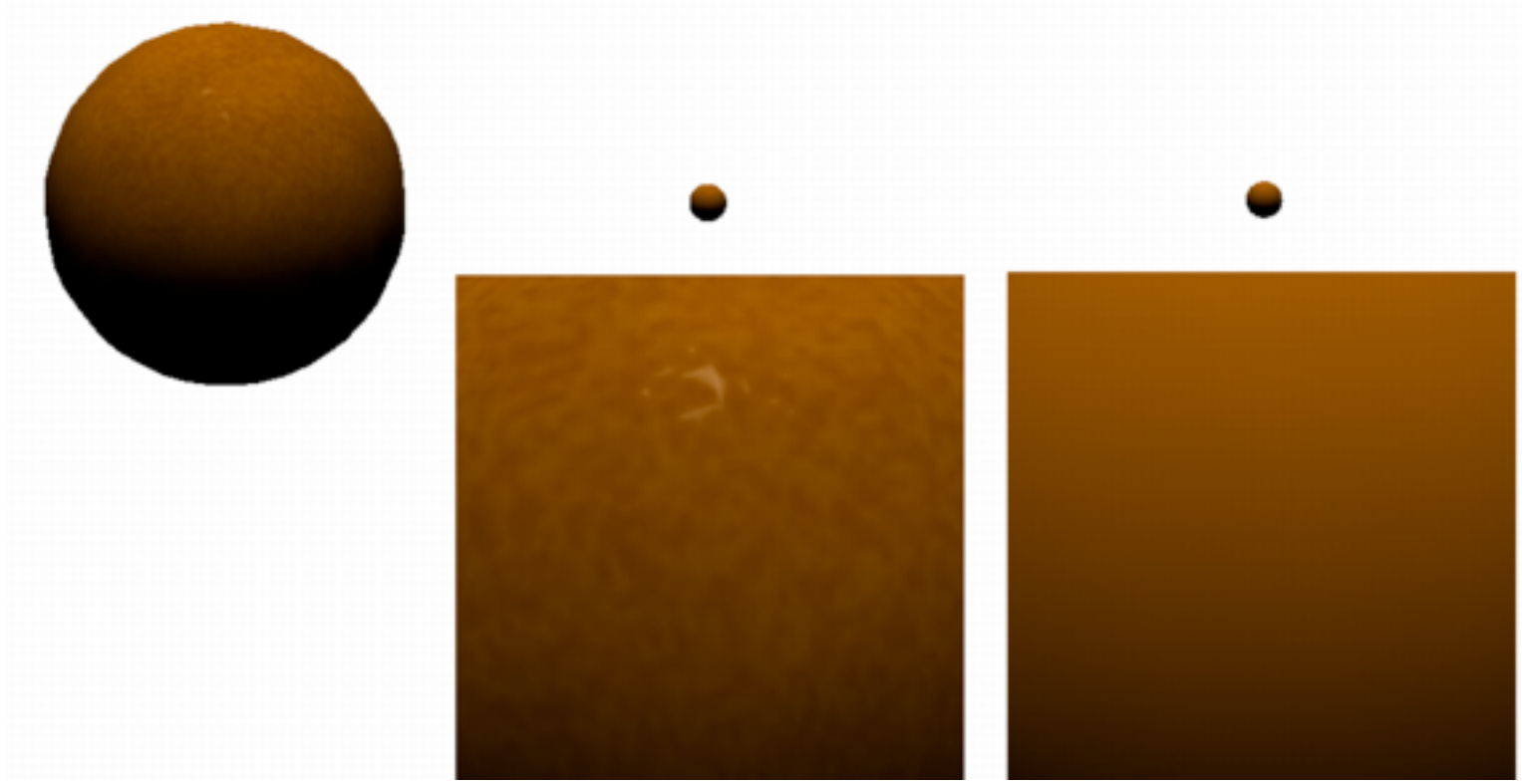
- Simplification
  - Rewrite to reduce cost
  - Allow possible loss of fidelity
- Optimization
  - Rewrite to reduce cost
  - Must produce identical result

Simplification operations

- Lossless
  - Identical results: optimization
- Resolution-specific lossless
  - Resampling errors only
- Lossy
  - Approximation errors

Simplification operations

- Texture Removal
- Texture Collapse



Texture Removal

- Replace texture with non-texture approximation
  - Lossy
  - Cost = RMS error at MIP level
- Demonstrated
  - Replace texture with constant
- Future
  - Replace environment w/ Phong
  - Replace texture with built-in operation

Texture Collapse

- Replace static sequence of operations **including at least one texture** with one new texture
- Similar to *specializing shaders* [Guenter95]
- Demonstrated
  - Lossless: single texture resolution
- Future
  - Resolution-specific lossless
  - Choose new size & resample

Results

Access	Active	Reduction	Speedup
45	14	0.00	1.0
23	11	0.49	1.8
9	5	0.80	1.9
0	0	1.00	2.3

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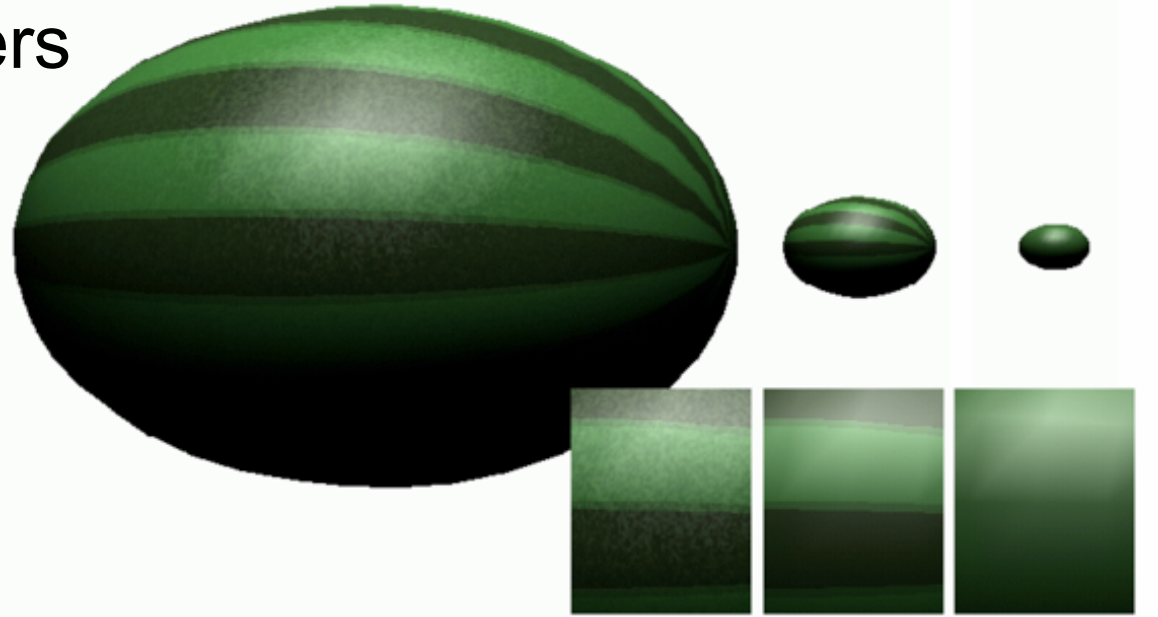
Observations

- RMS error at MIP level
  - Measure of error and frequency
- Possible error amplification
  - Solvable / not problem for most shaders



Observations

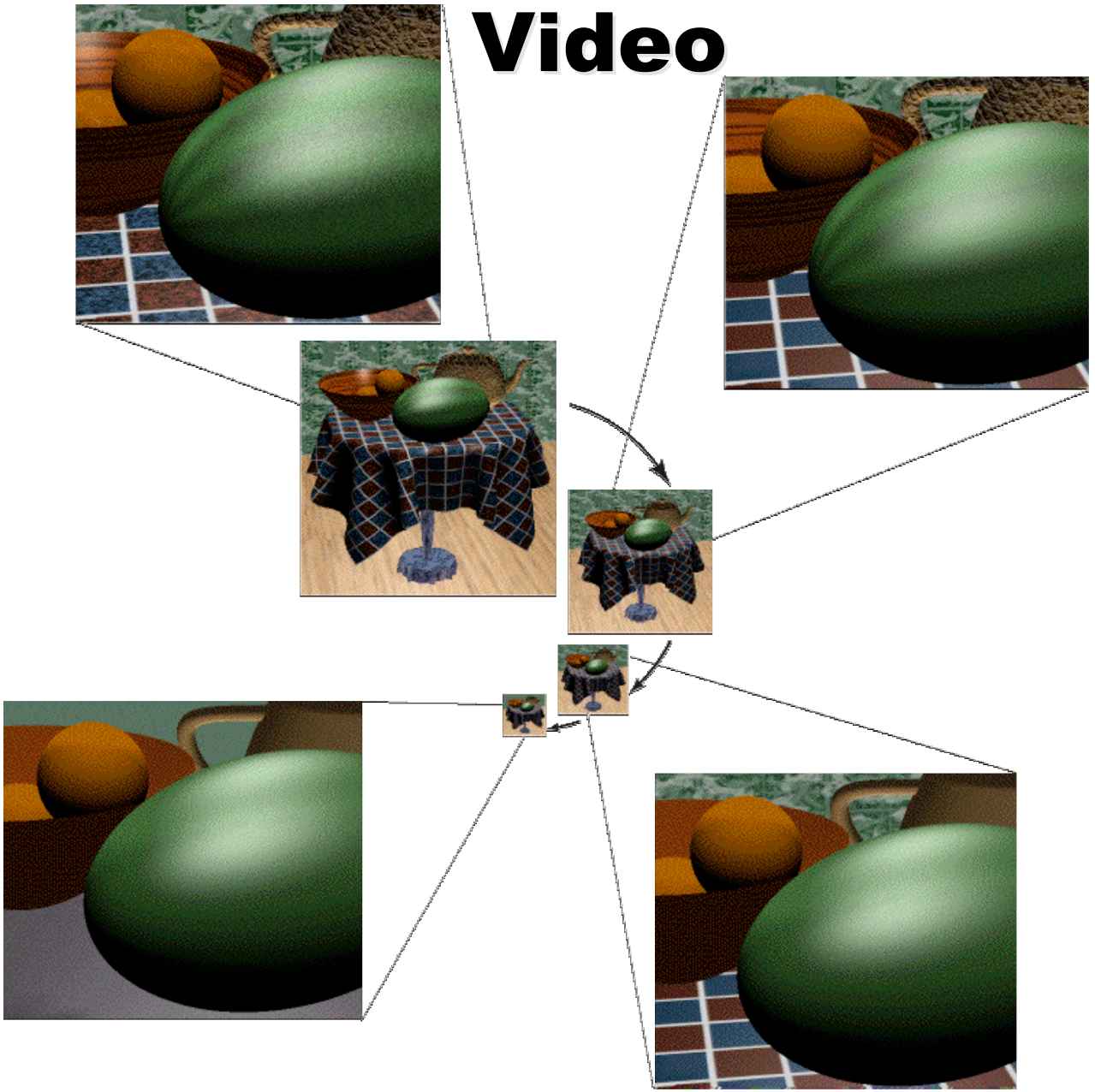
- Early antialiasing
  - Similar to automatic antialiasing [Perlin98] [Heidrich98]
  - Modify for NPR?
- Collapse enables Removal

System Interface

- SGI OpenGL Shader
- Source: ISL
- Simplify if *autoLOD* present
- Output: Single compiled shader

```
if (autoLOD < threshold1)
    original_shader
else if (autoLOD < threshold2)
    simplified_once
else
    simplified_twice
```

Video



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Conclusions

- Shader simplification
  - Possible, practical, useful
  - Necessary?
- General framework
  - modeled on geometric simplification
- Implementation
  - modeled as lossy compiler optimization

See Also

- Sketch: Per-Pixel Smooth Shader Level of Detail, Maryann Simmons and Dave Shreiner
  - Wednesday 10:30 Session
  - Convention Center Room 30 A-D

Future work

- Track error amplification
- Extend existing operations
- Consider other costs & goals
  - Reduce instructions: replace with texture
- Generalize for NPR
  - User-provided operations?
- Couple with geometric LOD