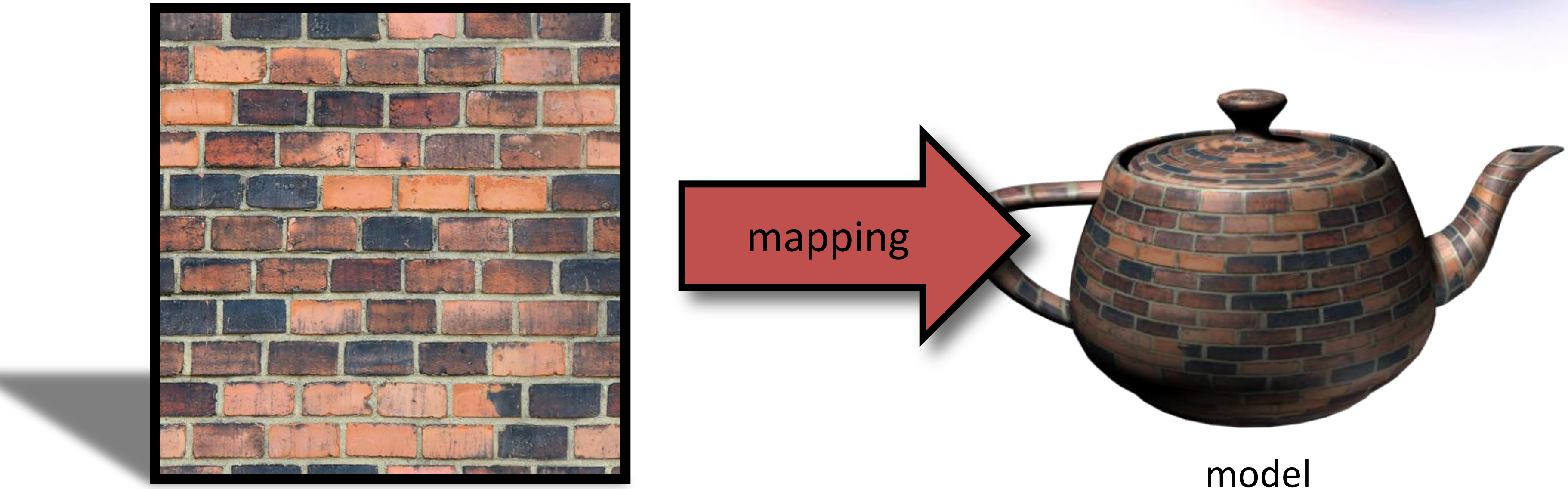
Mesh Colors

Cem Yuksel
Texas A&M University

John Keyser
Texas A&M University

Donald H. House
Clemson University

Texture Mapping



texture

mapping

model

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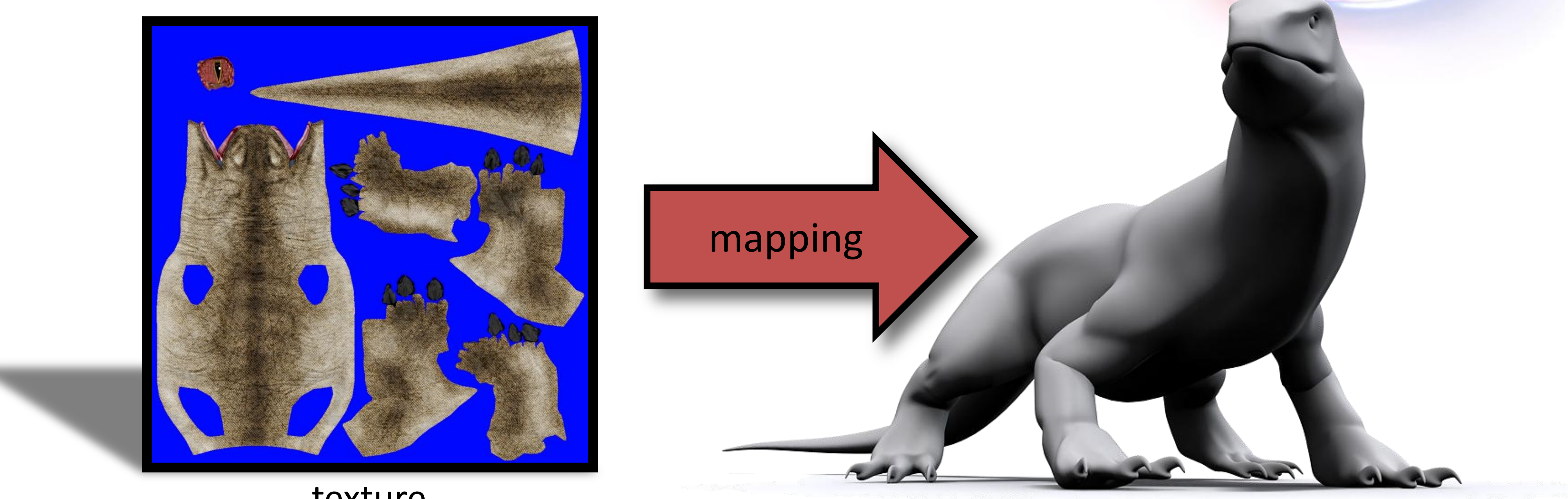

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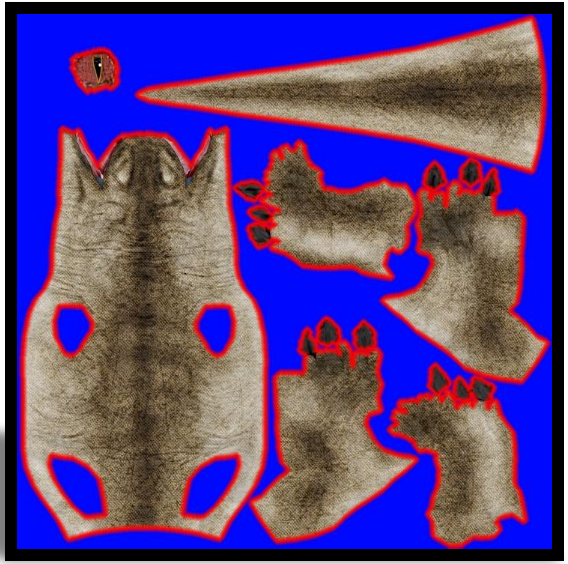
Texture Mapping

1 Parameterization



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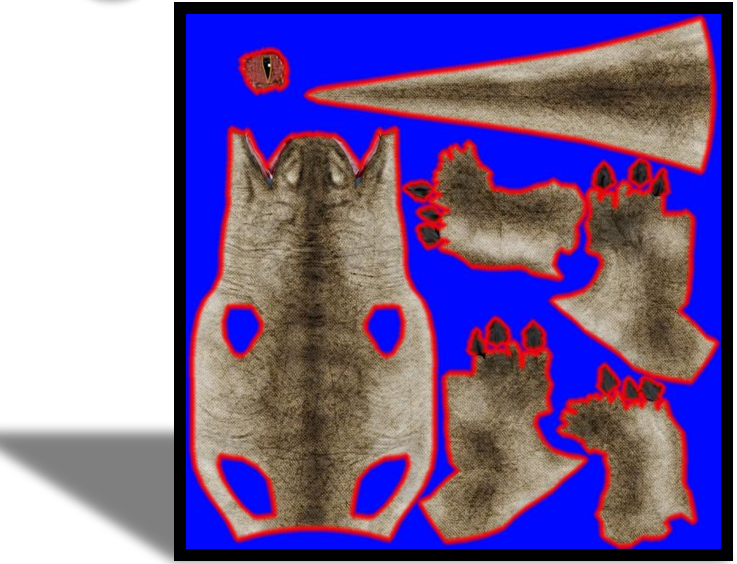
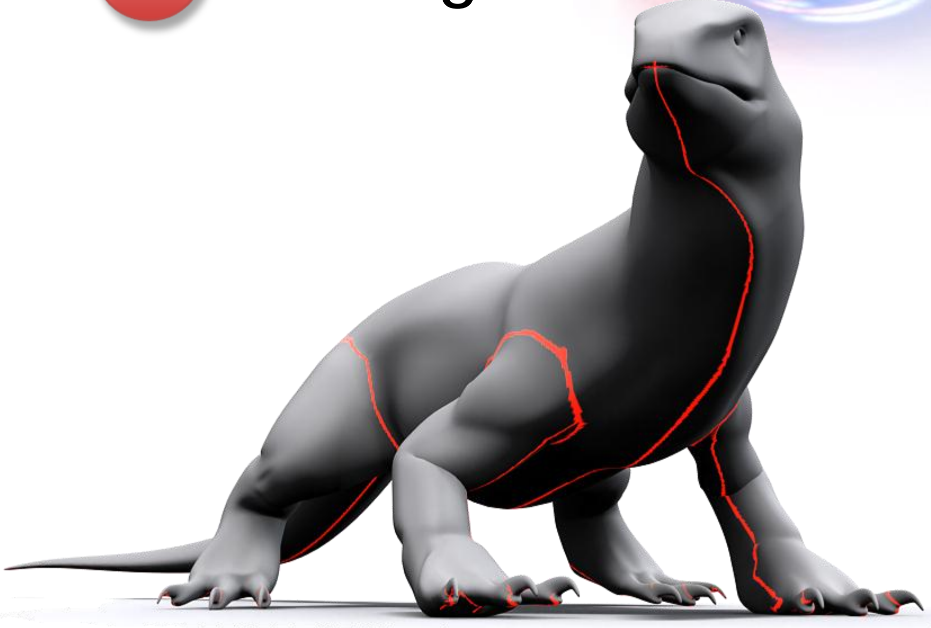


2 Filtering



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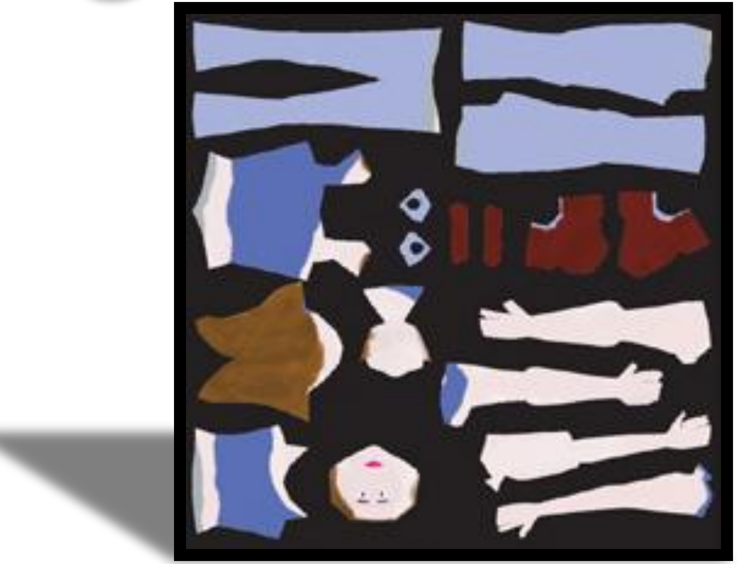

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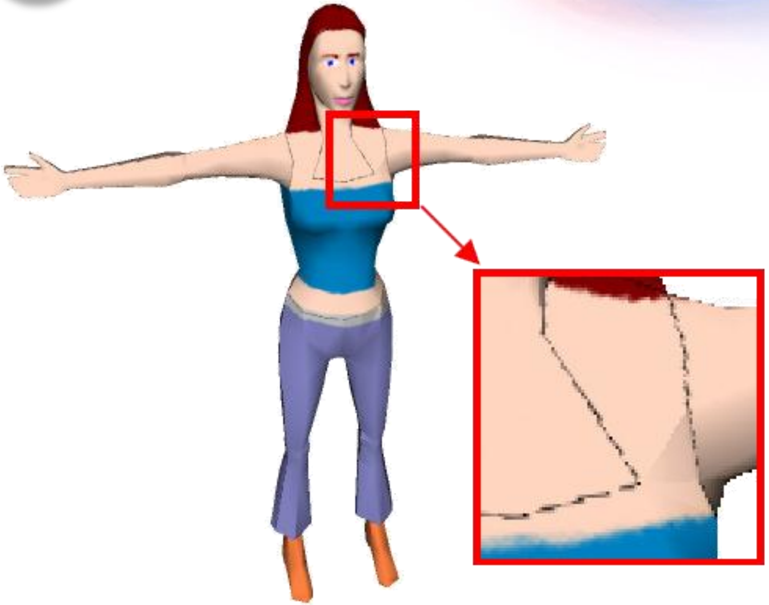

[Lefebvre et al. 2005]

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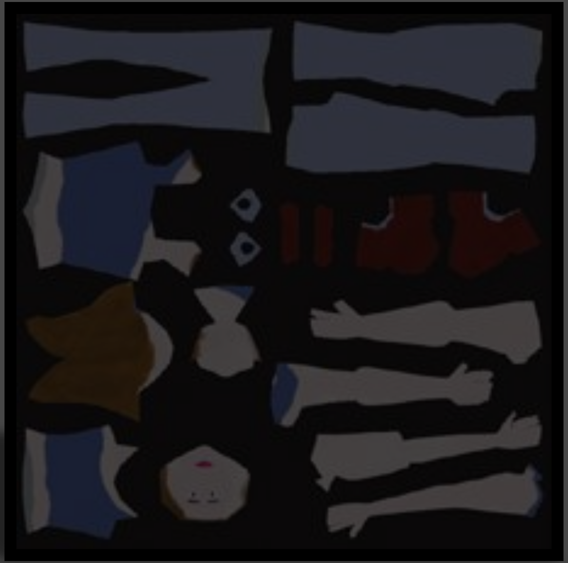

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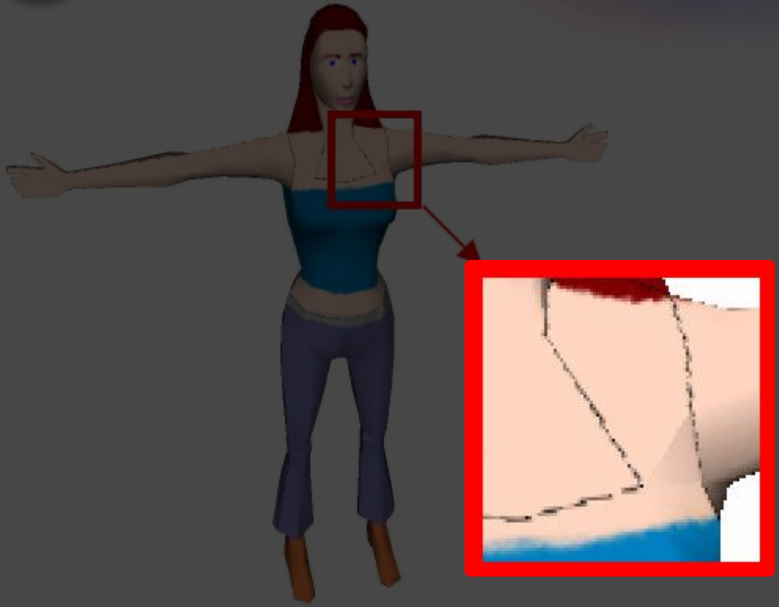

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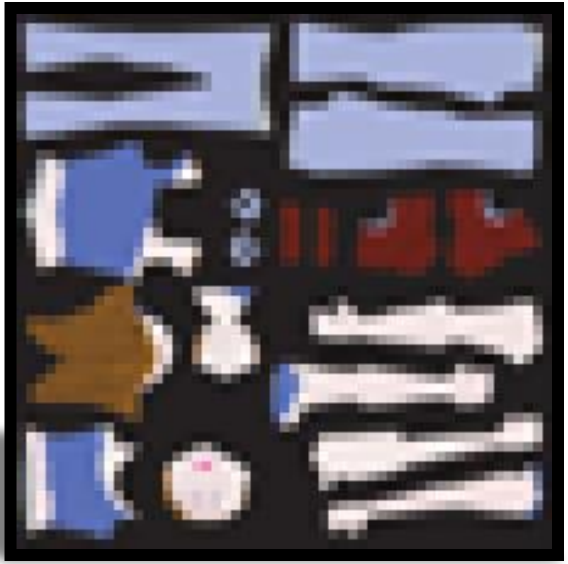

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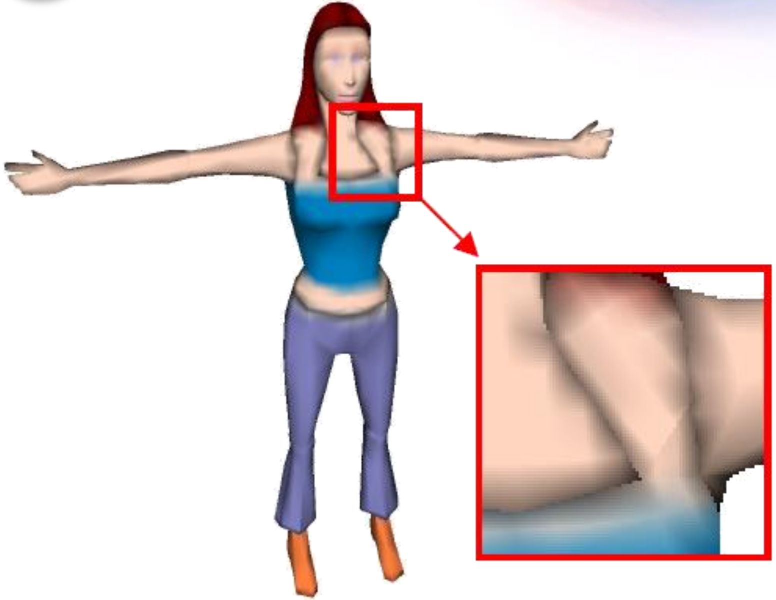

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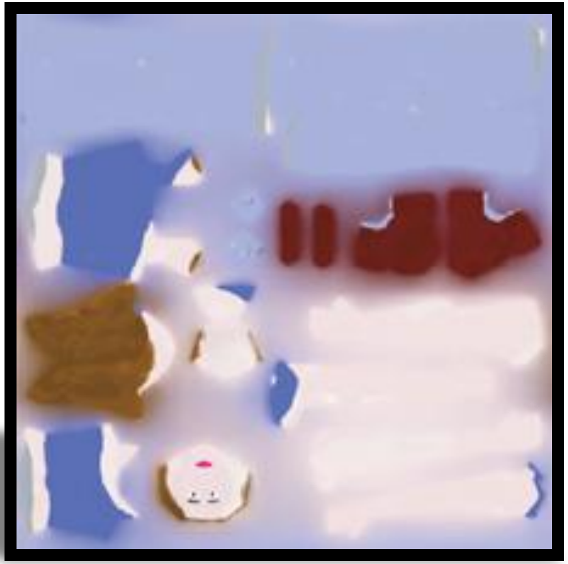

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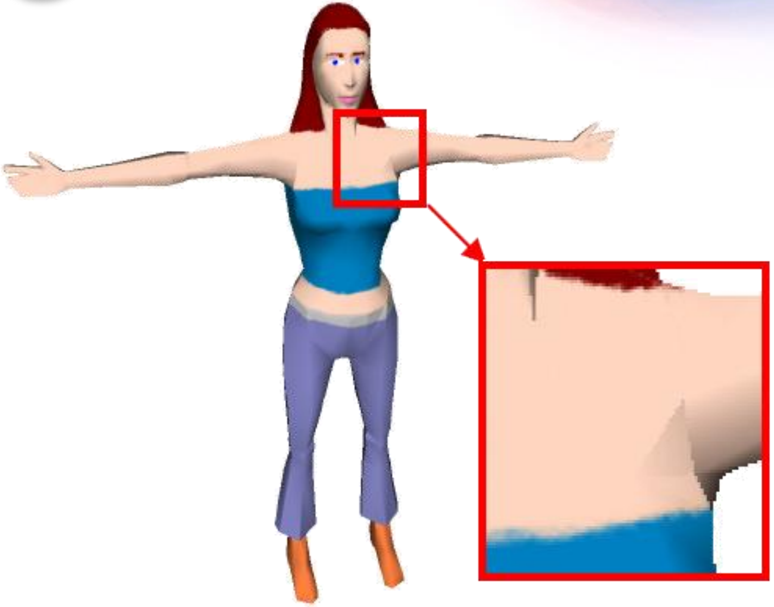

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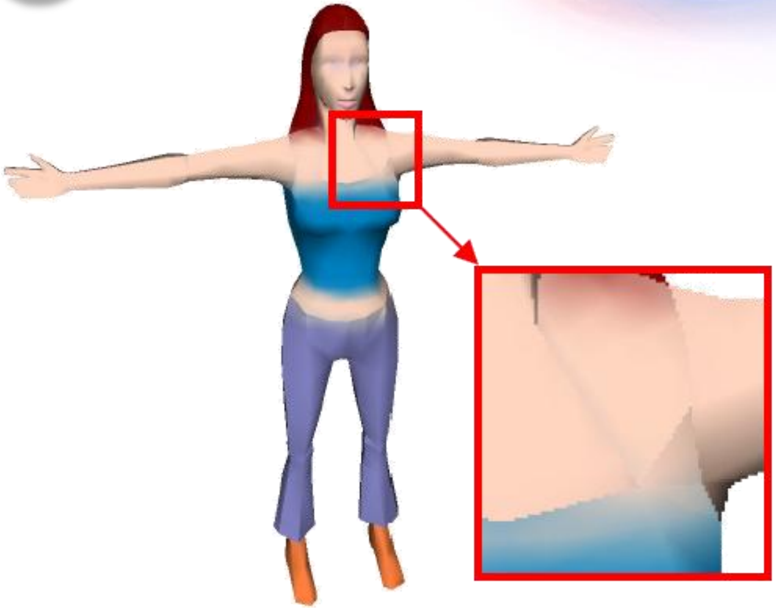

[Lefebvre et al. 2005]

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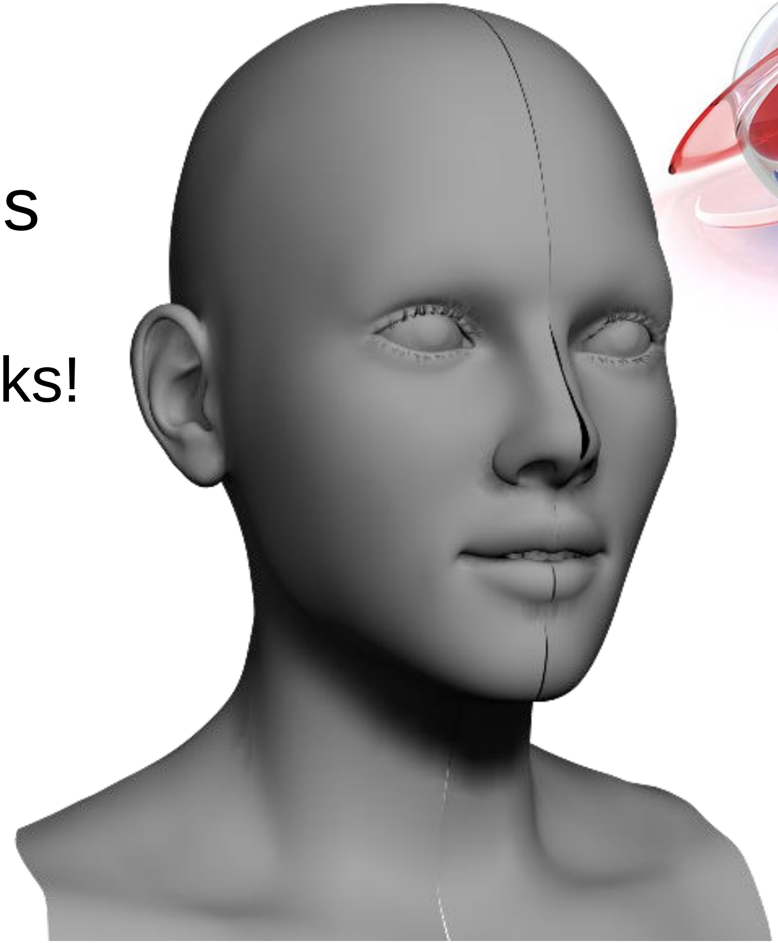
Texture Mapping

- Displacement Maps
  - Inconsistencies at seams cause cracks!



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Texture Mapping

- 2D Textures
  - Automatic planar parameterization

    [Ma and Lin 1988; Bennis et al. 1991; Maillot et al. 1993; Zhang et al. 2005; Lévy and Mallet 1998; Hunter and Cohen 2000; Piponi and Borshukov 2000; Haker et al. 2000; Lévy et al. 2002; Sheffer and Hart 2002; Zhang et al. 2005]
  - Guaranteed one-to-one mapping

    [Hormann and Greiner 1999; Sheffer and de Sturler 2000; Sander et al. 2001; Floater 2003]
  - User defined constraints

    [Lévy 2001; Desbrun et al. 2002; Kraevoy et al. 2003]
  - Higher resolution for detailed areas

    [Sloan et al. 1998; Balmelli et al. 2002; Sander et al. 2002; Carr and Hart 2004; Igarashi and Cosgrove 2001]

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Texture Mapping

- 2D Textures
  - Seams: Interpolation artifacts
  - Duplicated color values
  - Problems with MIP-map filtering
  - No local texture detail adjustment
  - Very sensitive to model topology

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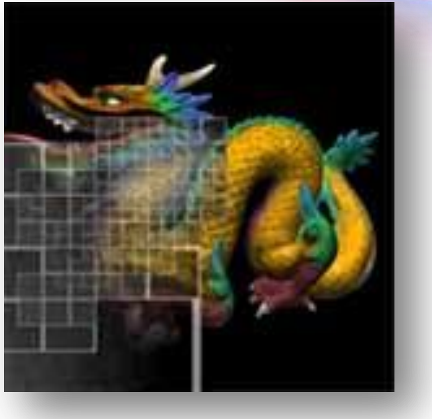
Texture Mapping

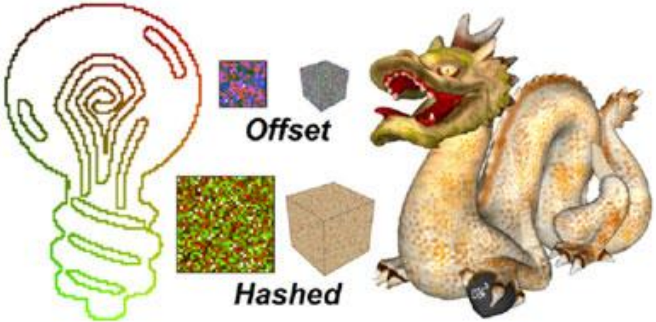
- 3D Textures
  - Octree Textures

    [Benson and Davis 2002; DeBry et. al. 2002]

  - Hash Textures

    [Lefebvre and Hoppe 2006]





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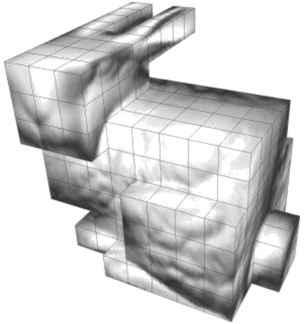
Texture Mapping

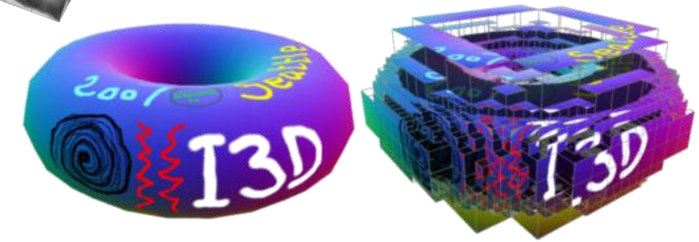
- Other Methods
  - **Polycube maps**

    [Tarini et. al. 2004]



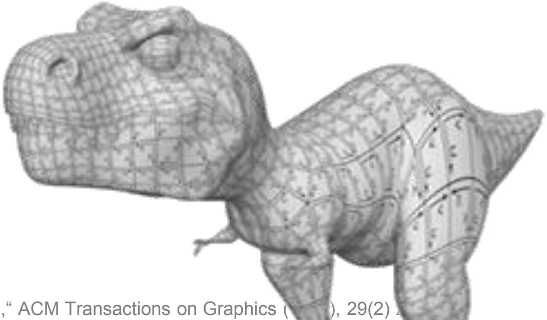
  - **Tile trees**

    [Lefebvre and Dachsbacher 2007]



  - **Ptex (per-face textures)**

    [Burley and Lacewell 2008]



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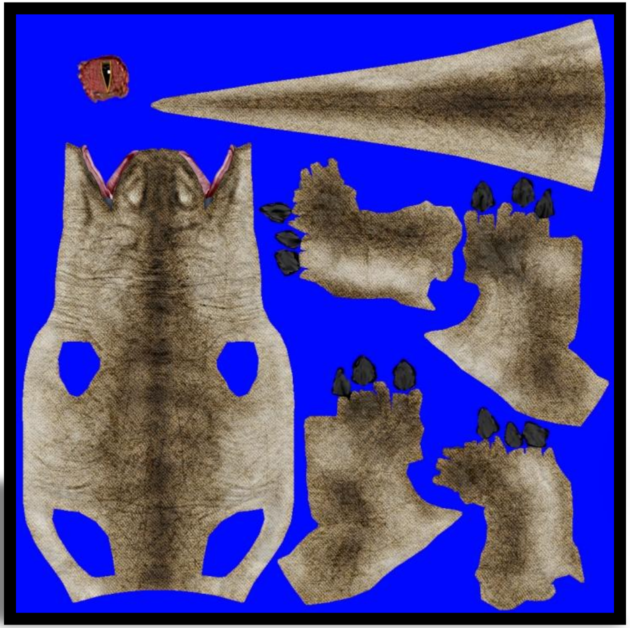
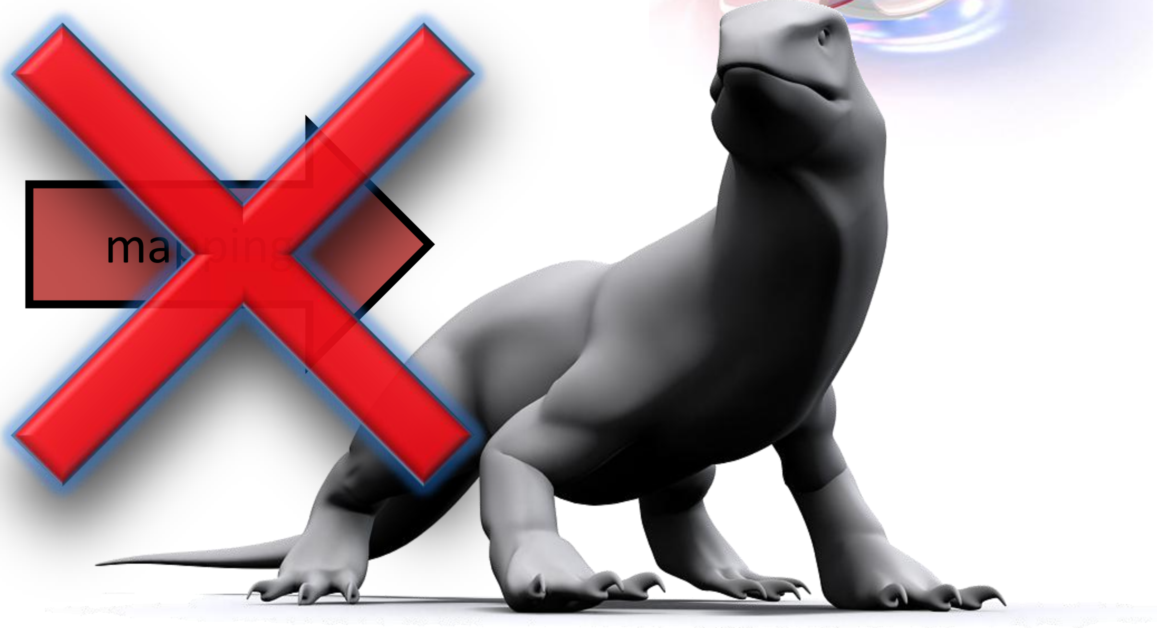
Texture Mapping



texture



model

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Mesh Colors

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Mesh Colors

- Properties:
  - No mapping
  - No discontinuities (no seams)
  - Guaranteed one-to-one correspondence
  - Correct MIP-map filtering
  - Local resolution adjustment
  - Permits model editing and subdivision
  - Compatible with current graphics pipeline

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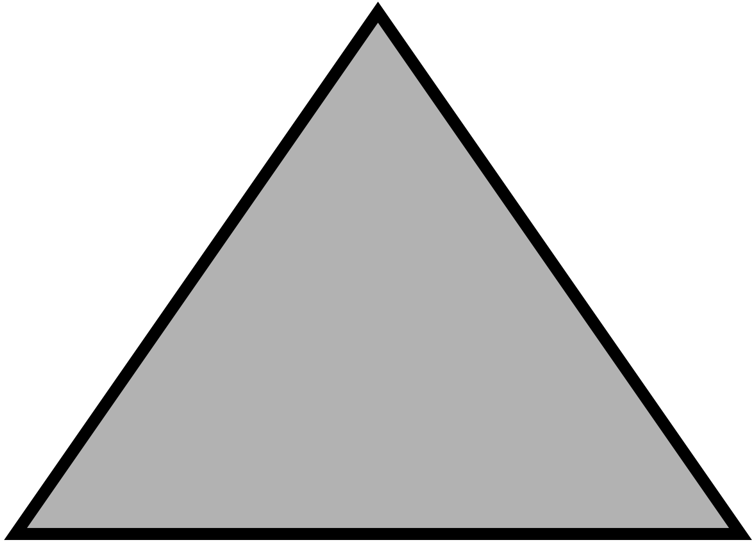
Mesh Colors



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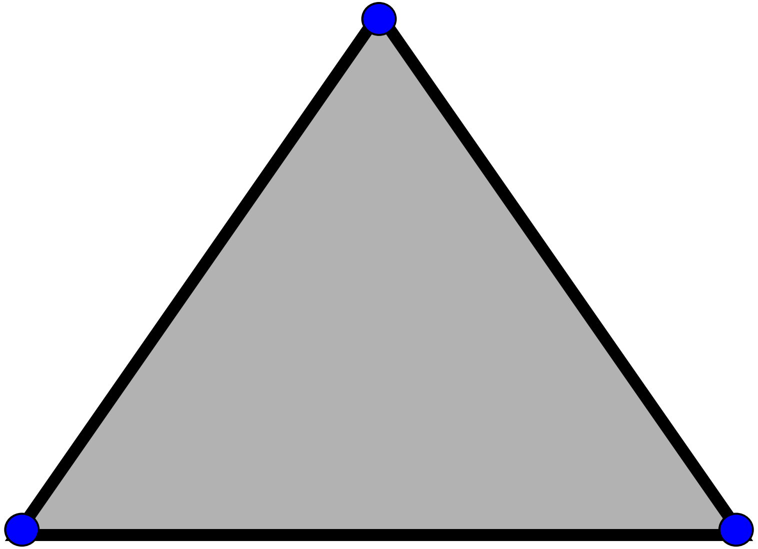
Mesh Colors

- $R = 1$
- Vertex colors



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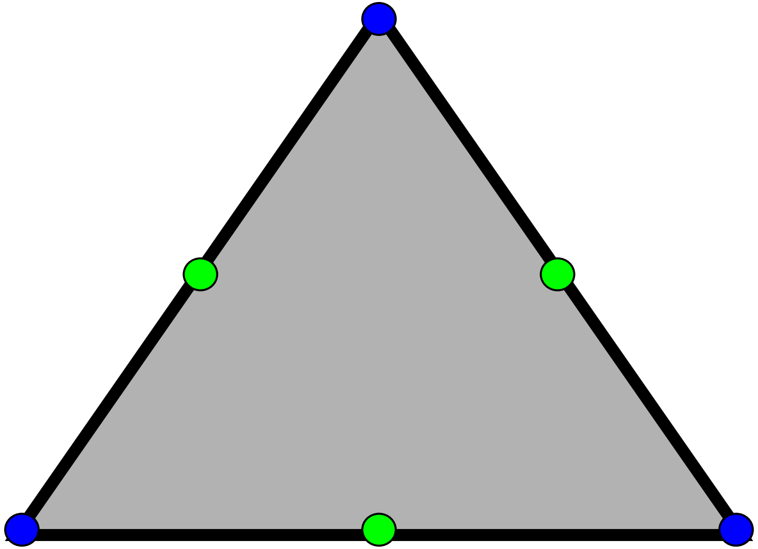
Mesh Colors

- $R = 2$
- Edge colors



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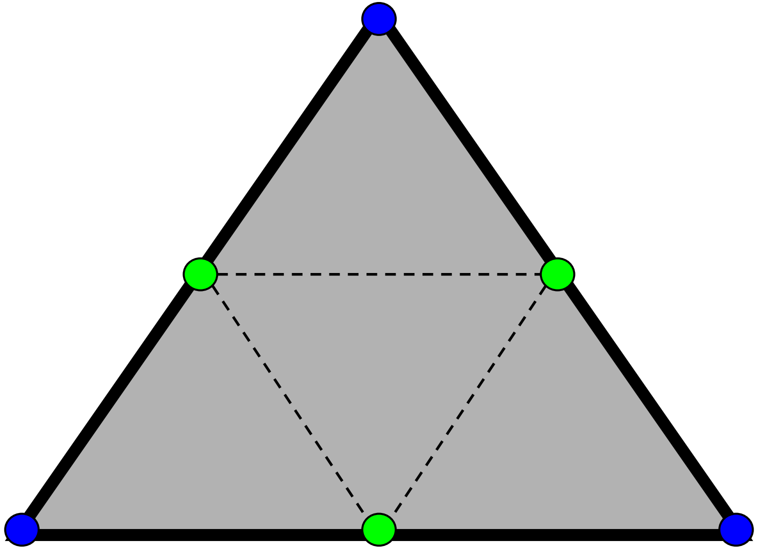

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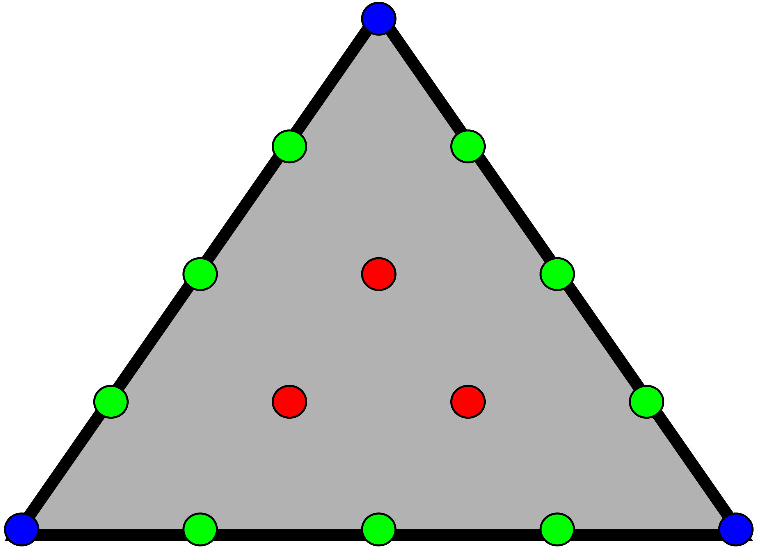
Mesh Colors

- $R = 4$
- Face colors



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Mesh Colors

- $R = 4$
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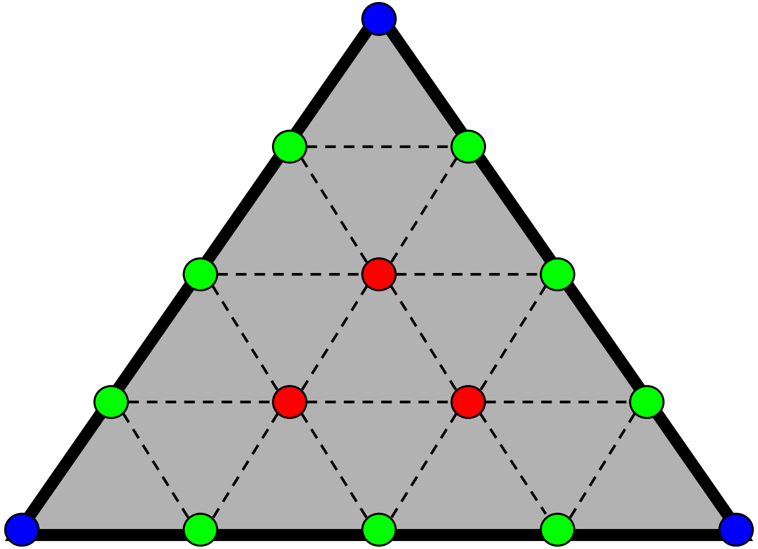

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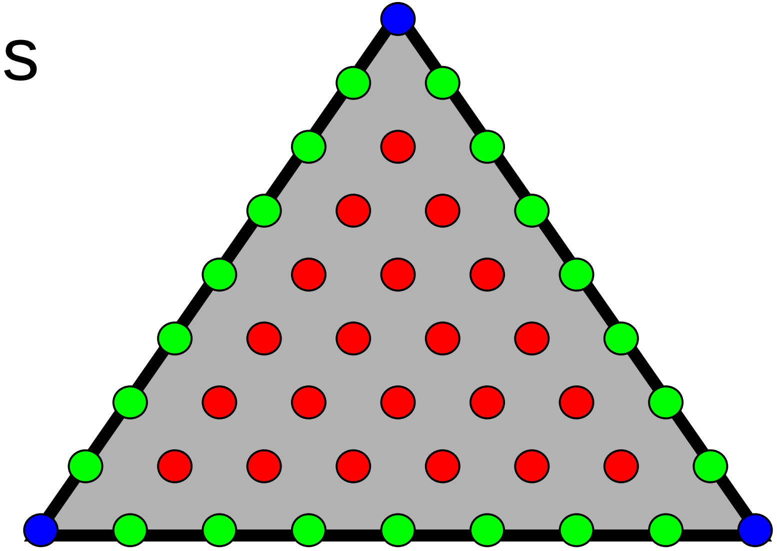
Mesh Colors

- $R = 8$
- Color positions from indices



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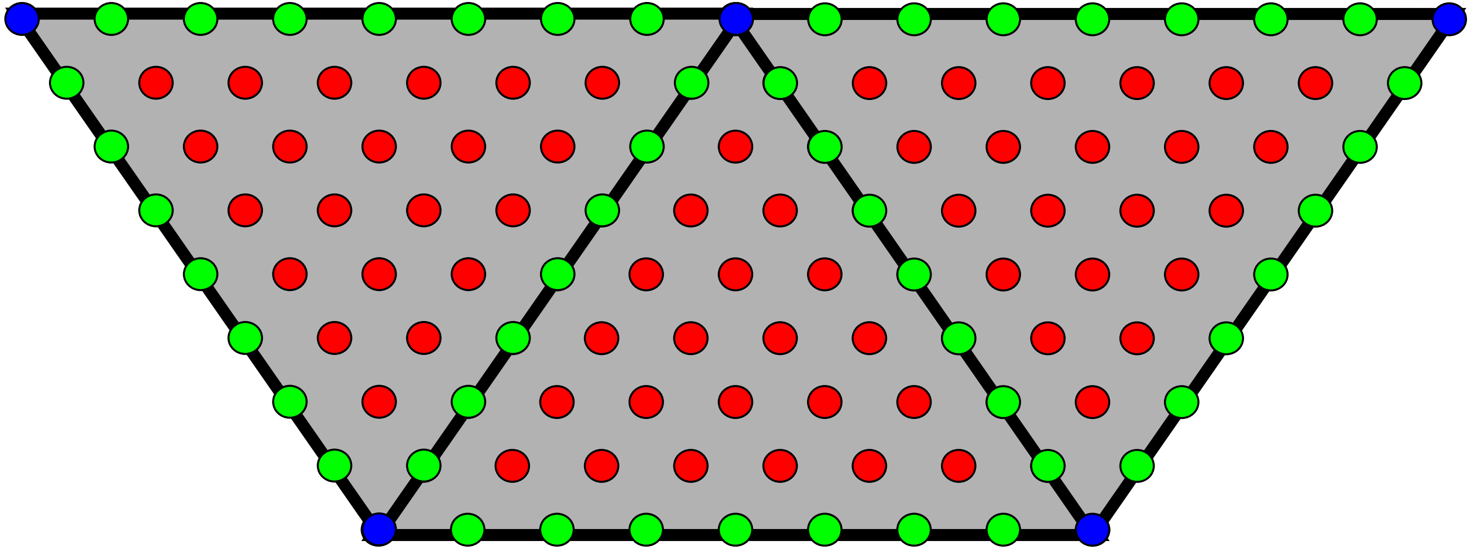
Mesh Colors

- Colors are shared along edges
  - Guaranteed continuity



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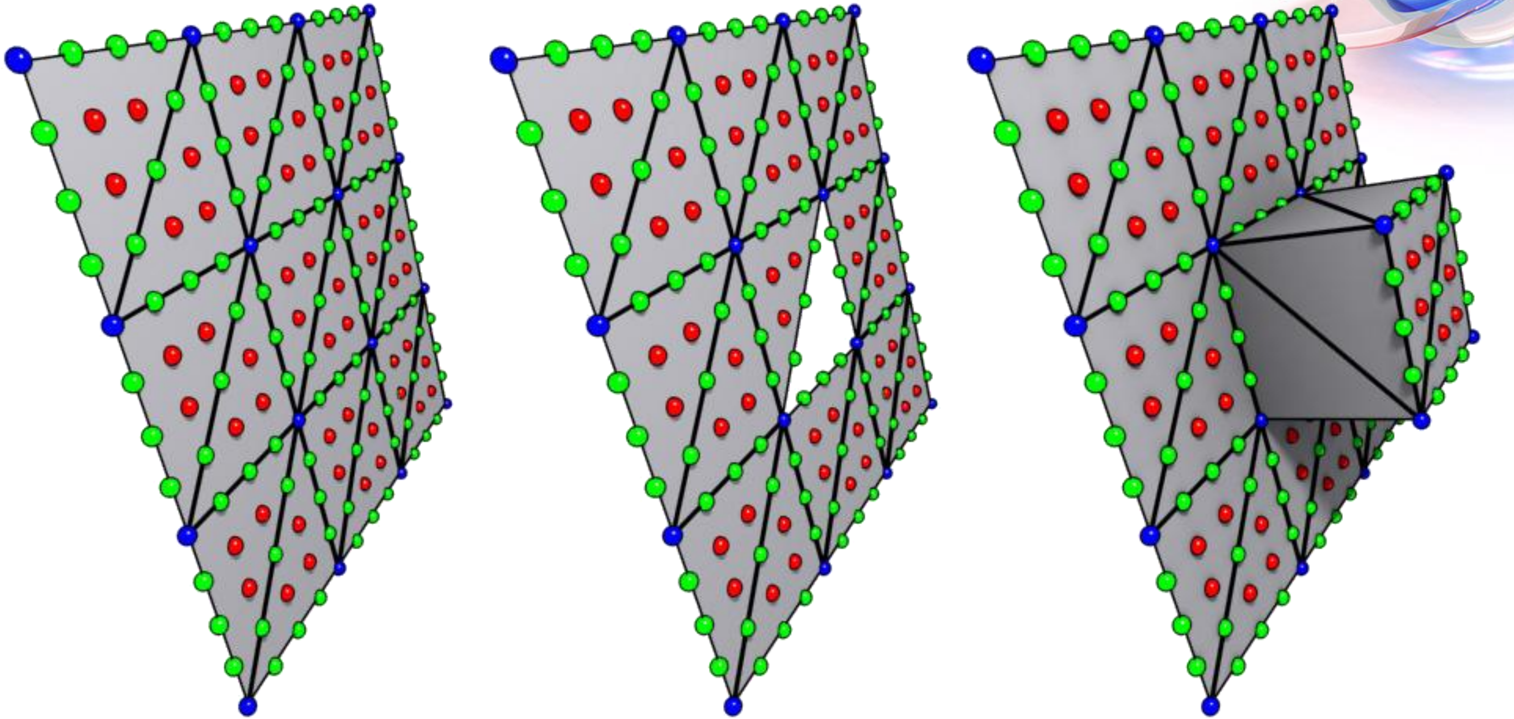
Mesh Colors & Modeling



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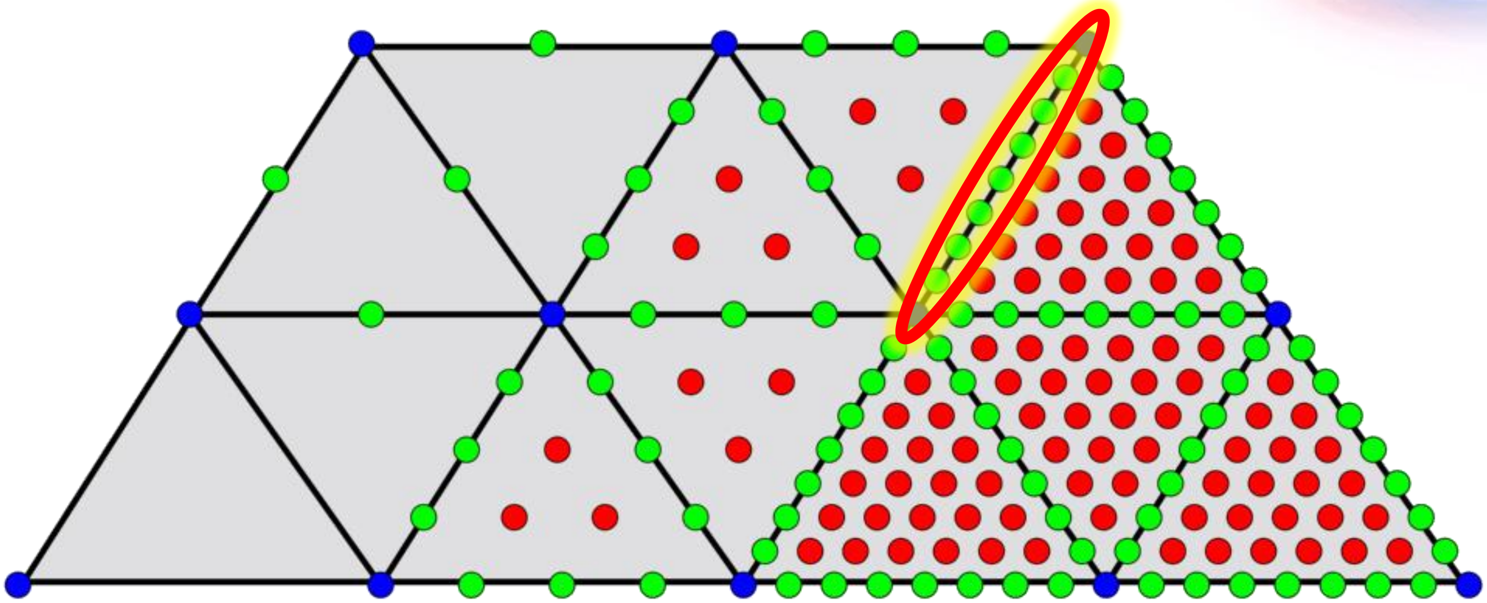
Mesh Colors

- Non-uniform face resolutions



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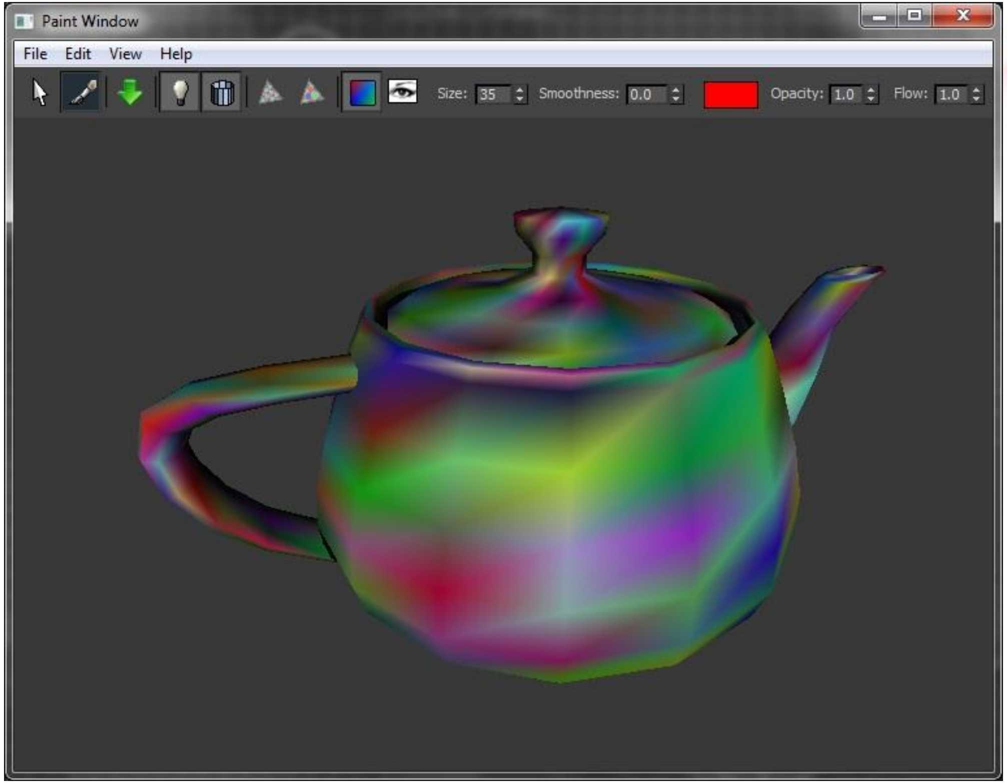

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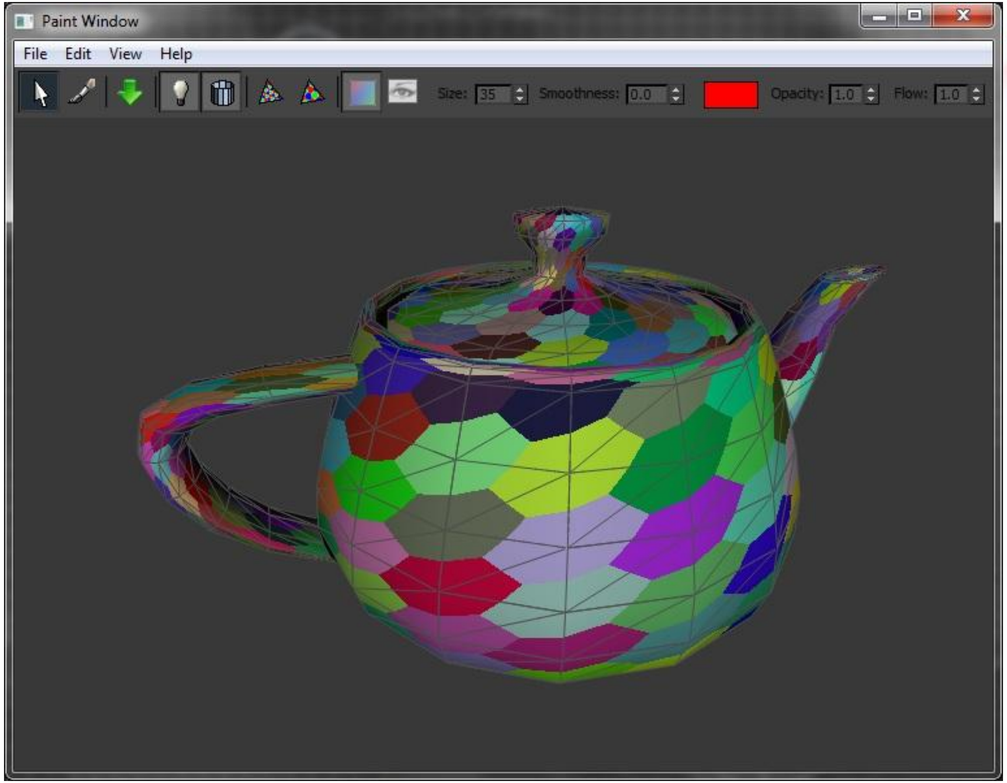

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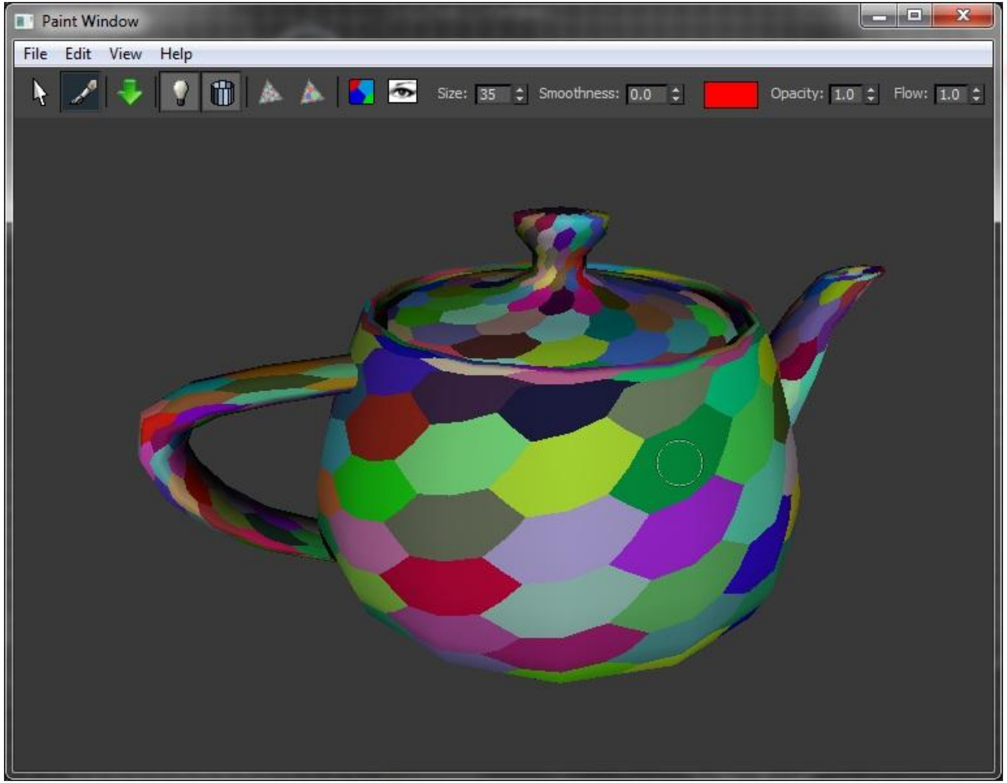

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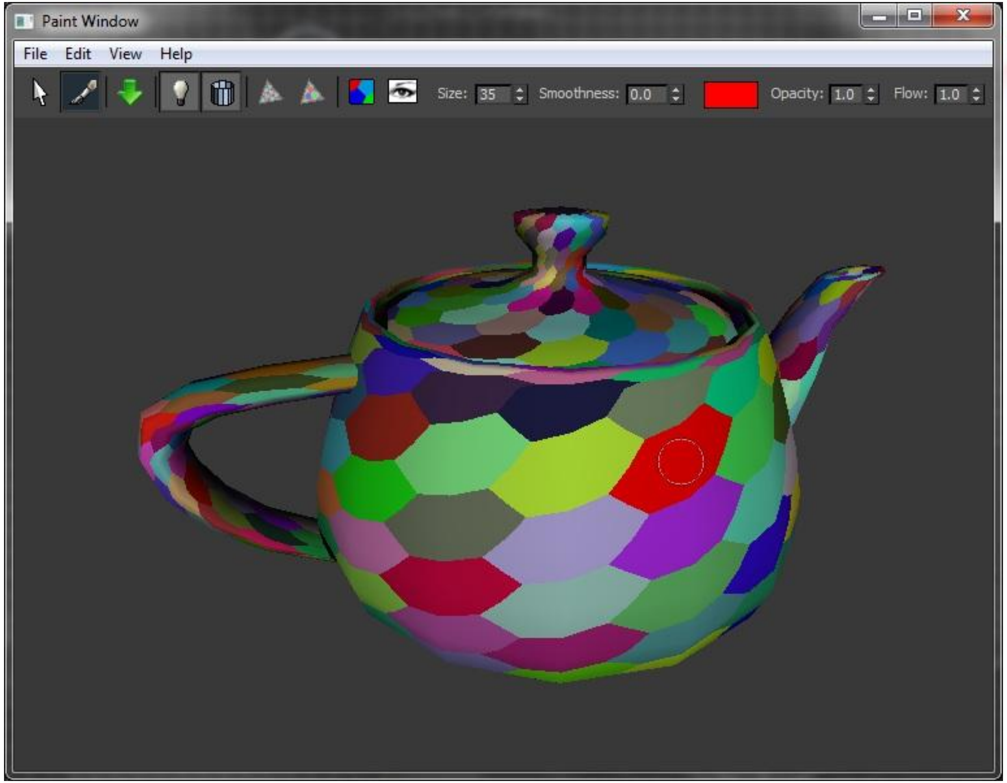

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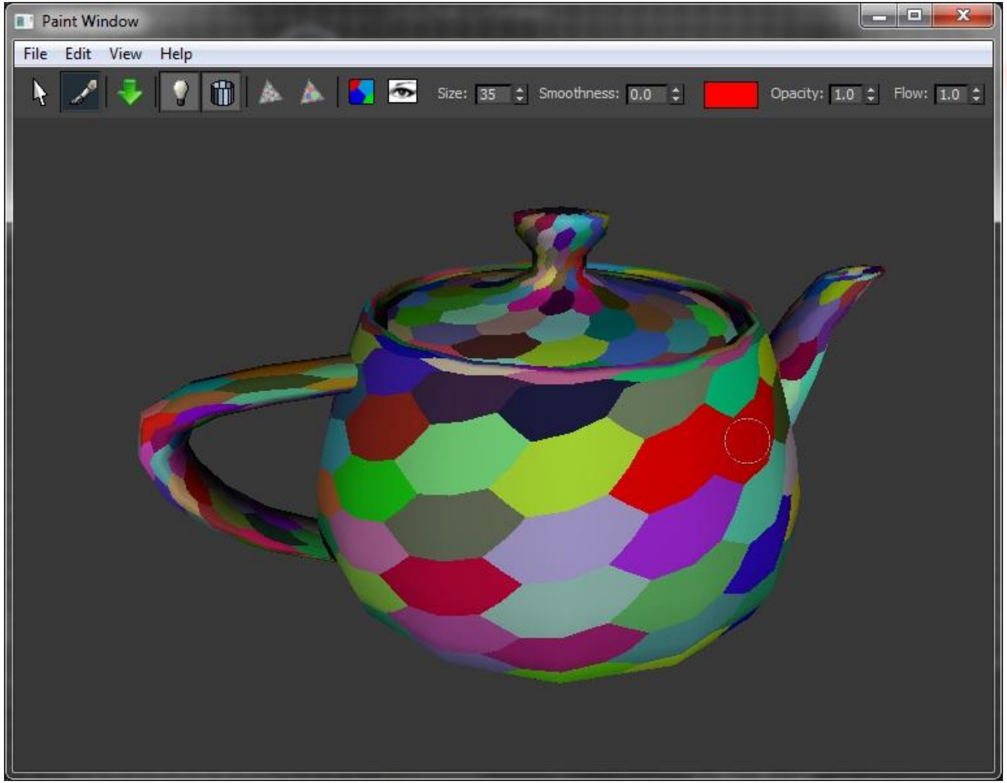

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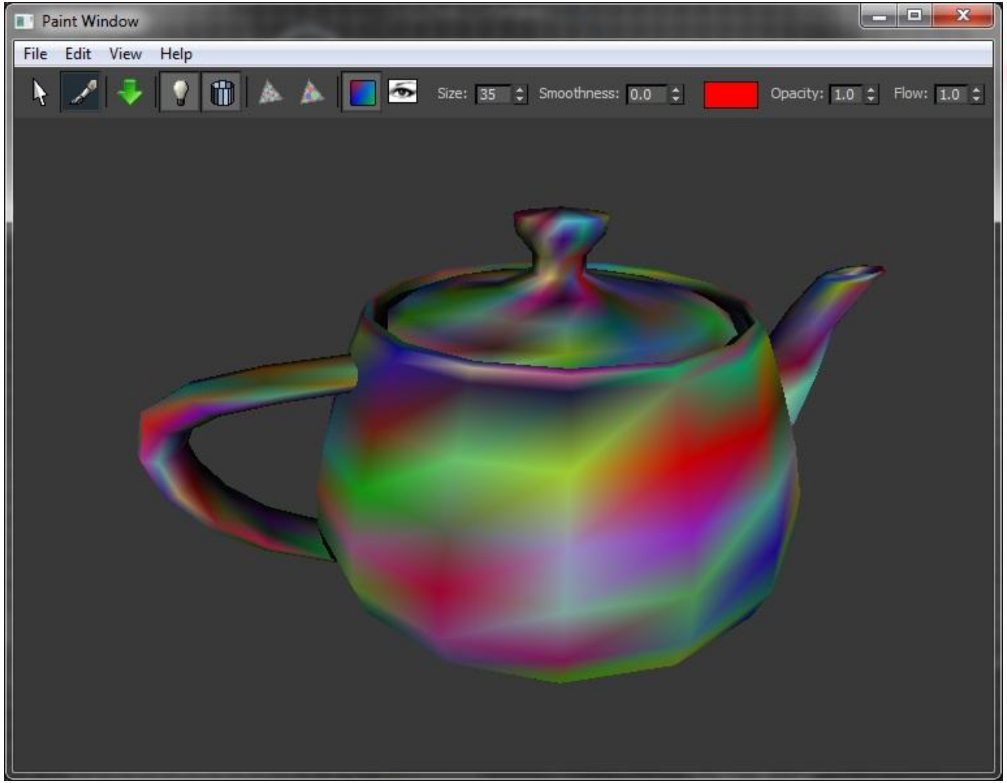

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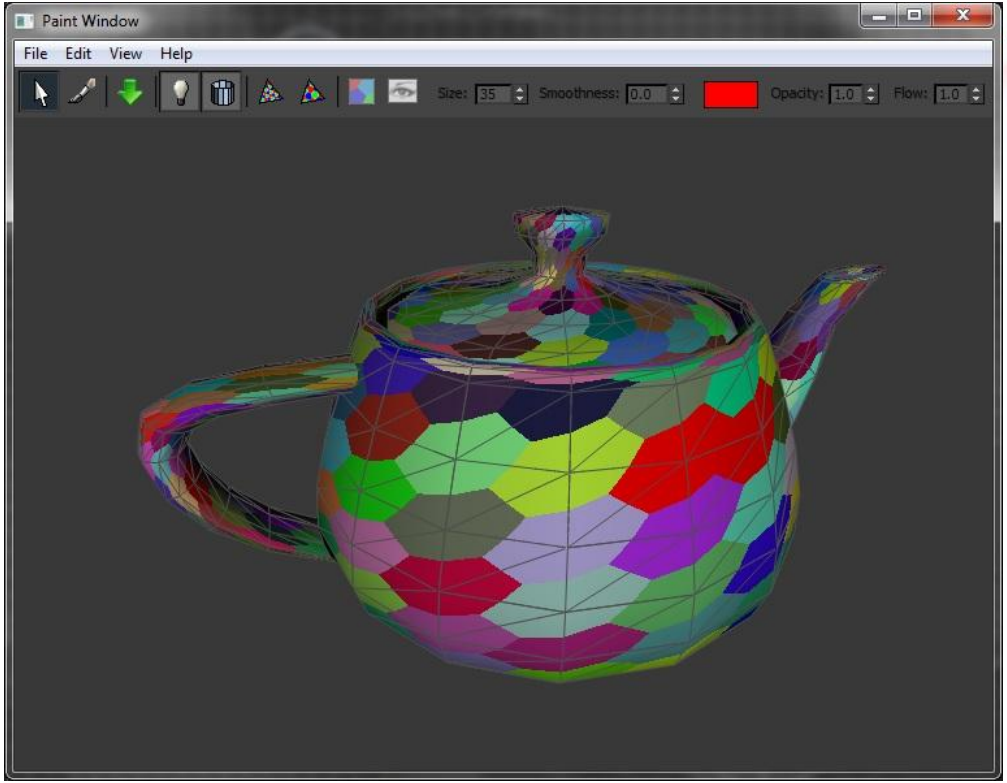

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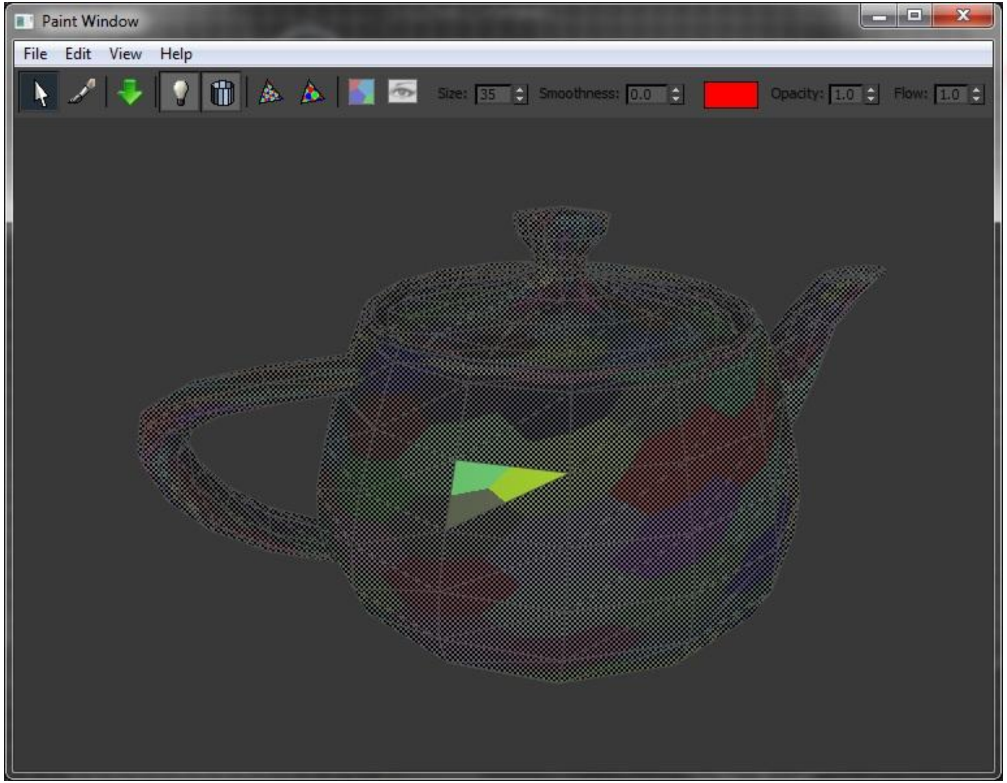

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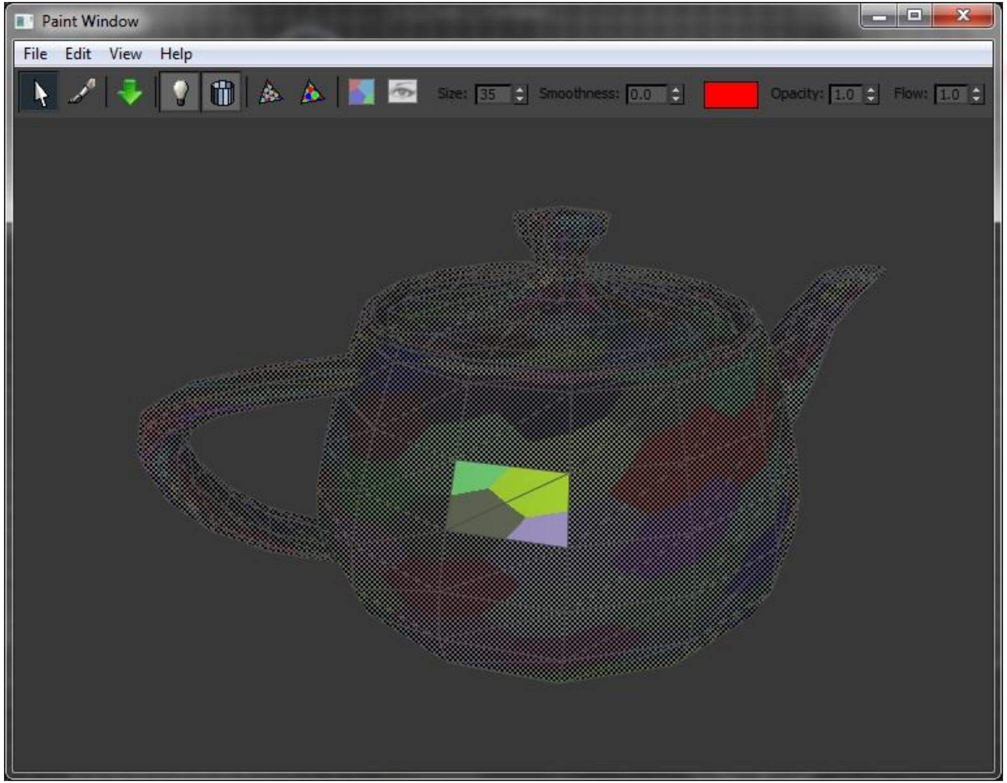

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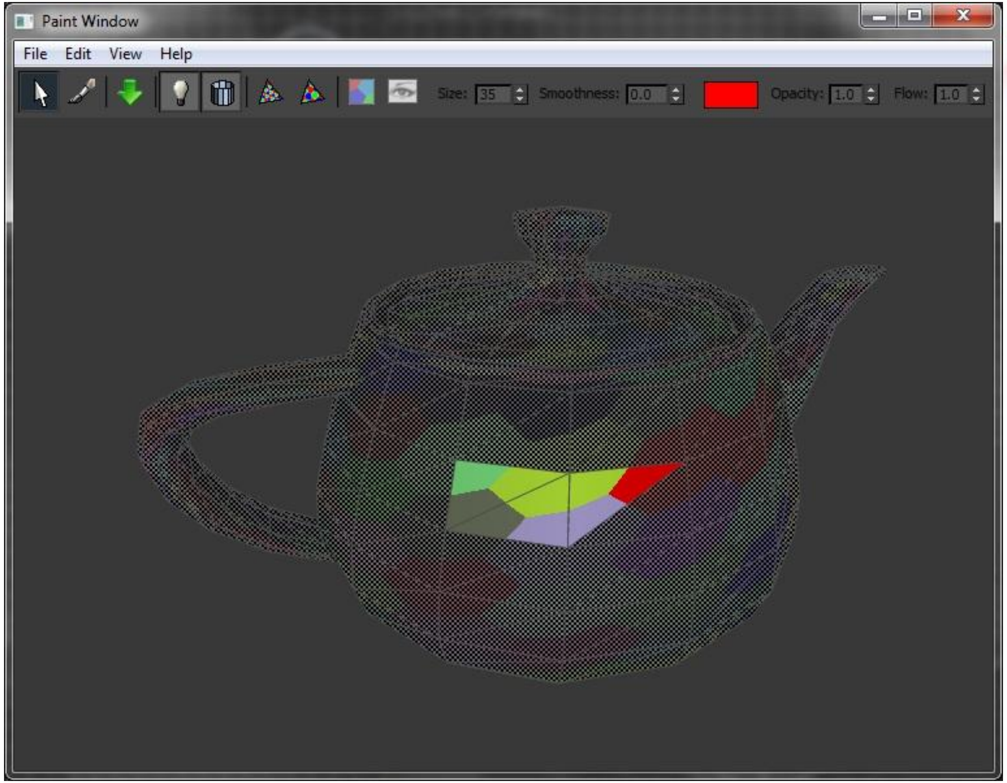

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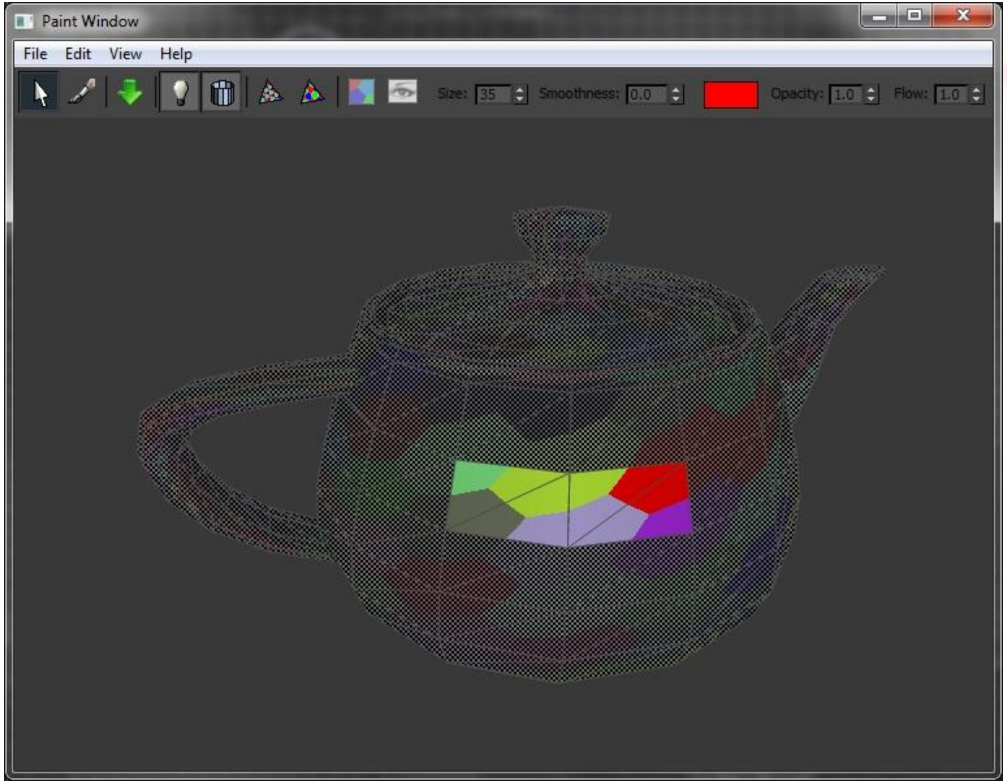

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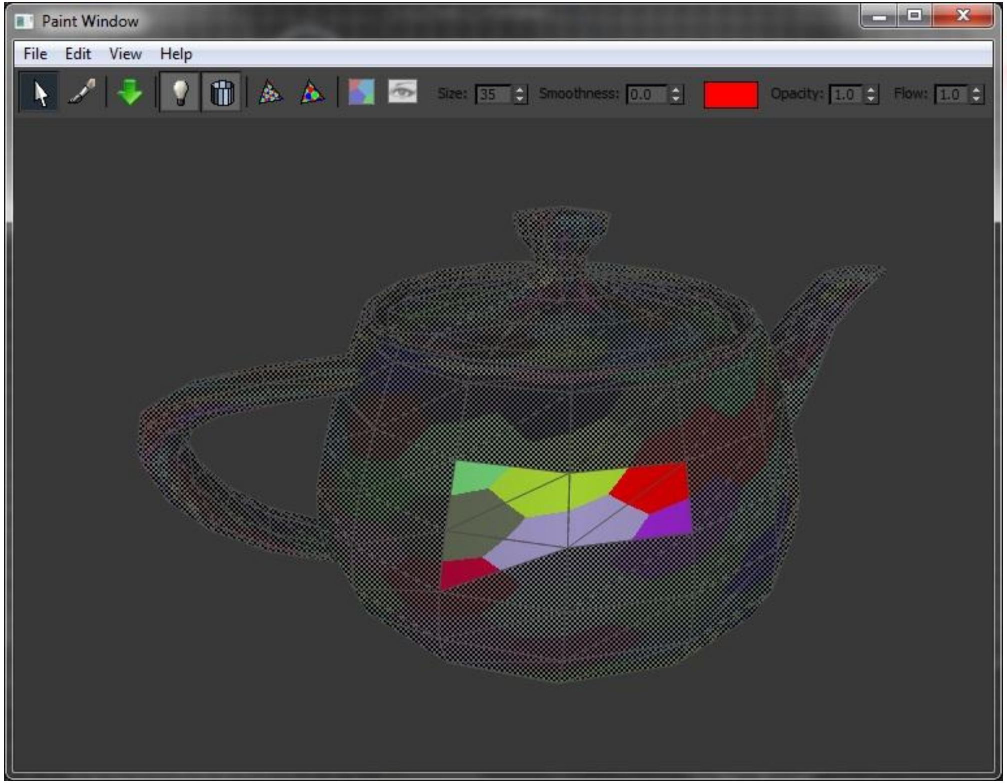

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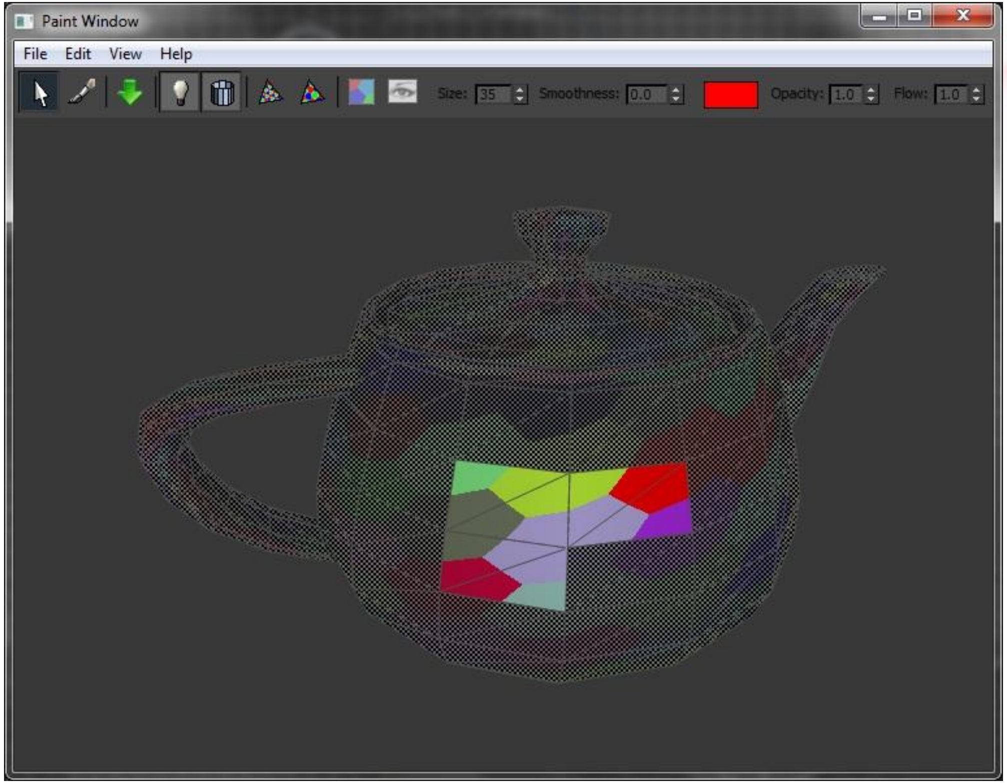

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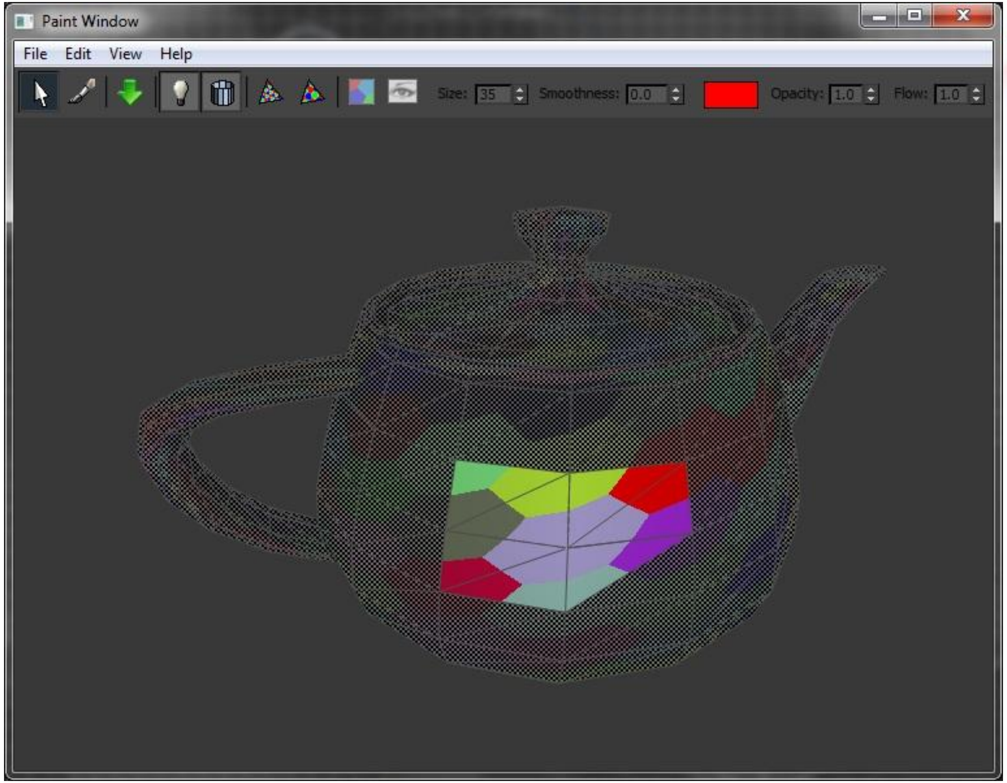

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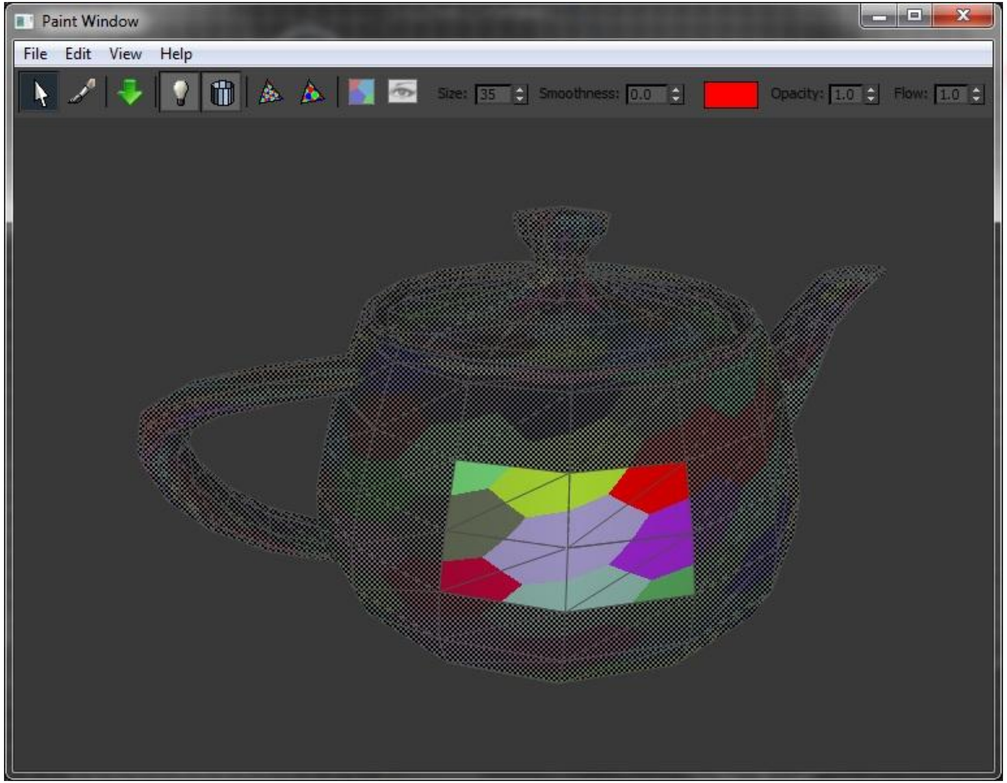

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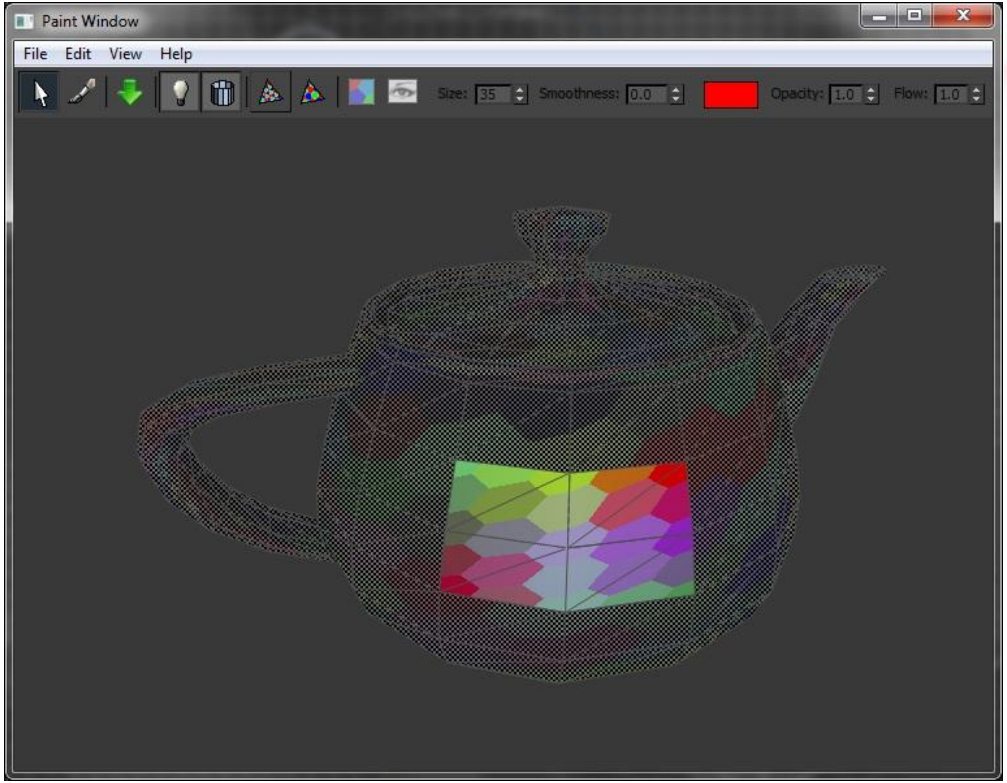

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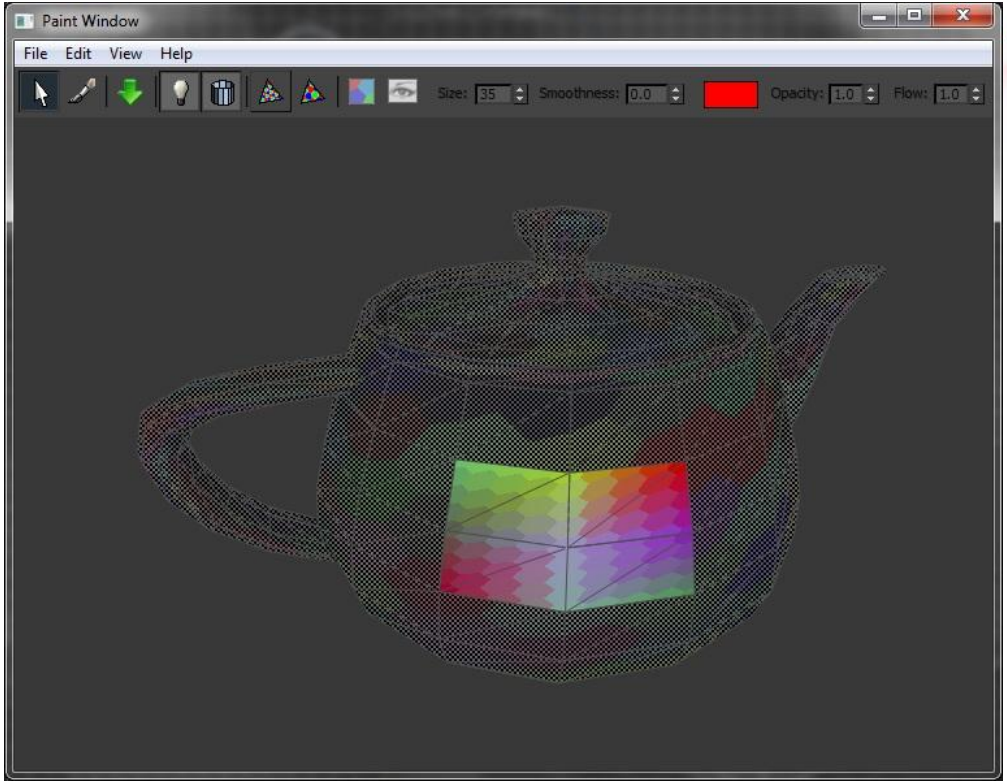

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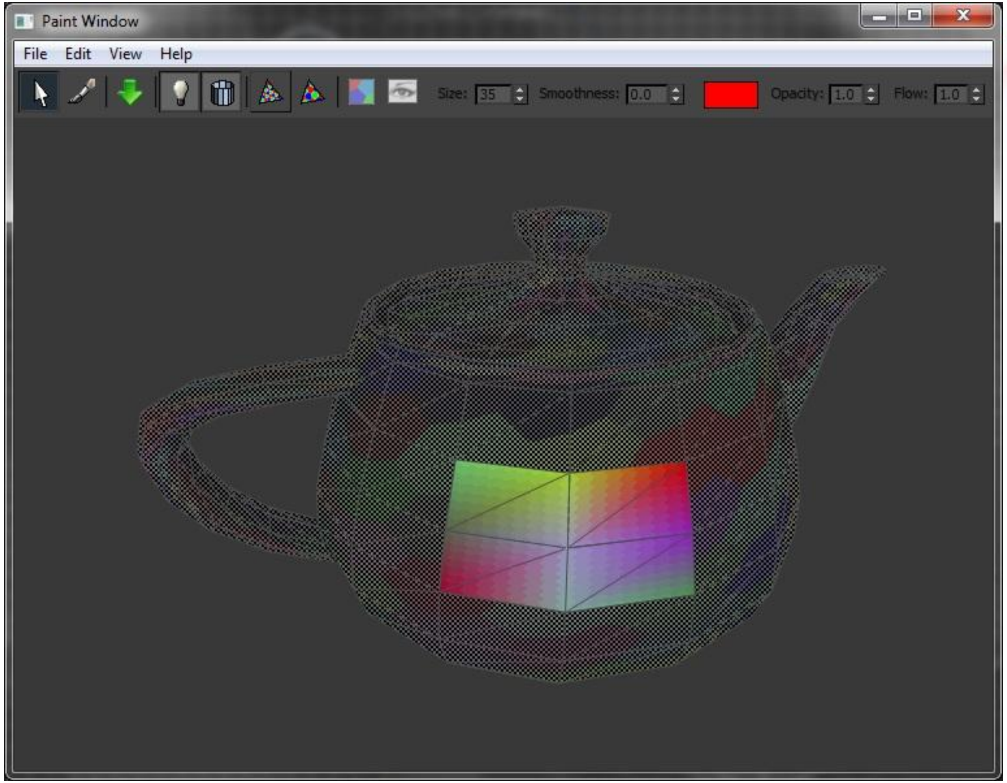
Cem Yuksel, John Keyser, and Donald H. House, “Mesh Colors,“ ACM Transactions on Graphics (TOG), 29(2) 2010

Mesh Colors



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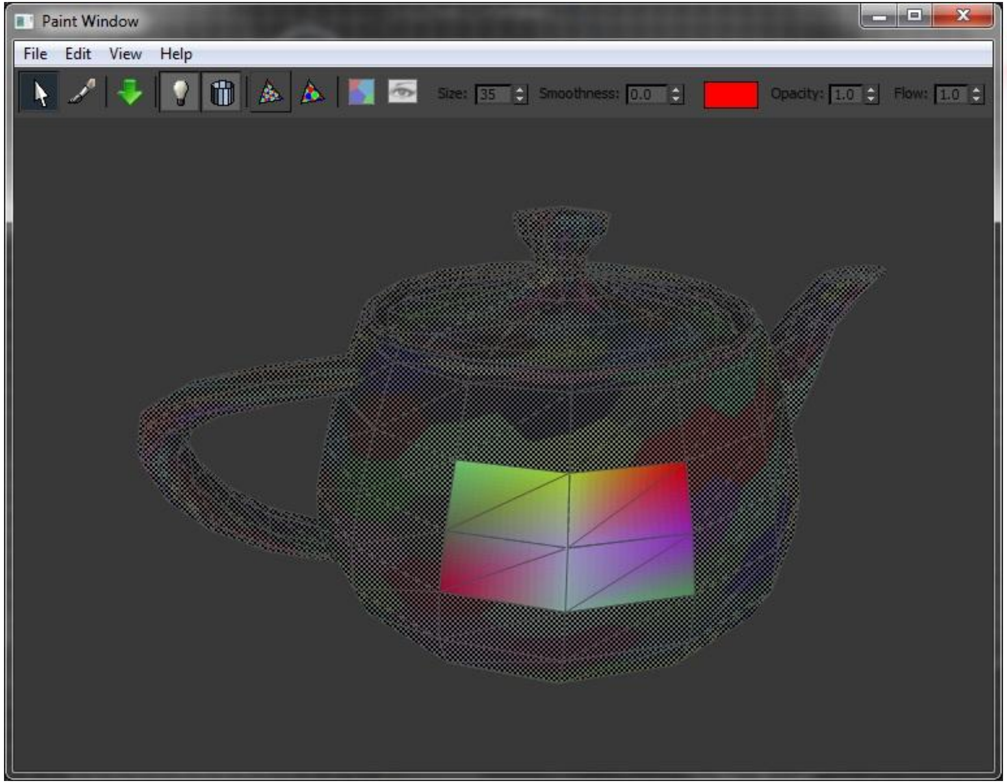
Mesh Colors



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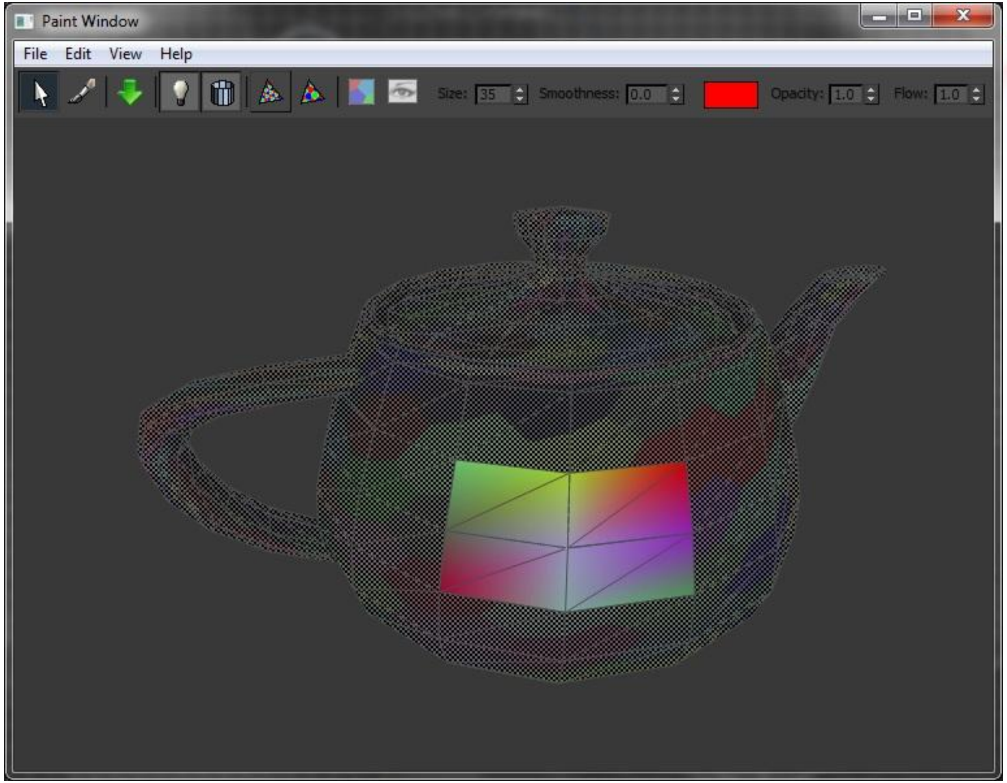

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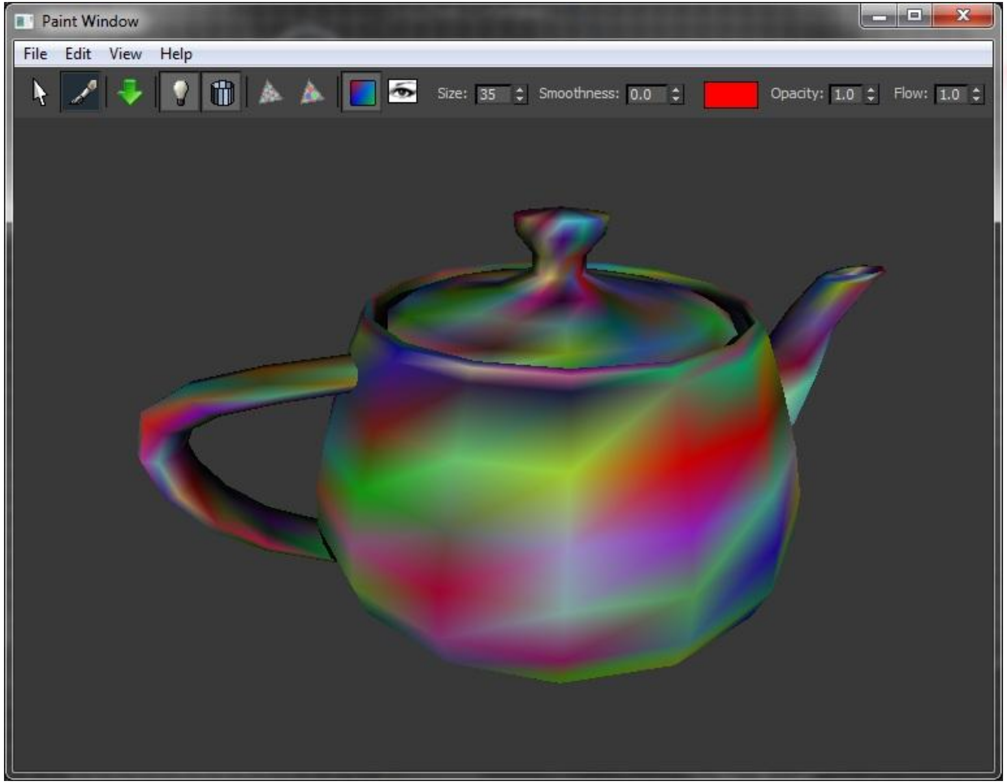
Mesh Colors



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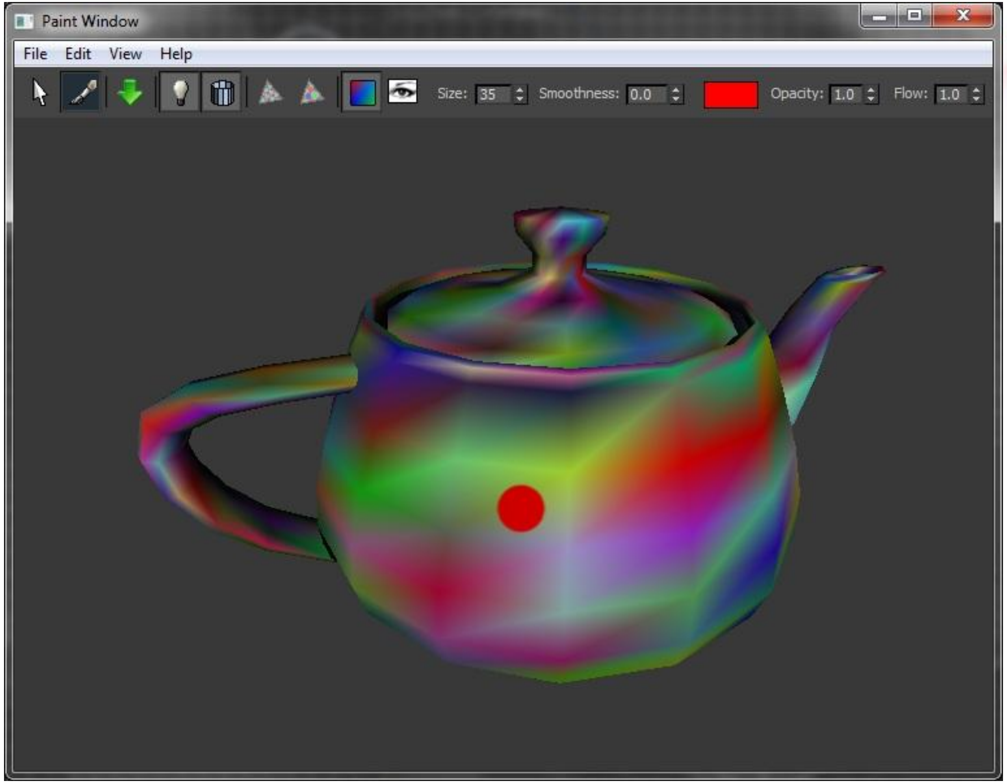

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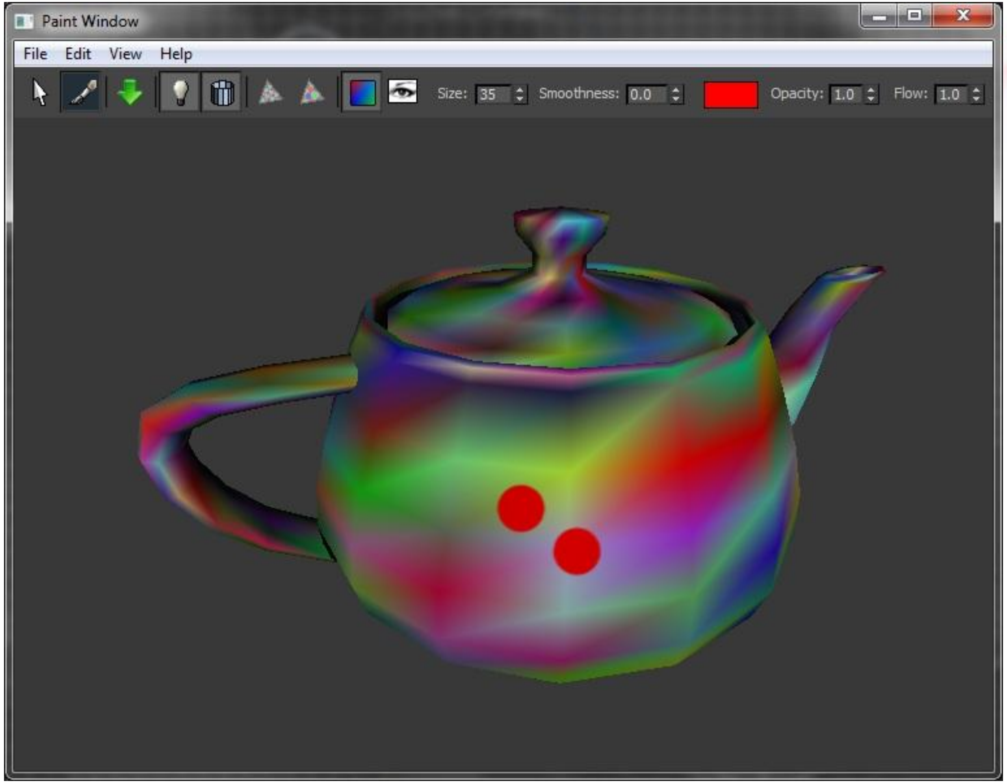
Mesh Colors



Size: 35 Smoothness: 0.0 Opacity: 1.0 Flow: 1.0

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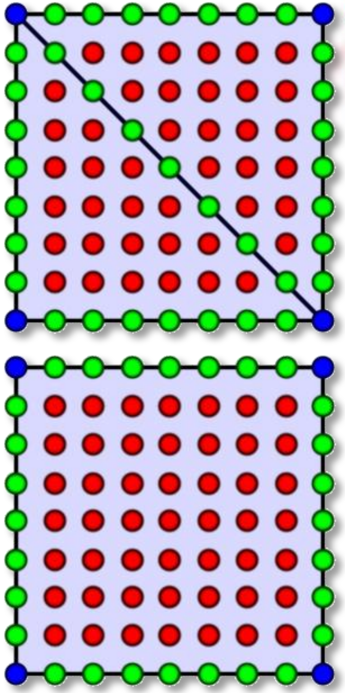
Mesh Colors

- Non-triangular Meshes
  - Quadrilaterals
    - Triangle pair
    - Quadrilateral positioning
  - NURBS
  - Subdivision surfaces
    - Dividing faces only



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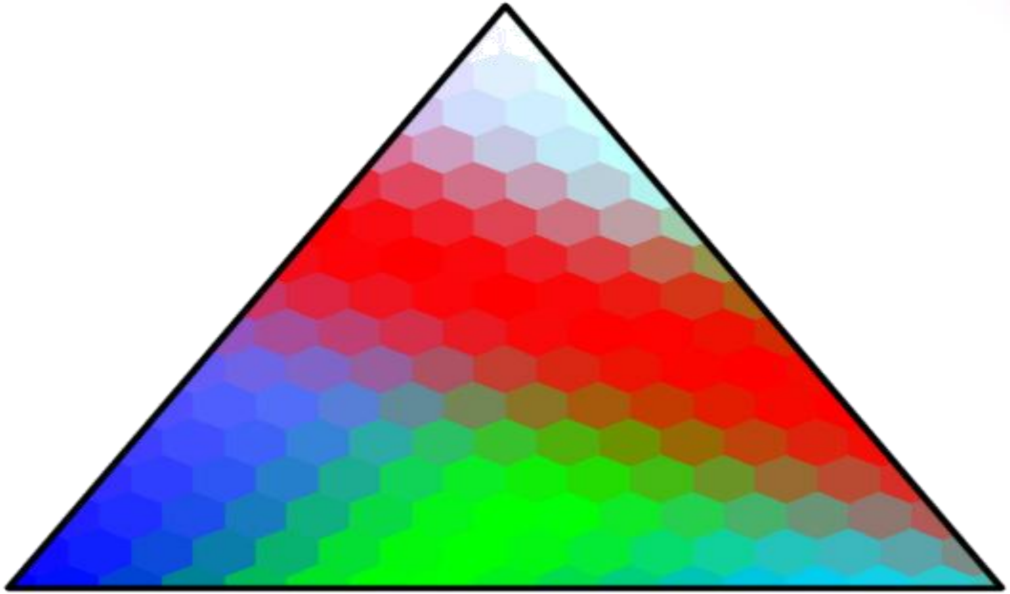
Filtering

Mesh Colors

Filtering Mesh Colors

- Nearest Filtering



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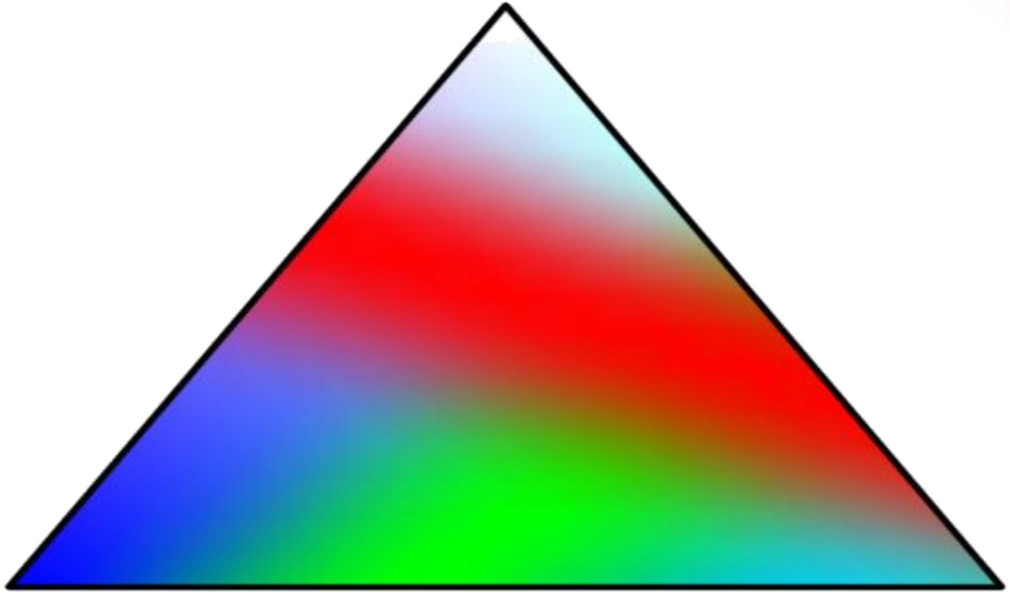
Filtering Mesh Colors

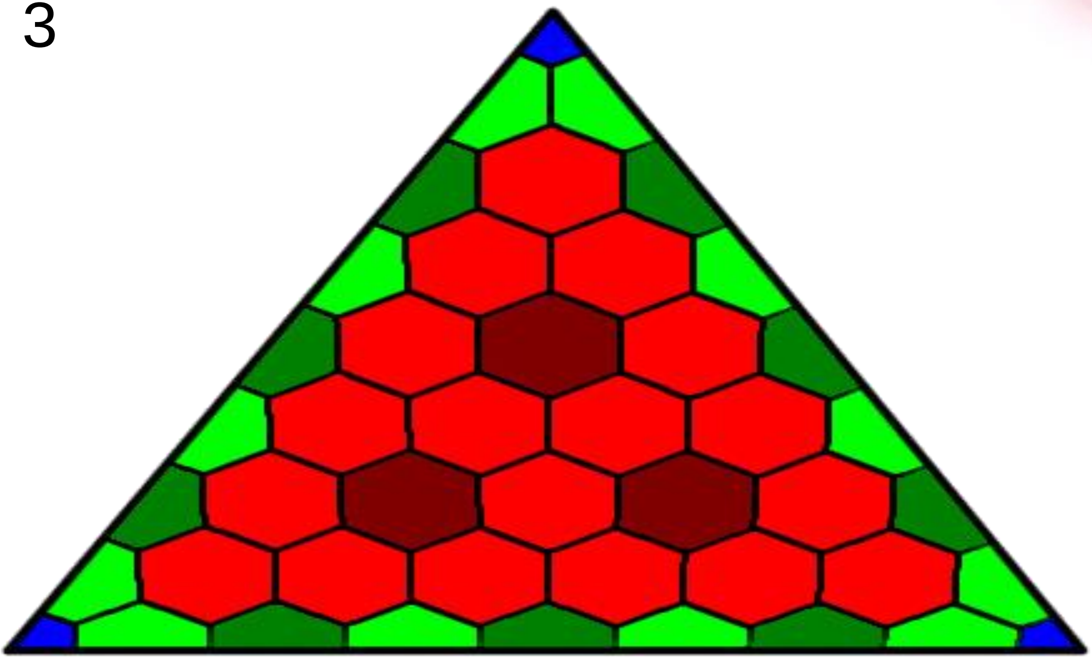
- Linear Filtering



Cem Yuksel, John Keyser, and Donald H. House, “Mesh Colors,“ ACM Transactions on Graphics (TOG), 29(2) 2010

Filtering Mesh Colors

- MIP-map Filtering
  - Level 3



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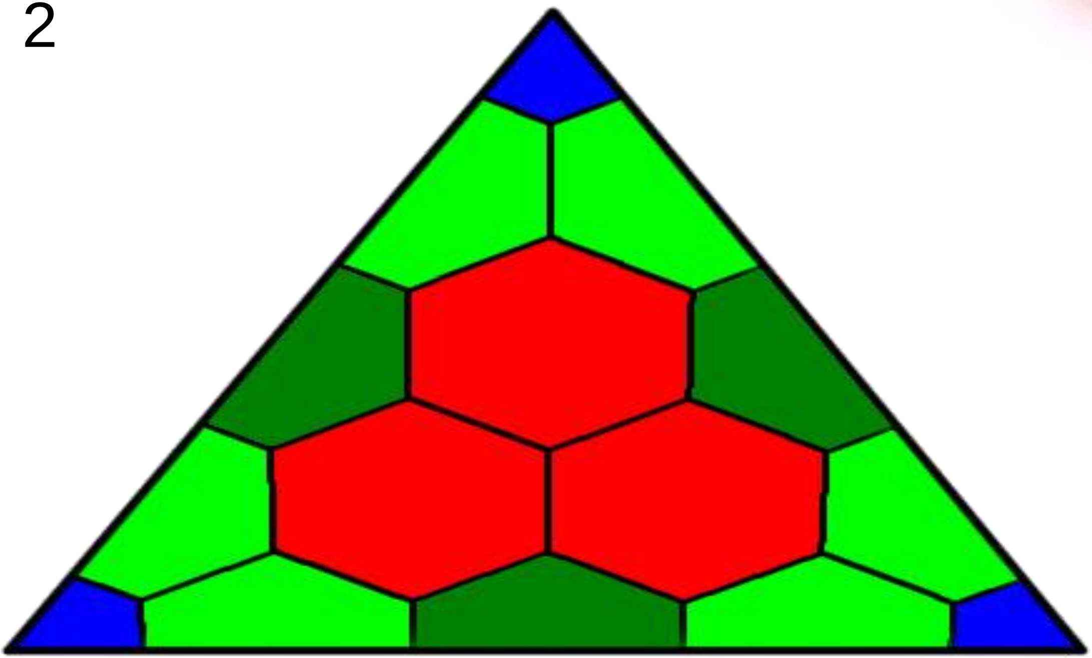
Filtering Mesh Colors

- MIP-map Filtering
  - Level 2



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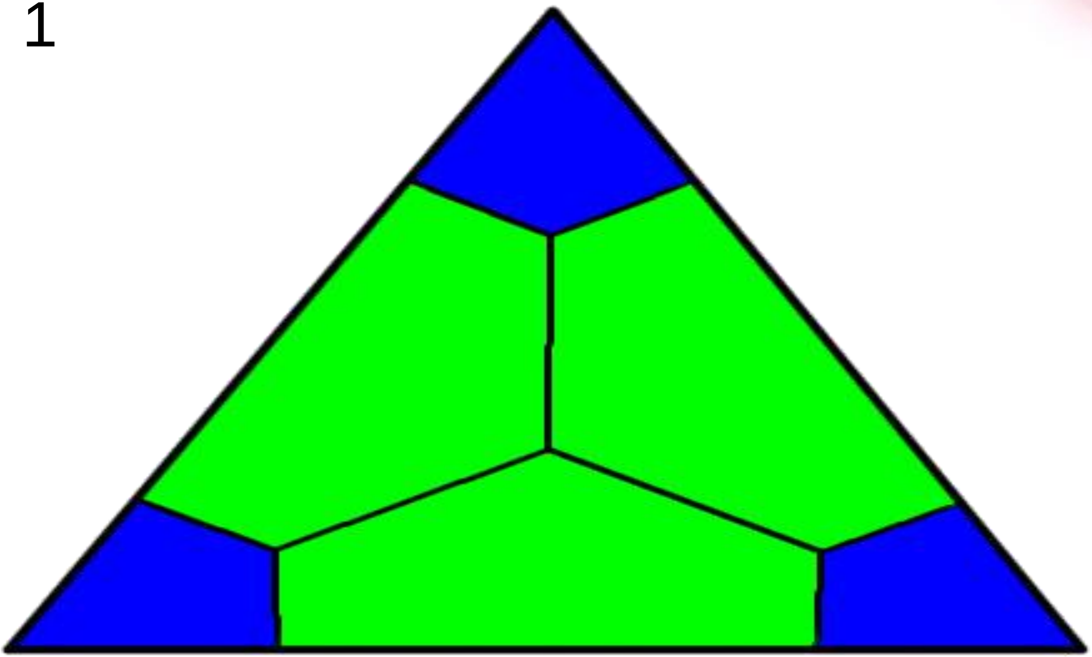
Filtering Mesh Colors

- MIP-map Filtering
  - Level 1



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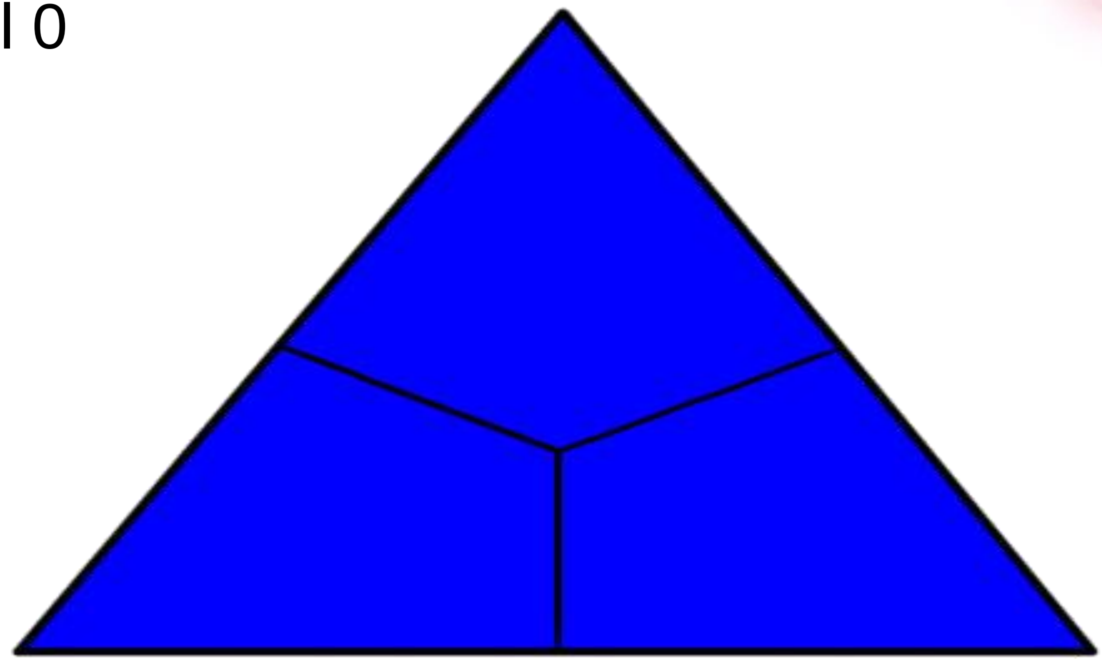
Filtering Mesh Colors

- MIP-map Filtering
  - Level 0



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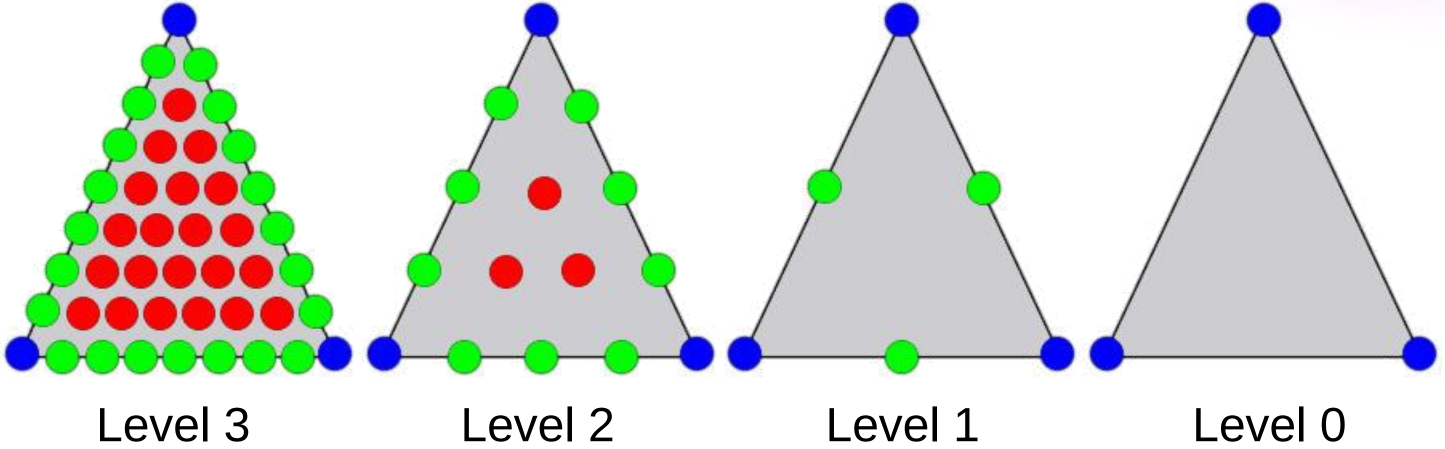
Filtering Mesh Colors

- MIP-map Filtering



Level 3 Level 2 Level 1 Level 0

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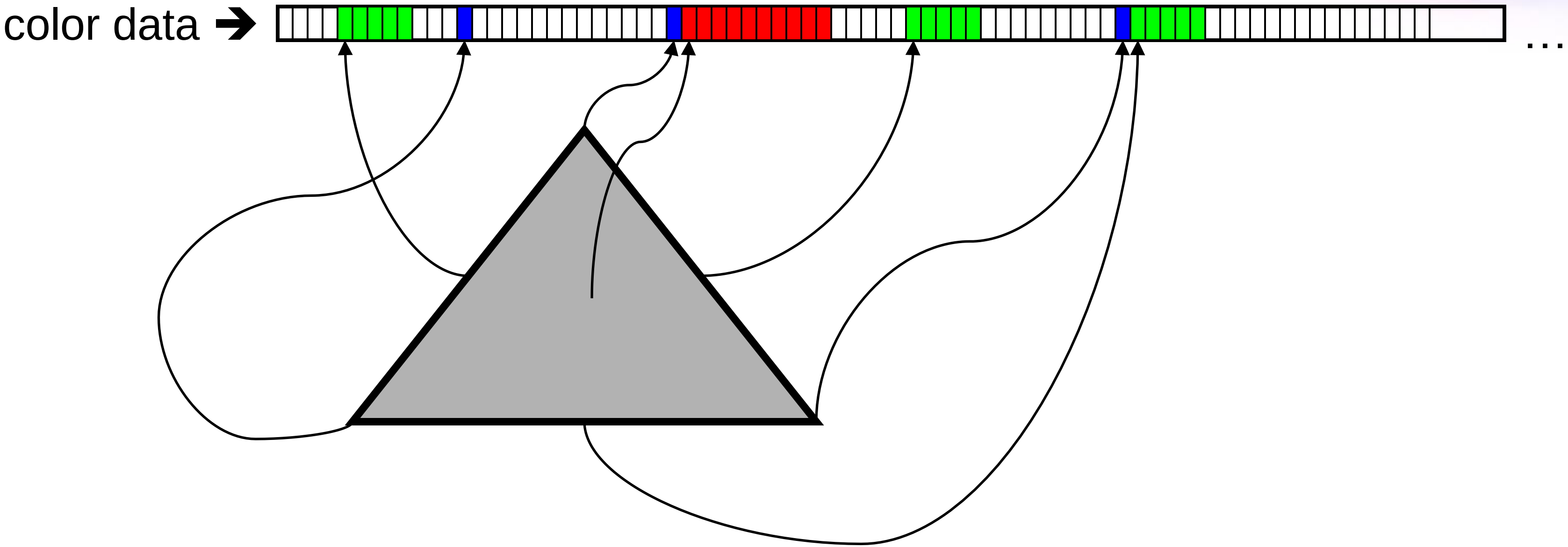
Implementation

Mesh Colors

Mesh Colors

- Separating mesh and color data



color data ➔

…

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Implementation

- All faces must know
  - 1 x Face color index
  - 3 x Edge color indices
  - 3 x Vertex color indices
  - Face resolution

Send to the shader

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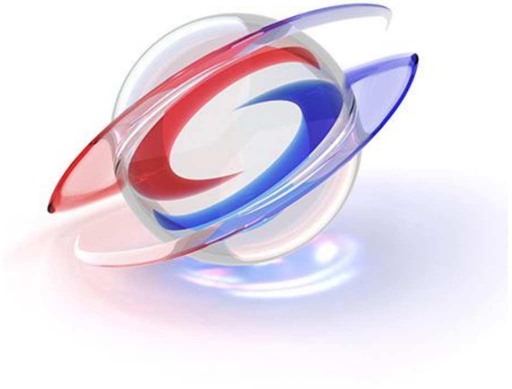
Analysis

Mesh Colors

Mesh Colors



- Unified content creation
- Memory efficient
- Fast
- Correct filtering

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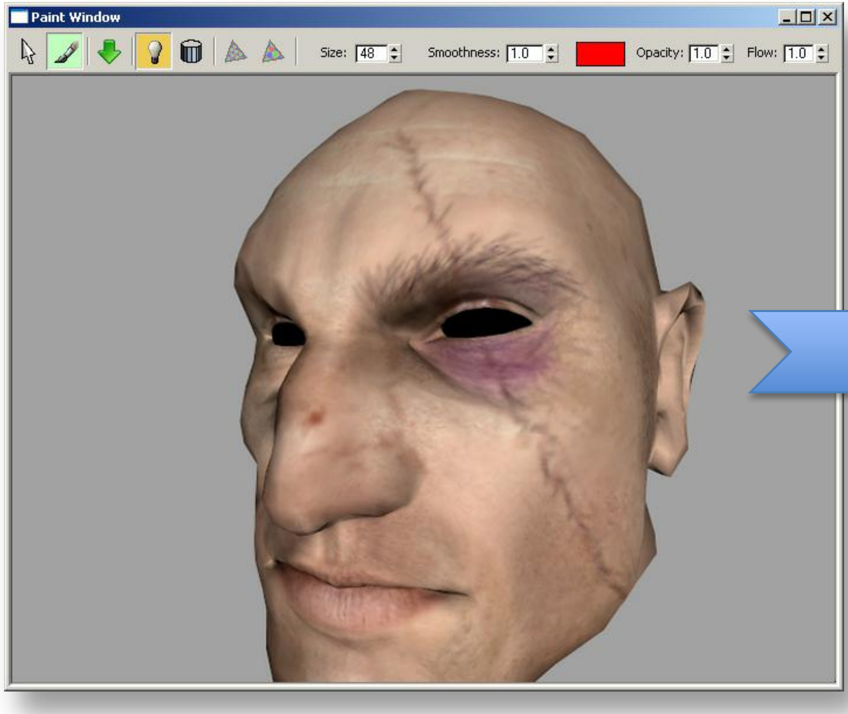
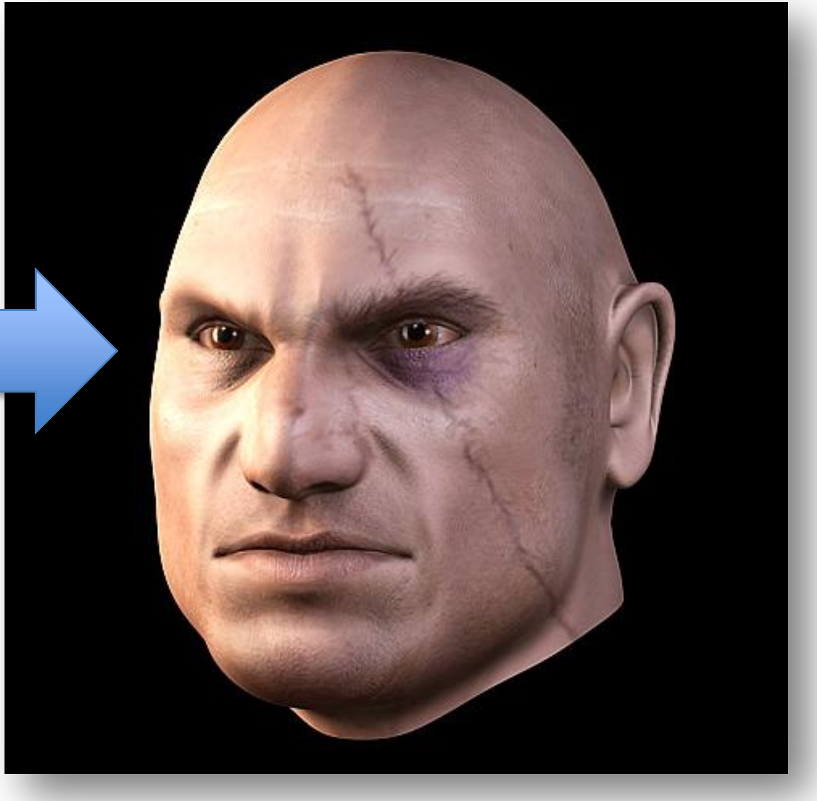
Content Creation with Mesh Colors



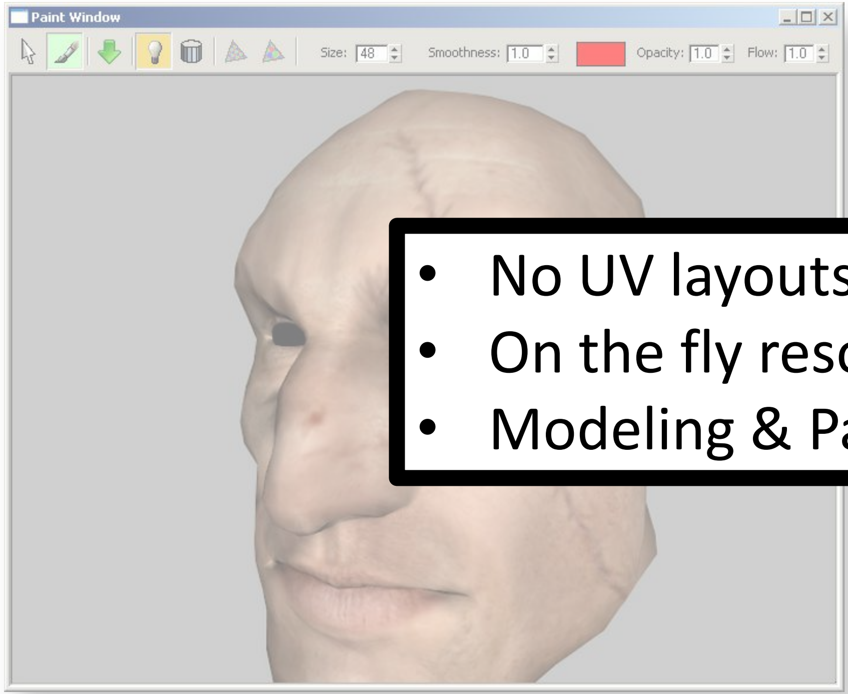
Size: 48 Smoothness: 1.0 Opacity: 1.0 Flow: 1.0



Mesh colors are on the low-res mesh.

Cem Yuksel, John Keyser, and Donald H. House, “Mesh Colors,“ ACM Transactions on Graphics (TOG), 29(2) 2010

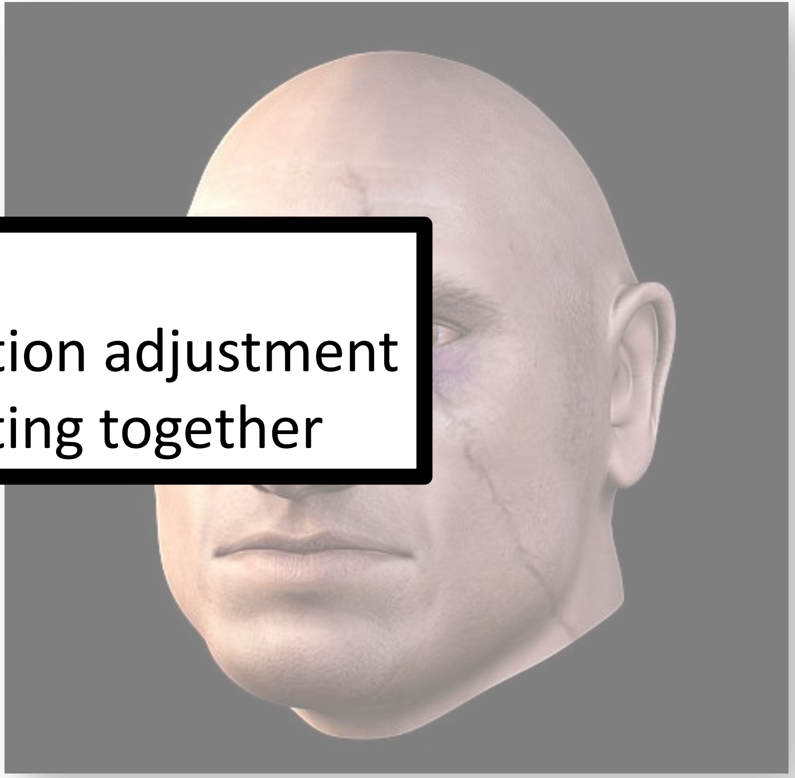
Content Creation with Mesh Colors


Paint Window

Size: 48 Smoothness: 1.0 Opacity: 1.0 Flow: 1.0

Mesh colors are on the low-res mesh.

- No UV layouts
- On the fly resolution adjustment
- Modeling & Painting together



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Mesh Colors

- ✓ Unified content creation
- Memory efficient
- Fast
- Correct filtering

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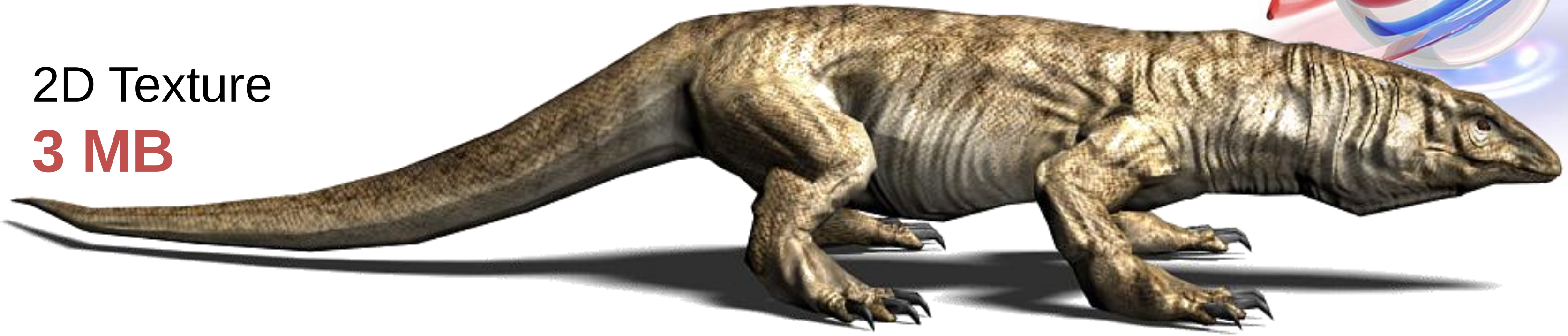
Similar Memory Use

2D Texture

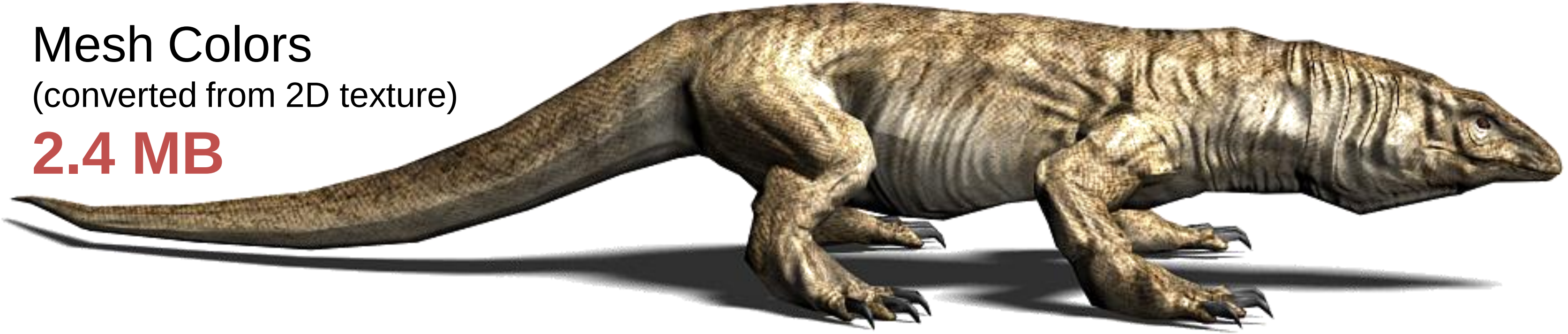
3 MB



Mesh Colors

(converted from 2D texture)

2.4 MB



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Mesh Colors

- ✓ Unified content creation
- ✓ Memory efficient
- Fast
- Correct filtering

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Real-time Rendering

	face count	3 K	50 K	218 K
	color count	530 K	530 K	9 000 K
Hardware ←	2D texture	3938 fps	2597 fps	337 fps
Mesh Colors	Nearest	2567 fps	1147 fps	273 fps
	Linear	2076 fps	862 fps	247 fps
	MIP-map	991 fps	376 fps	180 fps
	Anisotropic	452 fps	152 fps	109 fps

Texture filtering on hardware is ~20x faster!

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Real-time Rendering

- For high performance
  - Mesh Colors for content creation
  - Convert to 2D texture for rendering
- Hardware support for Mesh Colors?
  - 2D textures produce incorrect filtering!
  - Mesh Colors produce correct filtering

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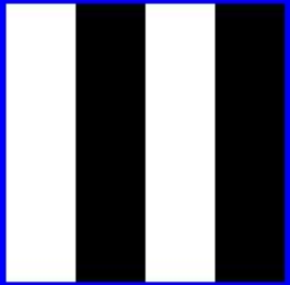
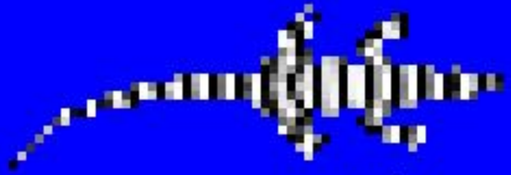
Tiled 2D texture

zoom: 4x

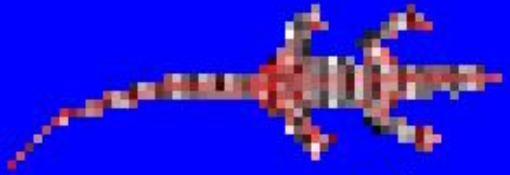


Tiled 2D texture

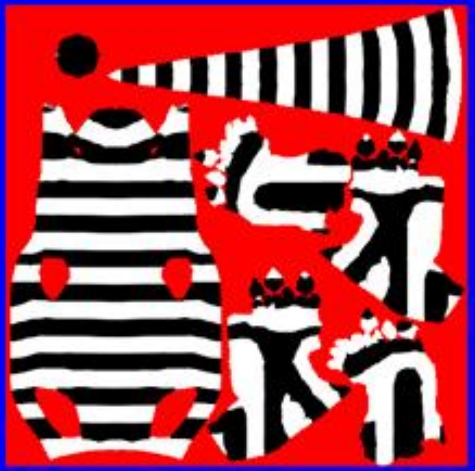


zoom: 4x

Unwrapped 2D texture

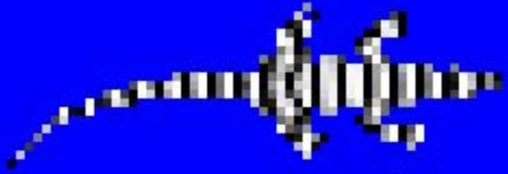


zoom: 4x



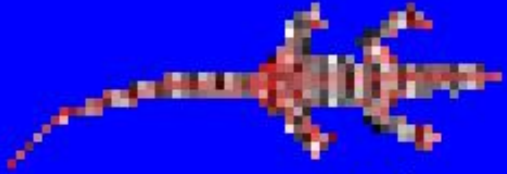
(scaled for display)

Tiled 2D texture

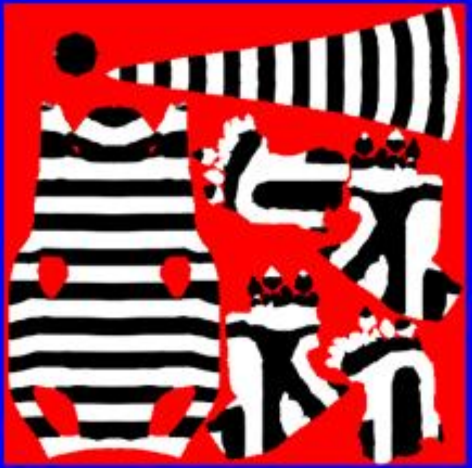


zoom: 4x

Unwrapped 2D texture

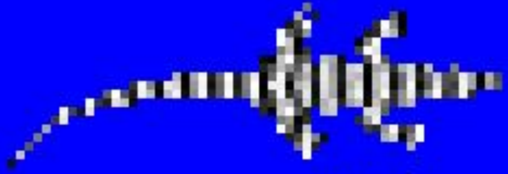


zoom: 4x



(scaled for display)

Mesh Colors



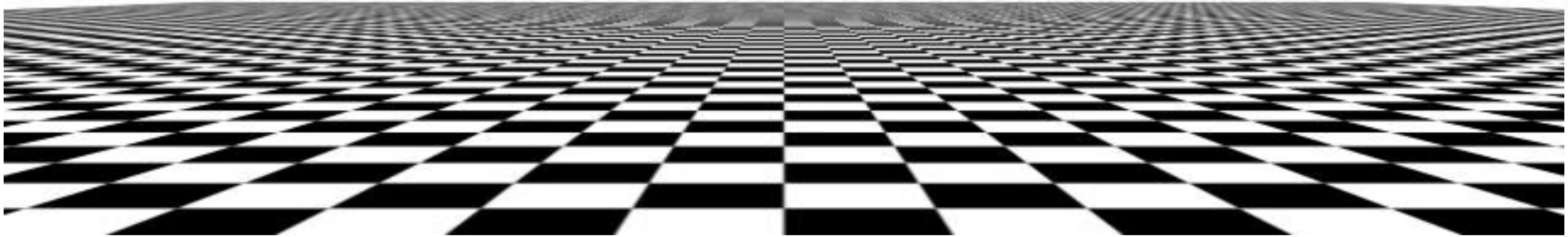
zoom: 4x

(scaled for display)

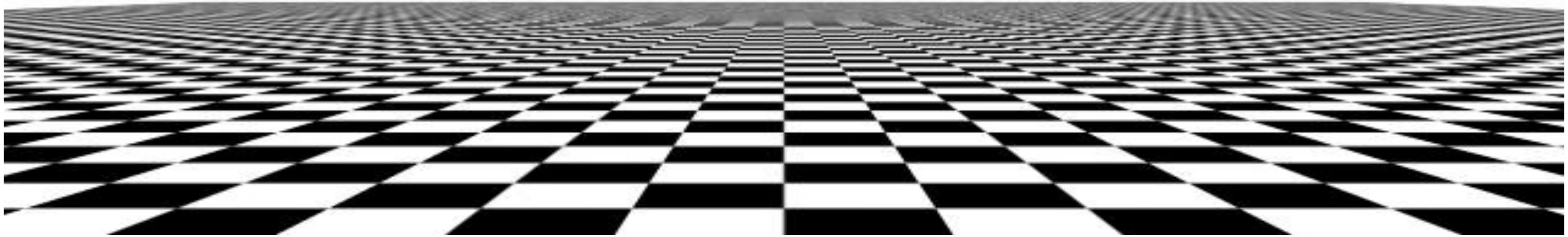
Offline Rendering

- Mesh Colors are ready!

Mesh Colors



2D Texture



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Mesh Colors

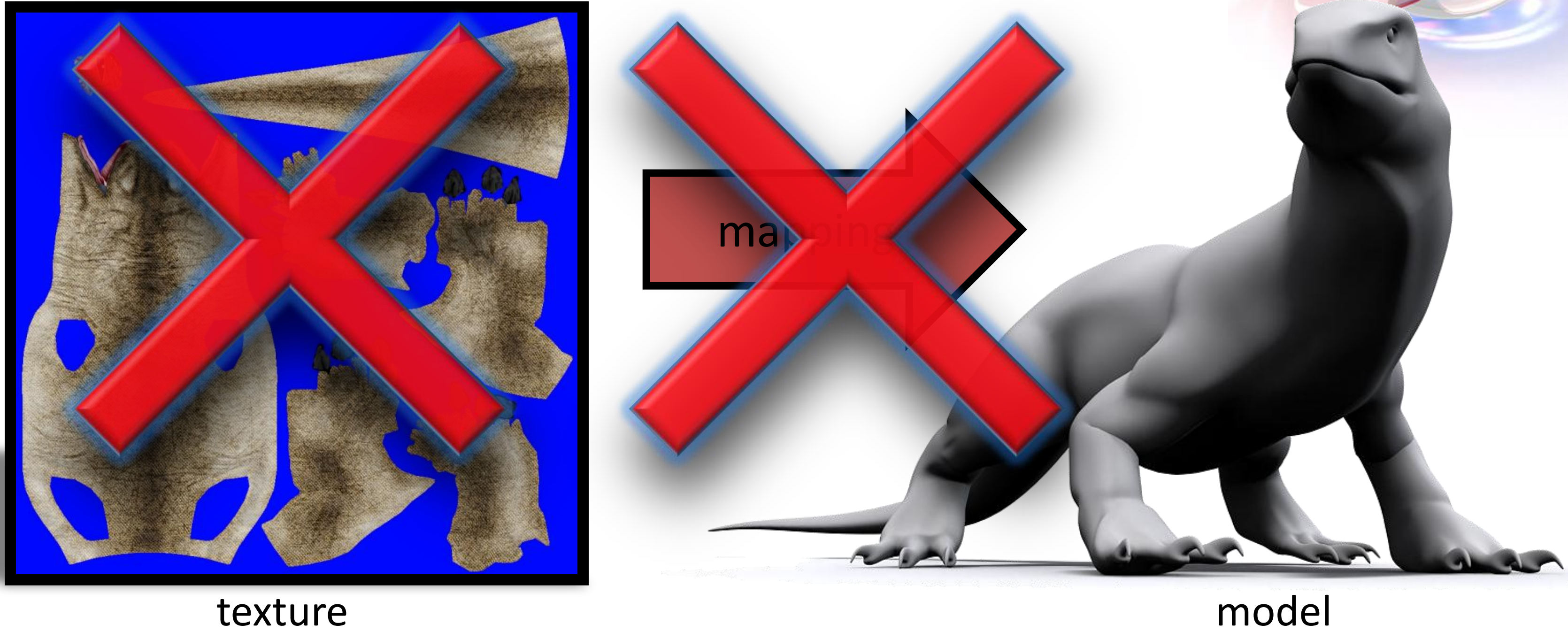
- ✓ Unified content creation
- ✓ Memory efficient
- ✓ Fast
- ✓ Correct filtering

Cem Yuksel, John Keyser, and Donald H. House, “Mesh Colors,“ ACM Transactions on Graphics (TOG), 29(2) 2010

Summary

Mesh Colors

No Mapping!



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No Discontinuities

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Guaranteed 1-1 Correspondence

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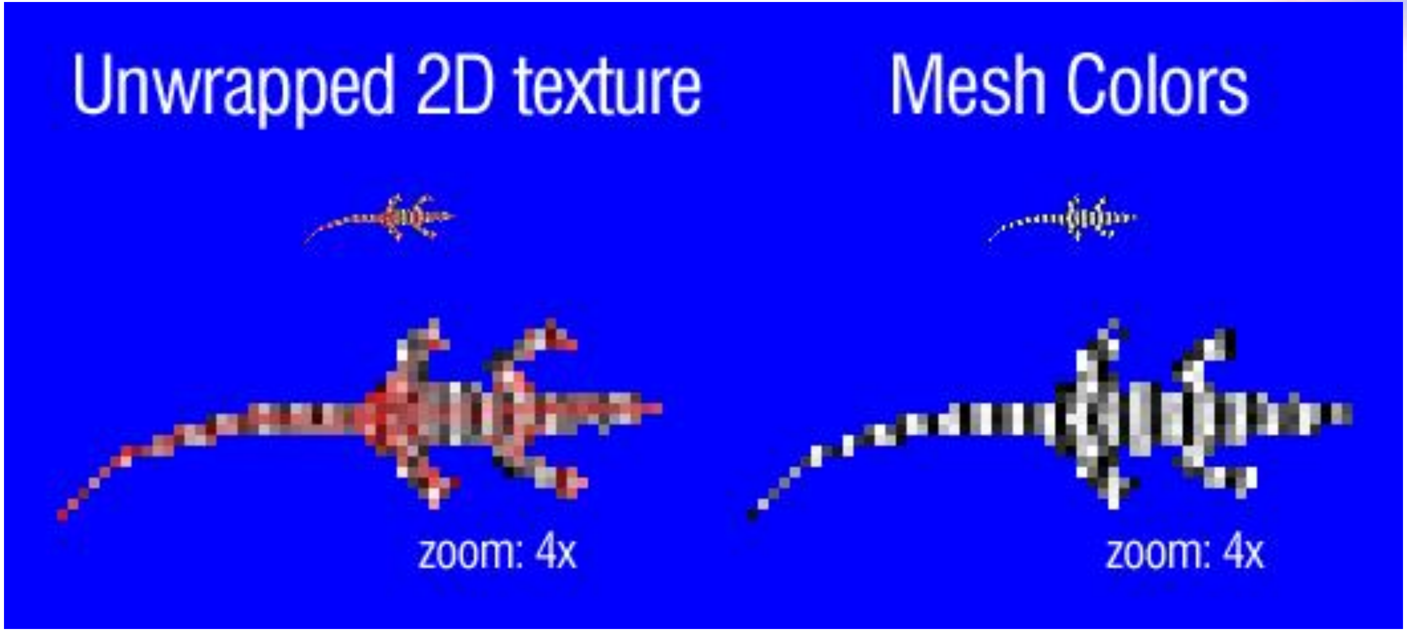
Correct MIP-map Filtering



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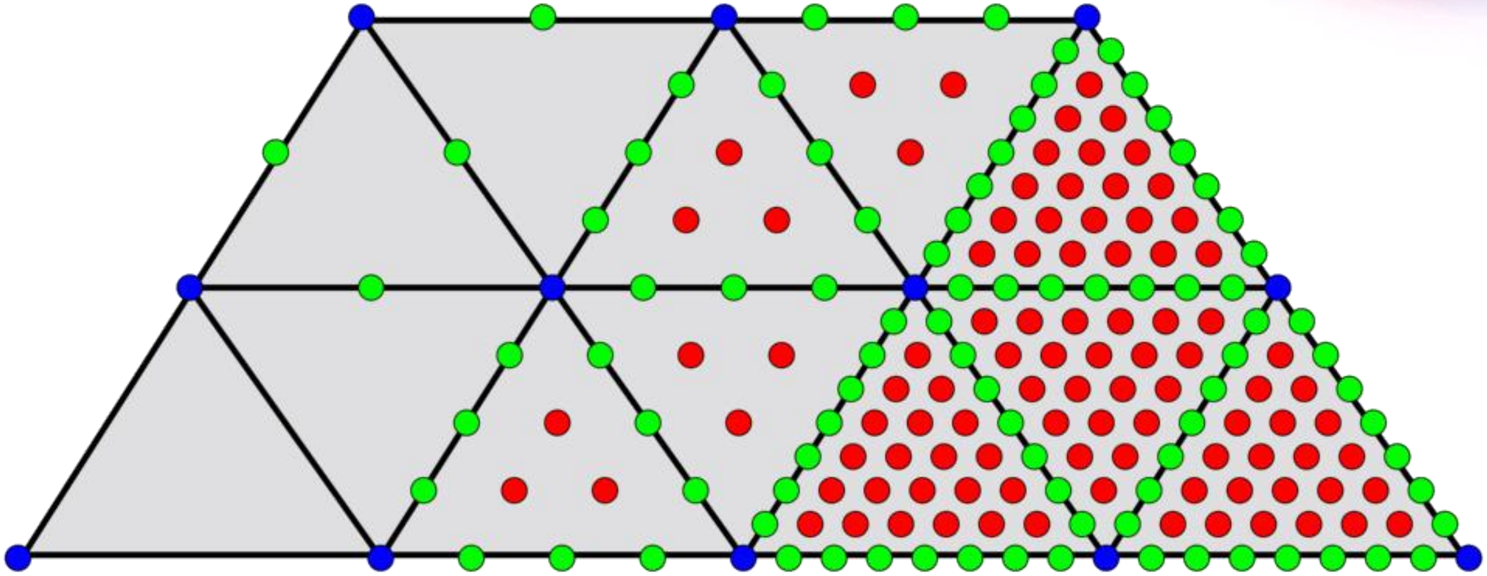
Local Resolution Adjustment

- Non-uniform face resolutions



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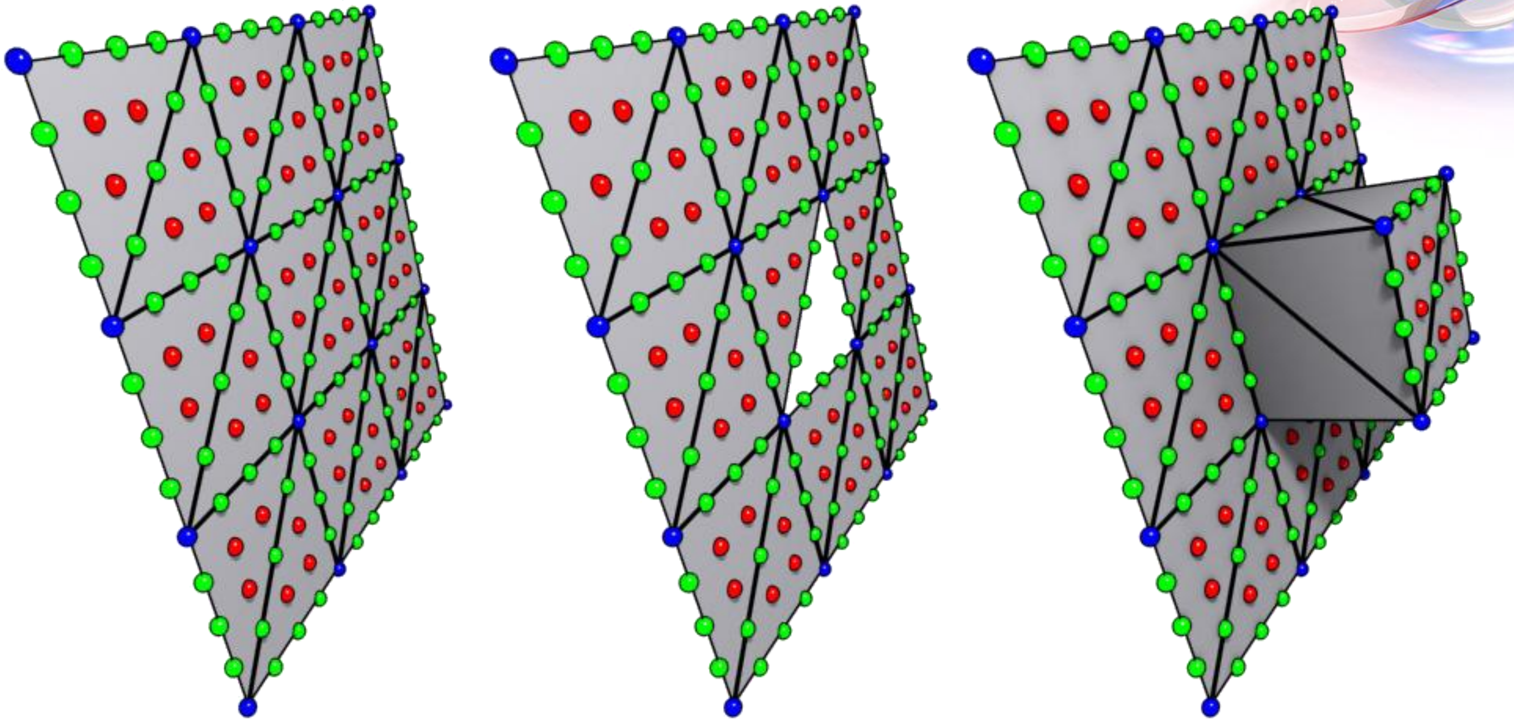
Modeling with Painting



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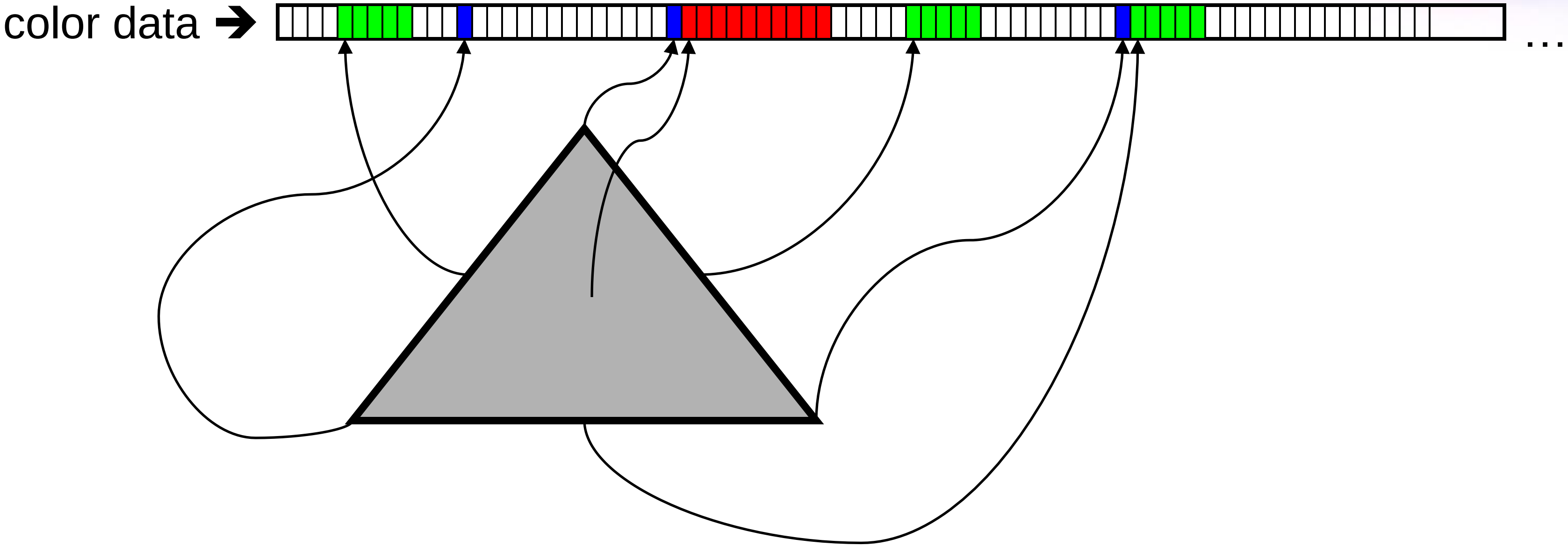
Compatible with Current Pipeline

- Separating mesh and color data



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Mesh Colors

- Easy to use (for end user)
  - No mapping
  - High flexibility
- Easy to implement (for programmer)
  - Colors have well-defined positions on the surface
- High quality
- High performance

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Mesh Colors

- Mesh Colors are ideally suited for
  - 3D painting
  - Storing precomputed data
    - Ambient occlusion
    - Radiosity
  - Displacement
- Mesh Colors provide a solution to the *fundamental* problems of texture mapping.

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Acknowledgements

- Murat Afsar
- Anonymous reviewers
- NVIDIA
- Microsoft
- NSF IIS Award #0917286

Mesh Colors

Questions?