Improving the Parameterization of Approximate Subdivision Surfaces

Lei He[1], Charles Loop[2], Scott Schaefer[1]

[1]Texas A&M University

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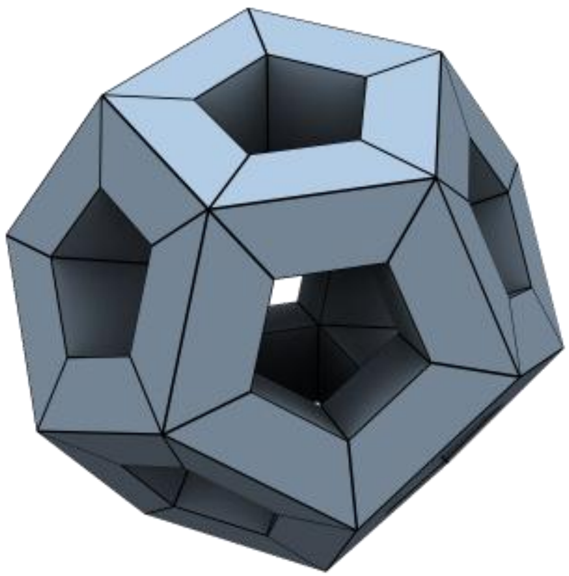
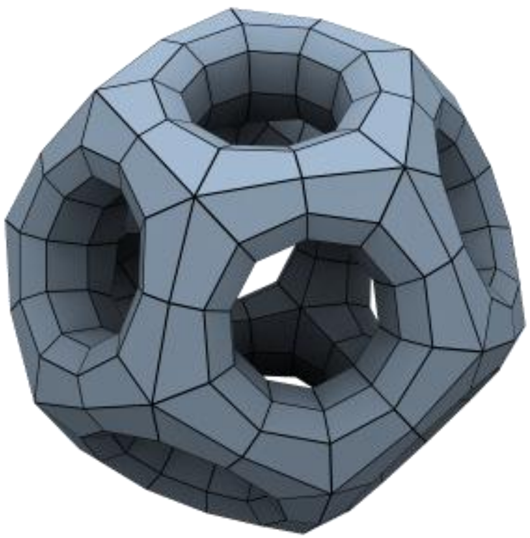
Subdivision Surface



Subdivision Surface



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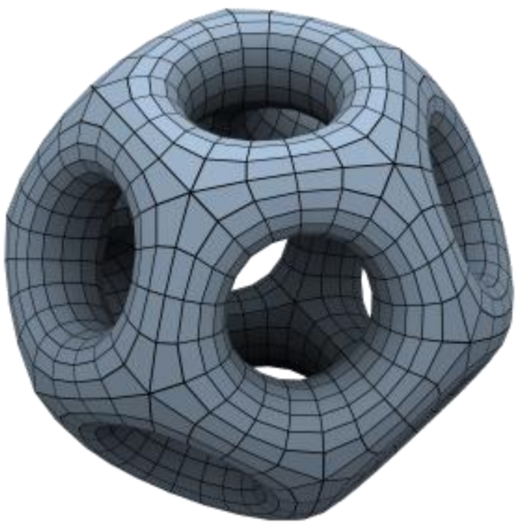
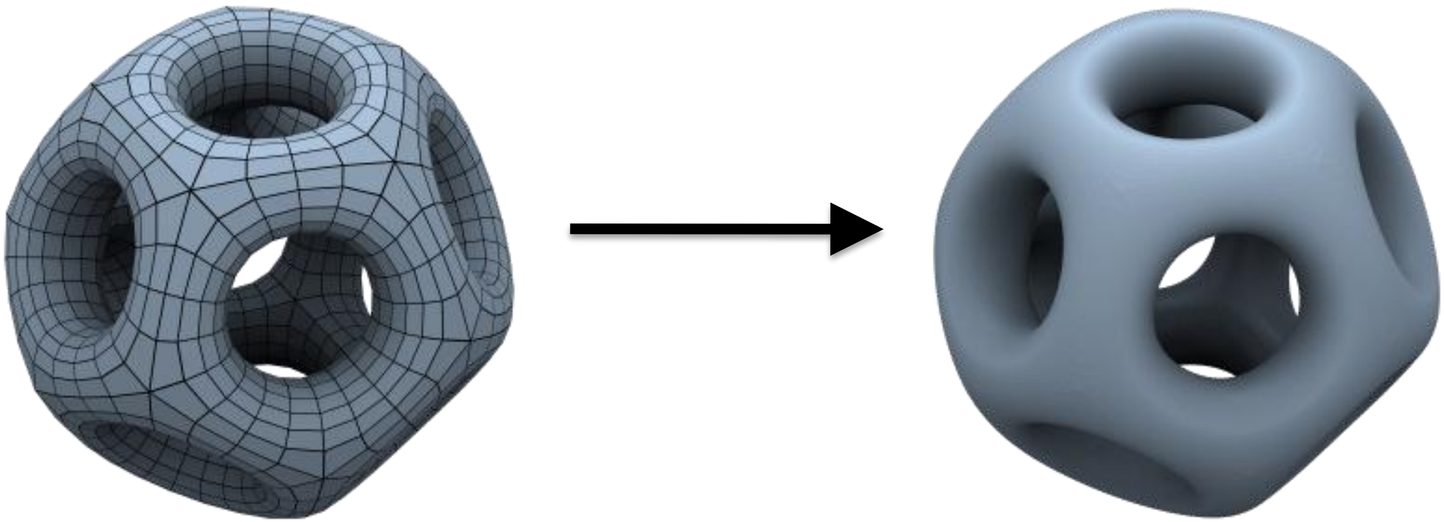


Subdivision Surface

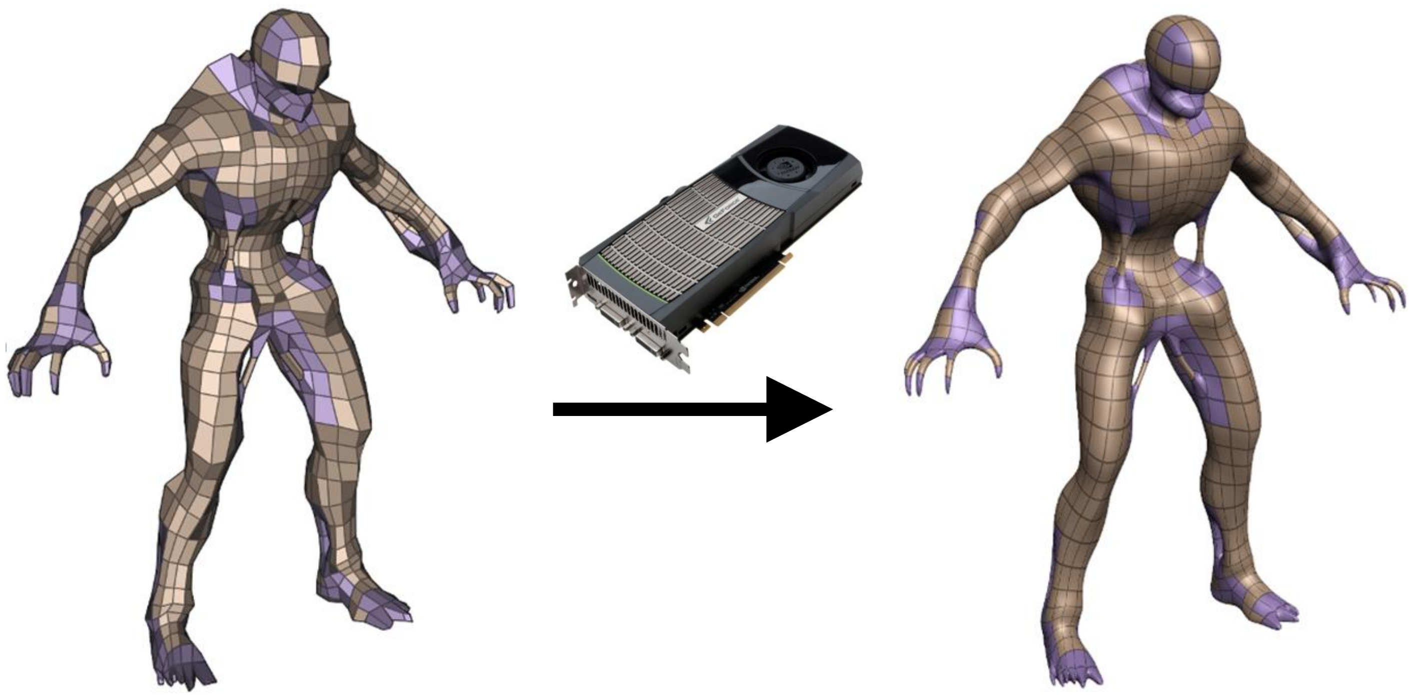


Motivation

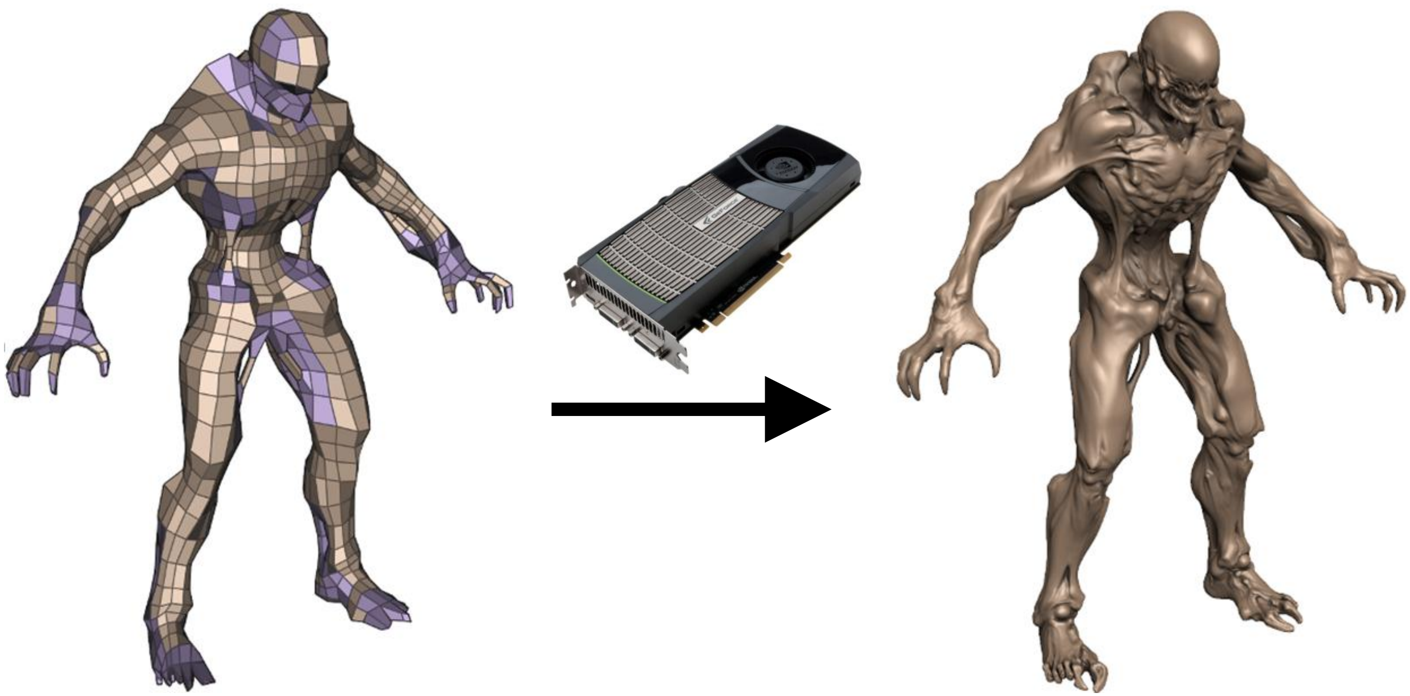
Toy Story © Disney / Pixar

Geri’s Game © Pixar Animation Studios

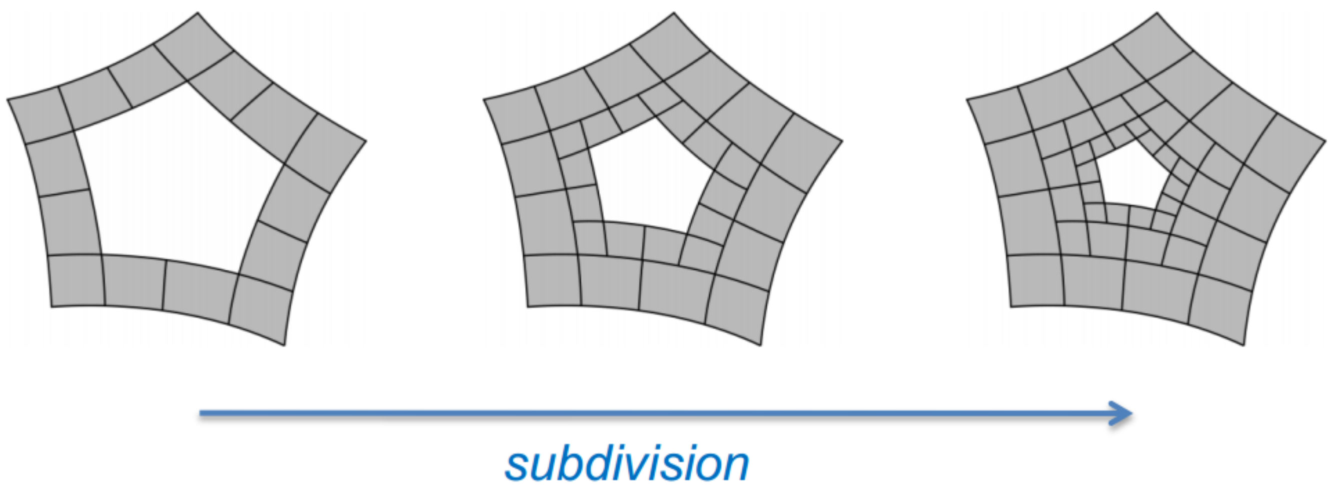
Motivation



Motivation



Problem of Subdivision Surfaces



- Expensive to do the exact evaluation
- Hard to fit hardware tessellation

Approximate Subdivision Surfaces

- Loop, C. and Schaefer, S. 2008,
  Approximate Catmull-Clark subdivision surfaces with bicubic patches
- Ni, T., Yeo. Y.I., Myles, A, and Peters, J. 2008,
  GPU smoothing of quad meshes
- Myles, A, NI, T., and Peters, J. 2008,
  Fast Parallel construction of smooth surfaces from meshes with tri/quad/pent facets
- Loop, C., Schaefer, S., Ni, T., and Castaño, I. 2009,
  Approximating subdivision surfaces with Gregory patches for hardware tessellation

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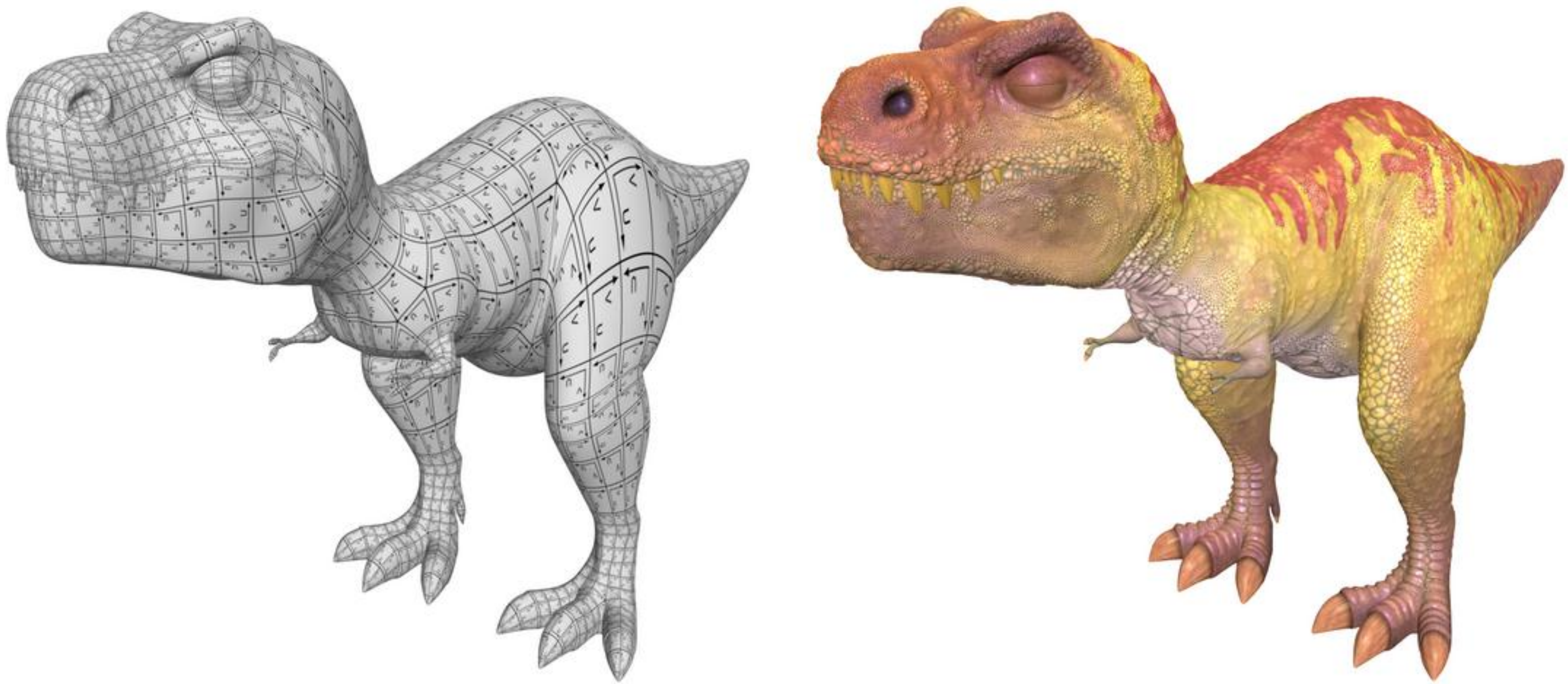
Where we are?

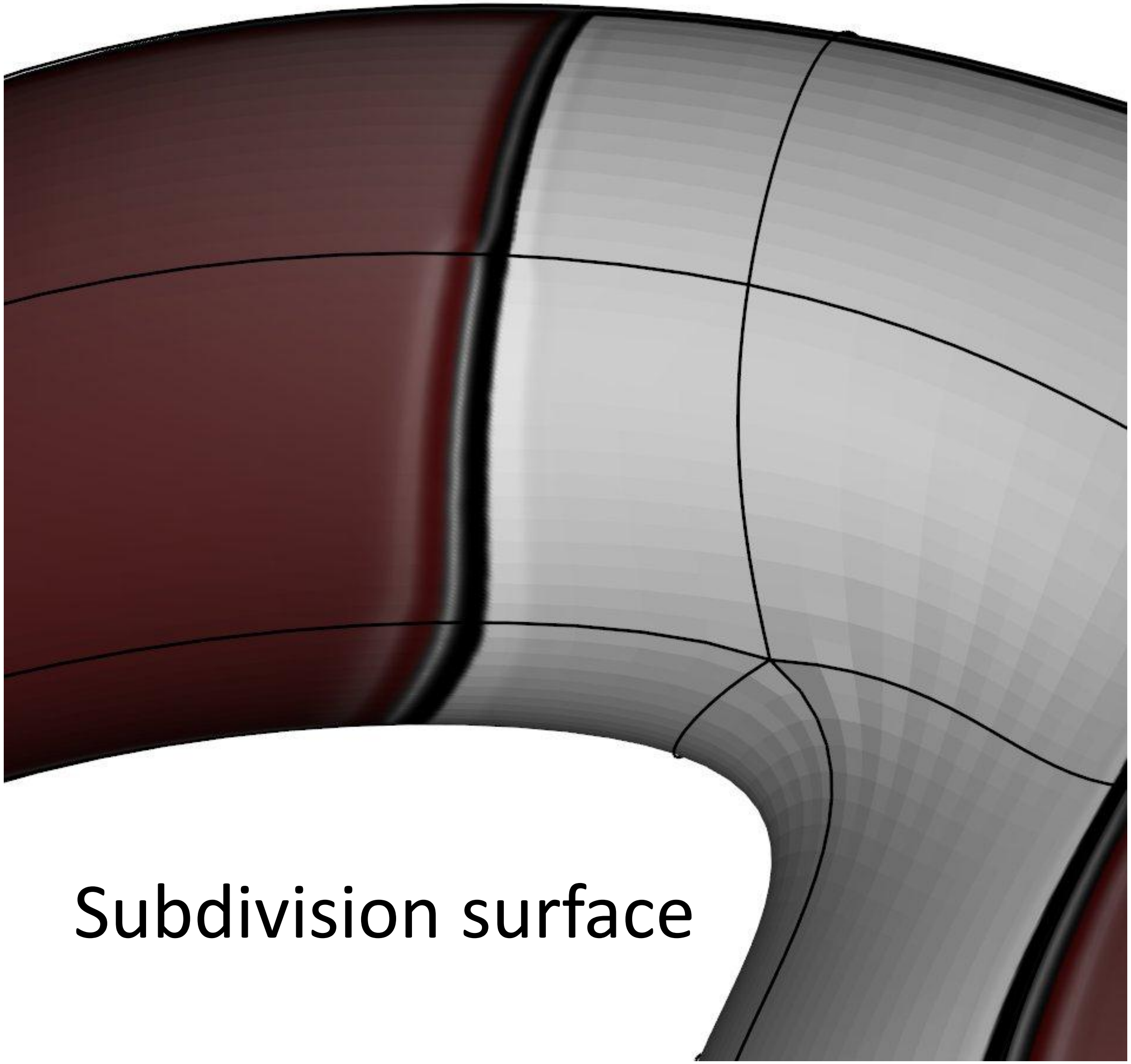
- ✓ Subdivision Surface
- ✓ Texturing Subdivision Surface
- ✓ Approximate Subdivision Surface
- ✗ Texturing Approximate Subdivision Surface

Ptex

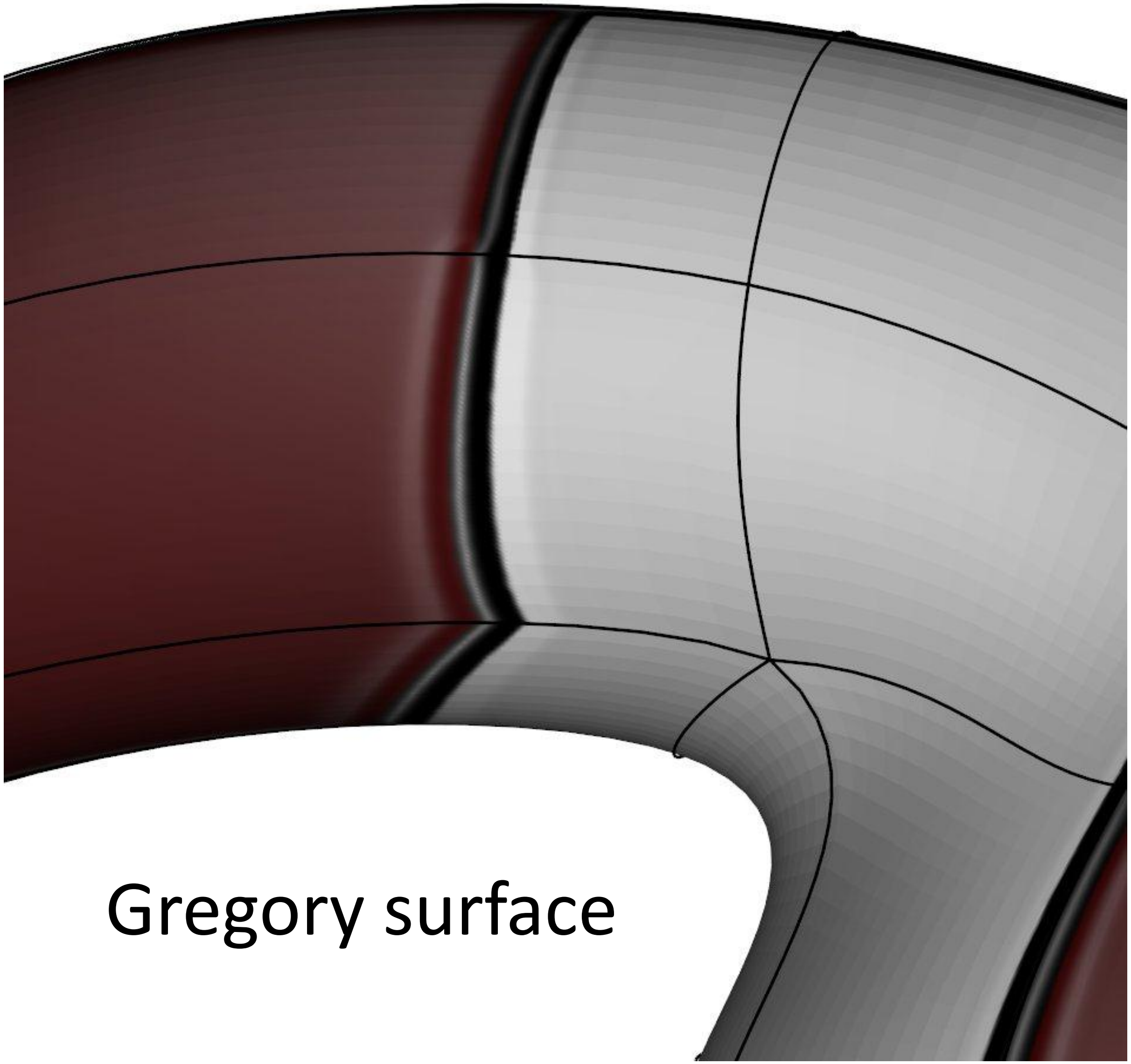


Burley B., and Lacewell D. 2008

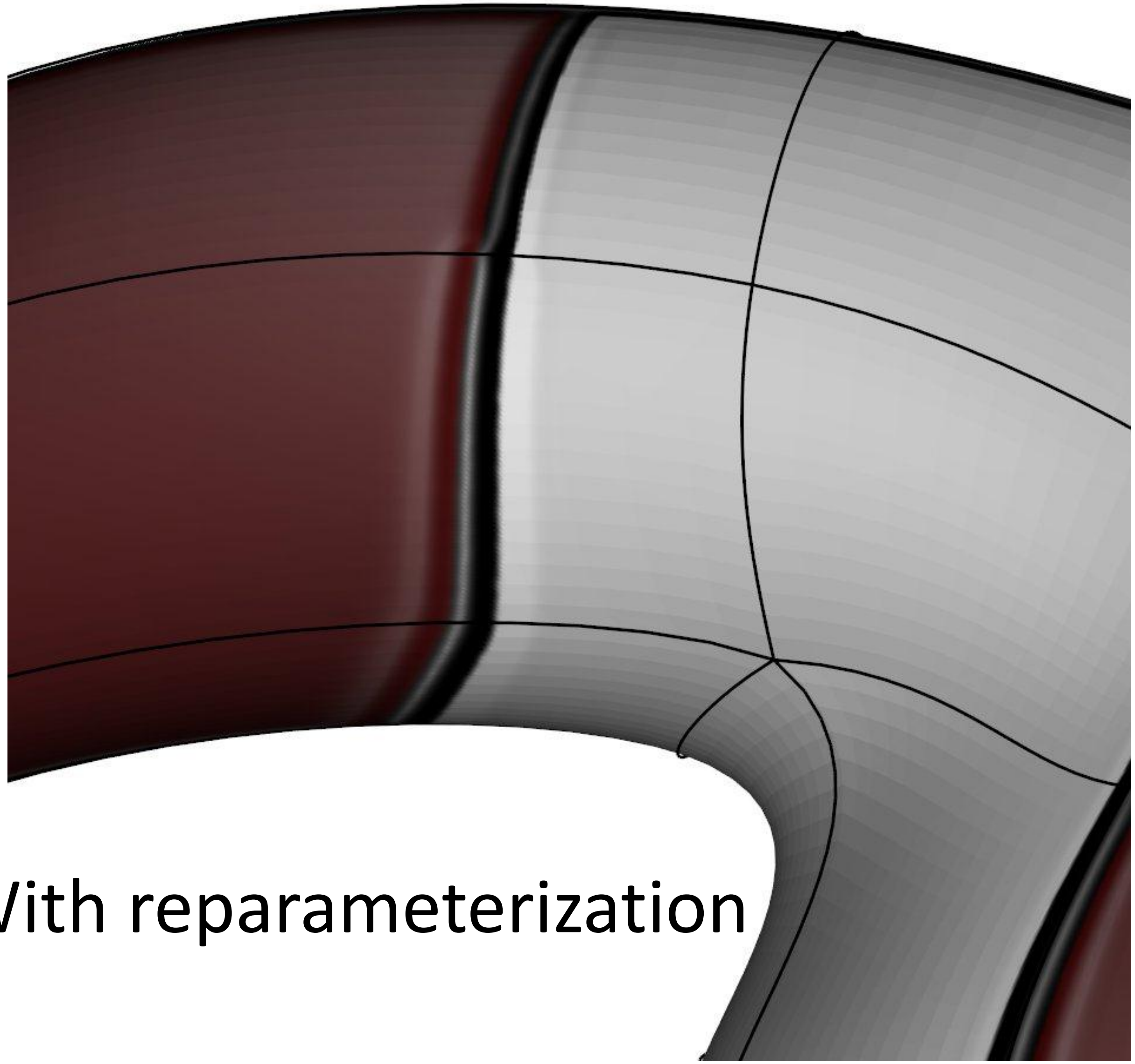
Ptex: Per-face texture mapping for production rendering



Subdivision surface

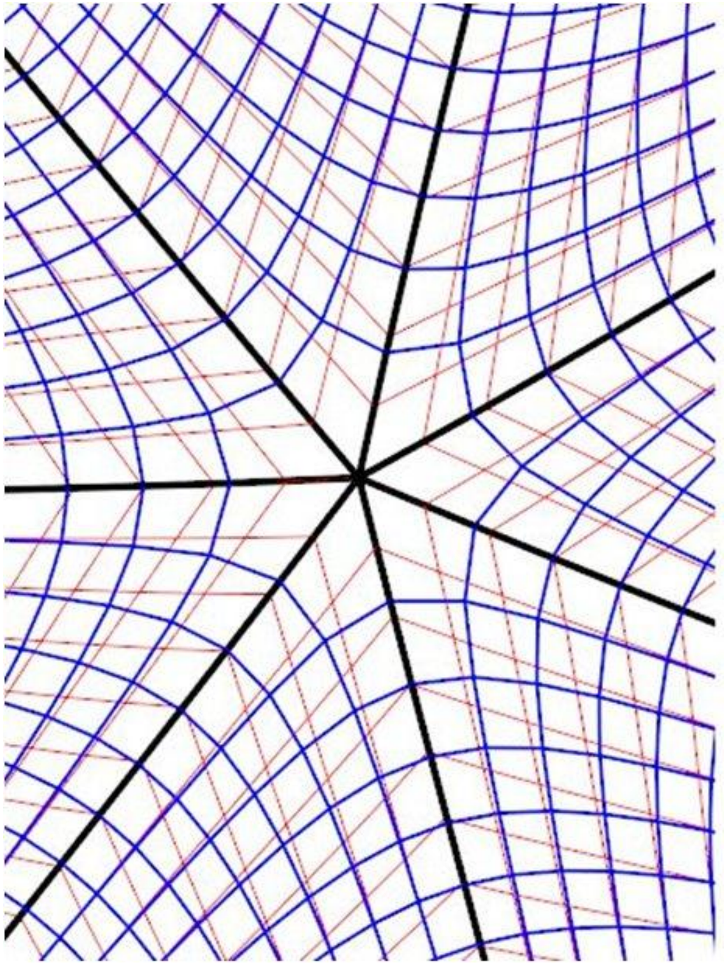


Gregory surface



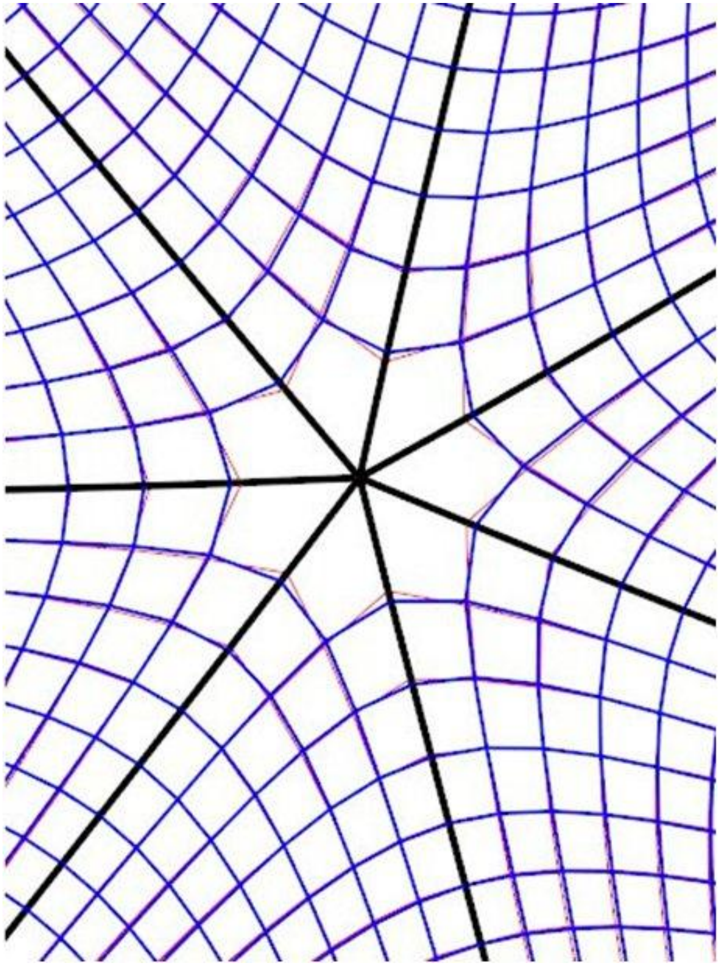
With reparameterization

Reparameterization



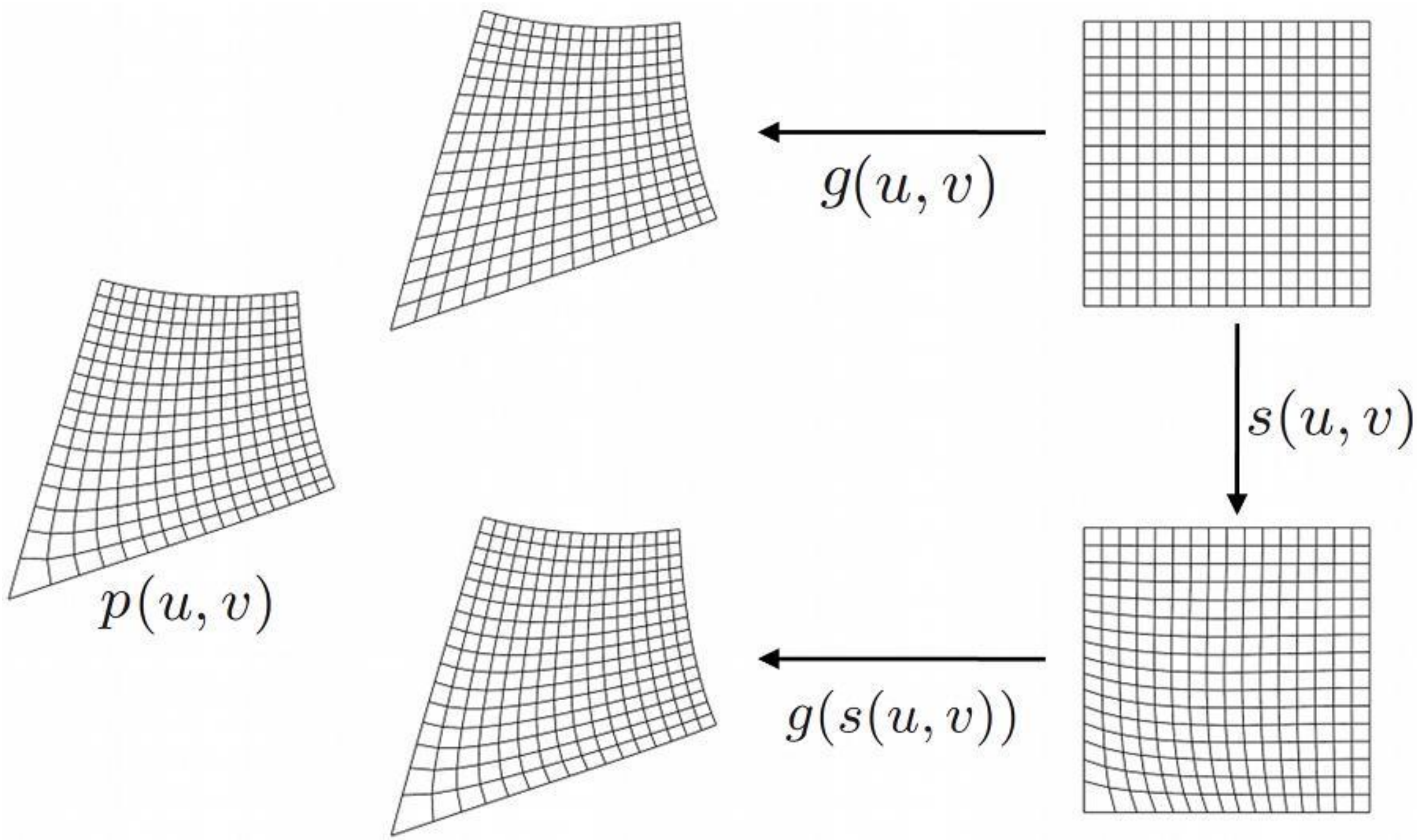
Original

Reparameterization

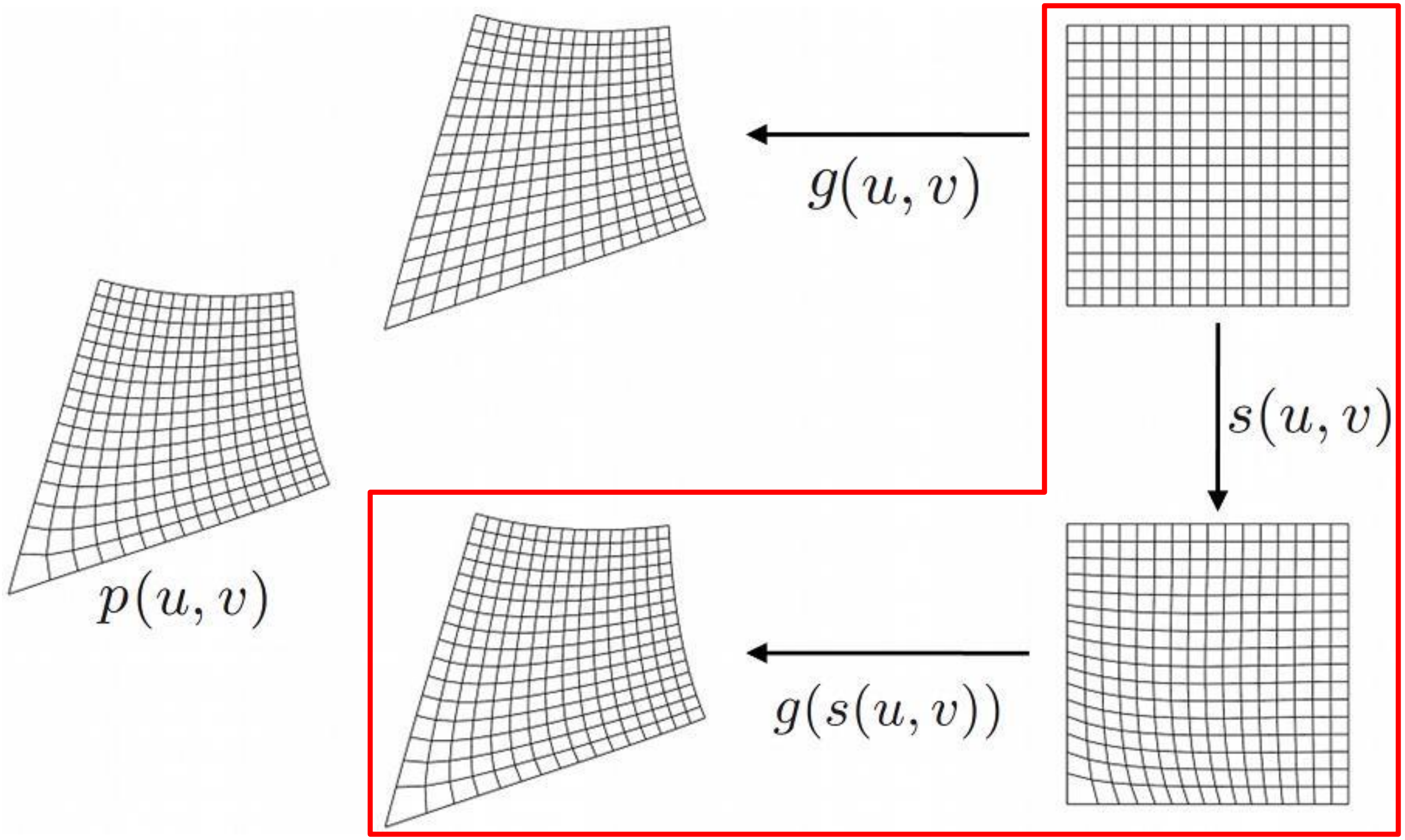


With reparameterization

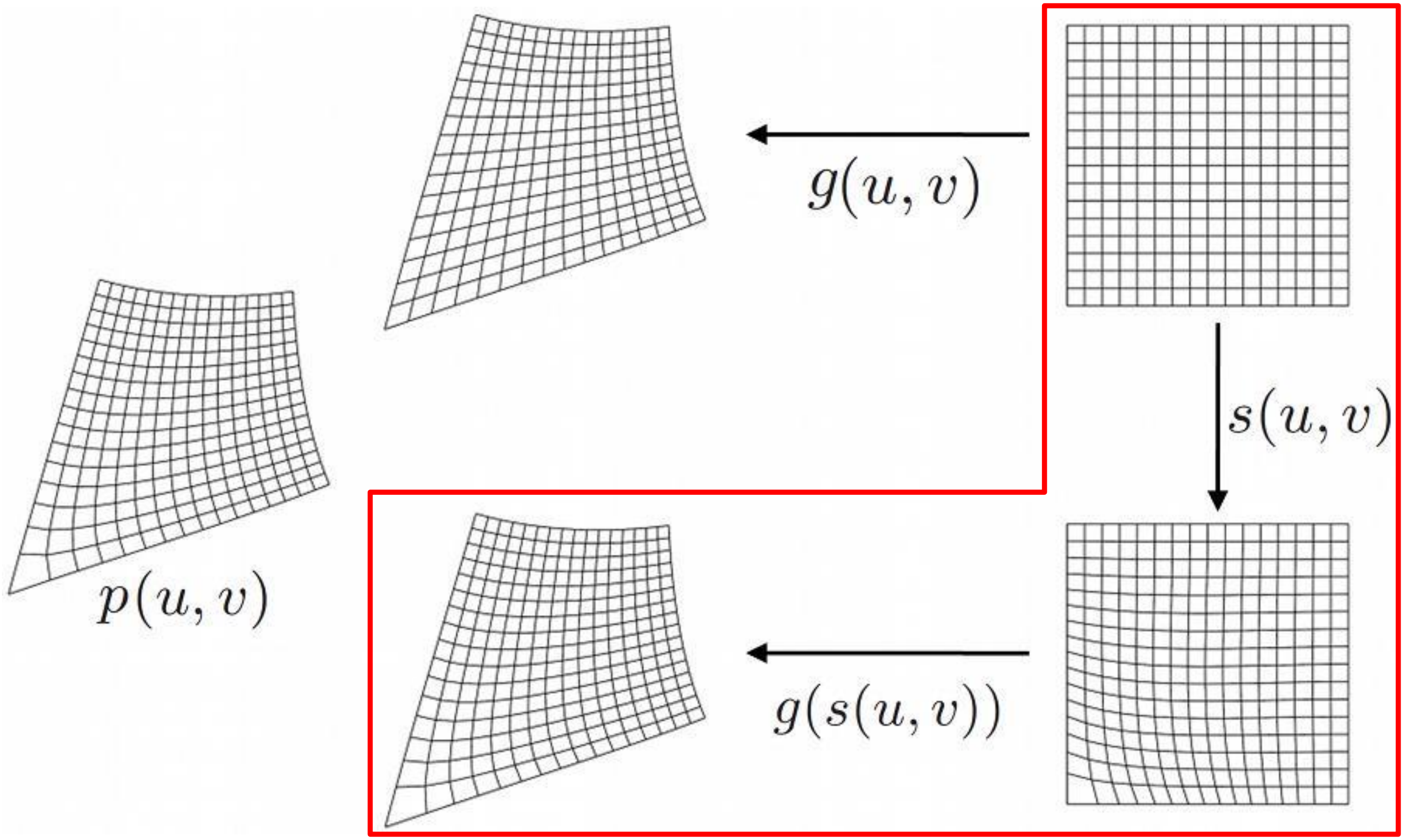
Reparameterization



Reparameterization



Reparameterization



$$\min_s \int_{u=0}^{1}\int_{v=0}^{1} \left| p_i(u,v) - g_i(s_i(u,v)) \right|^2$$

Reparameterization

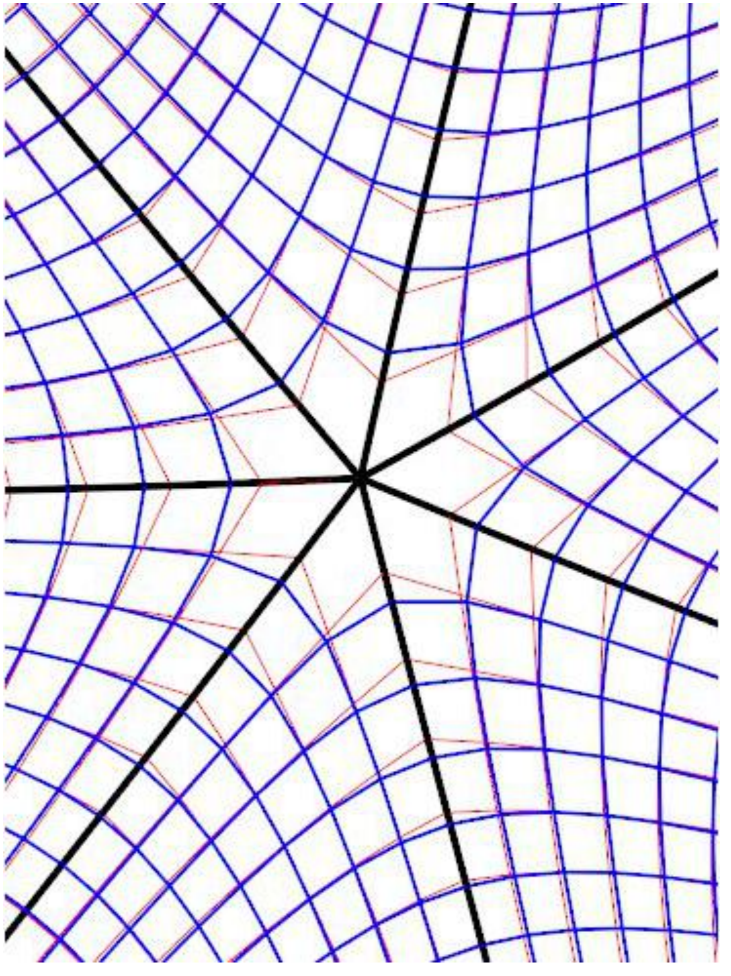
- Optimizing on 2D texture space instead of 3D

$$\min_{s_i} \sum_j \left| (u_j, v_j) - s_i(u_{k(j)}, v_{k(j)}) \right|^2 dp_j$$

k(j) gives the index of the closest point $g(u_k,v_k)$ to $p(u_j,v_j)$.

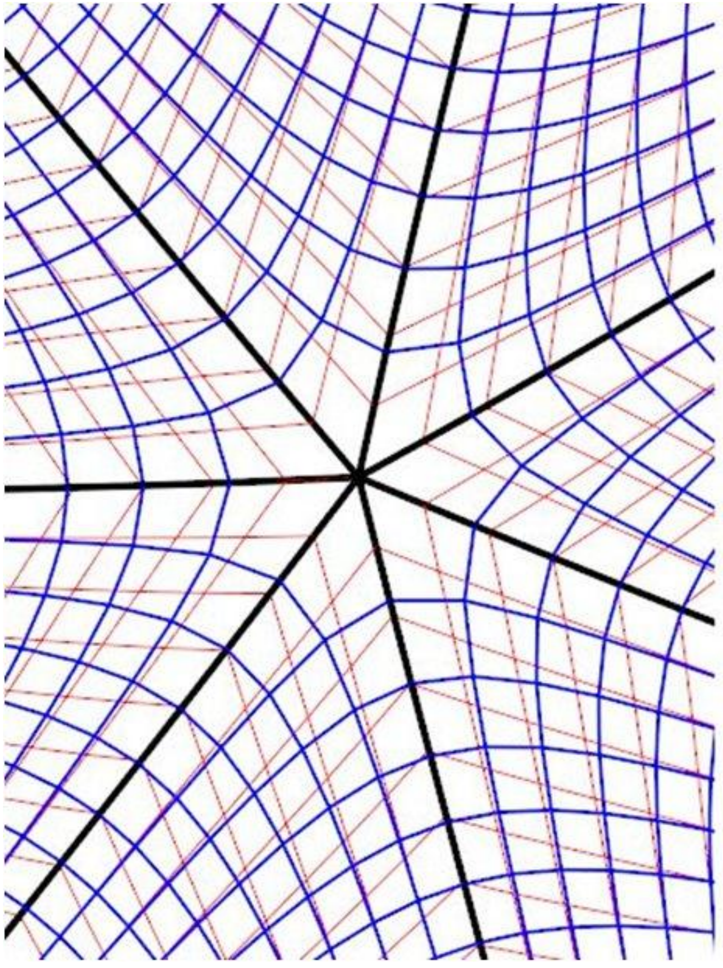
Uniform grid of size 17^2 for (u_j,v_j) and 5000^2 for (u_k,v_k).

Reparameterization



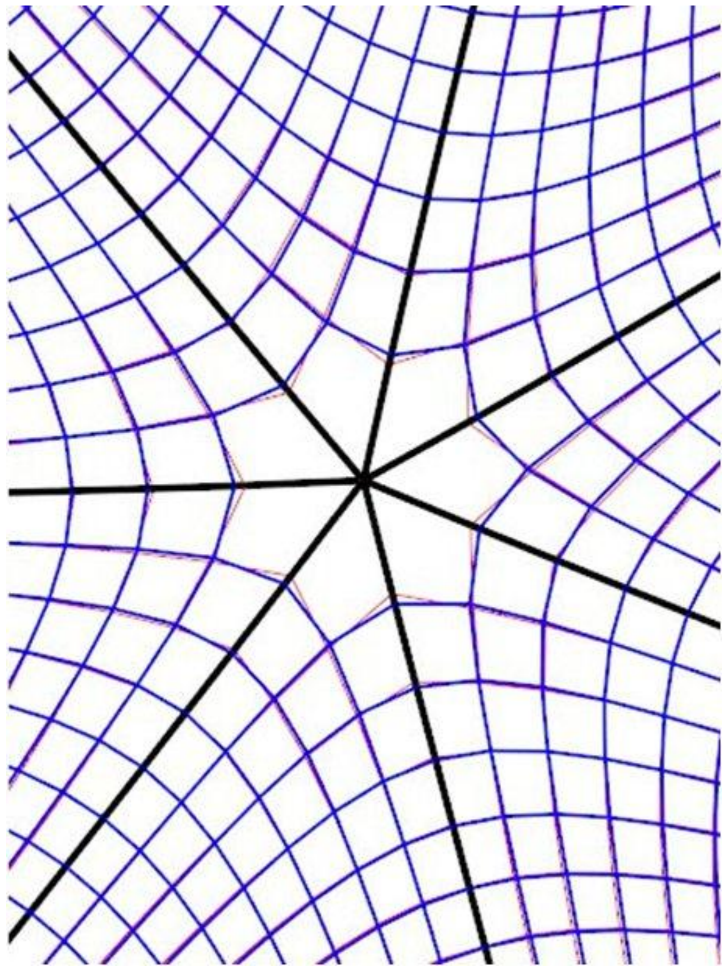
Bicubic function

Reparameterization



Original

Reparameterization



Rational bicubic function

Reparameterization

- Optimizing on 2D texture space instead of 3D

$$\min_{s_i} \sum_j \left| (u_j, v_j) - s_i(u_{k(j)}, v_{k(j)}) \right|^2 dp_j$$

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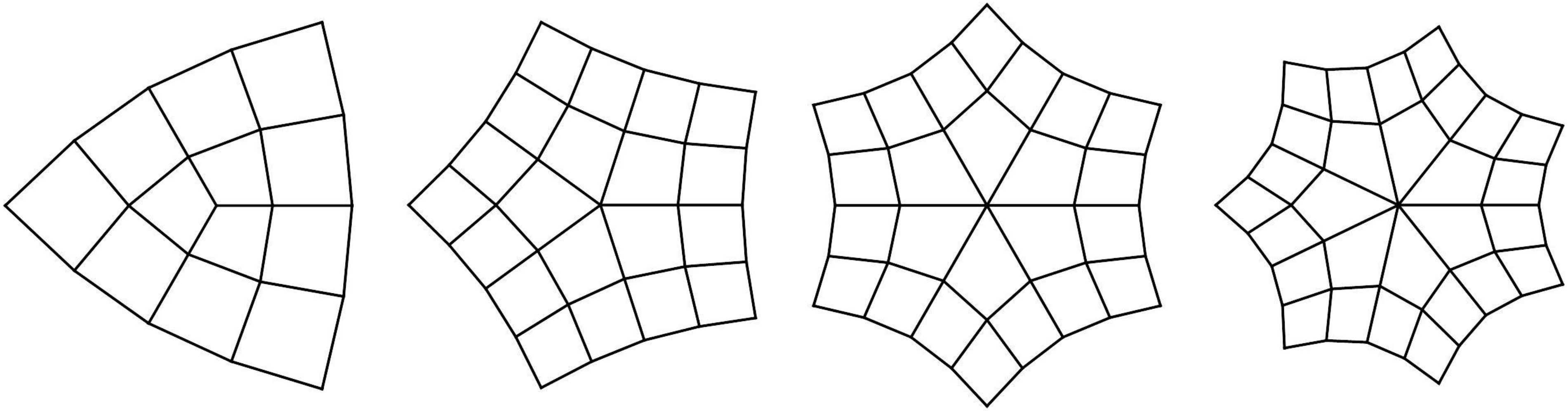
Uniform grid of size 17^2 for (u_j,v_j) and 5000^2 for (u_k,v_k).

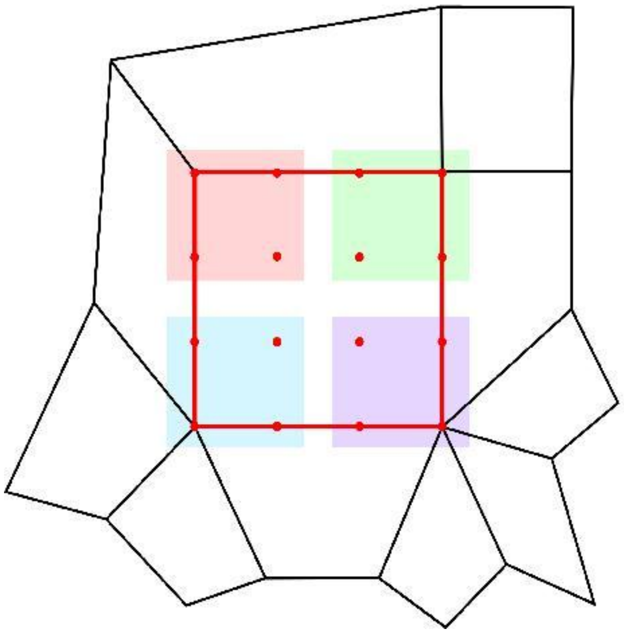
- Geometry Independence

every single patch requires an individual optimization to obtain the fitting function *s*

Geometry Independence



Multiple Extraordinary Vertices



$$\begin{pmatrix} 0,0,c_0^3 & 0,c_1^3,c_2^3 & 0,\overline{c}_1^4,c_2^4 & 0,1,c_0^4 \\ c_1^3,0,c_2^3 & c_3^3,c_3^3,c_4^3 & c_3^4,\overline{c}_3^4,c_4^4 & c_1^4,1,c_2^4 \\ \overline{c}_1^5,0,c_2^5 & \overline{c}_3^5,c_3^5,c_4^5 & \overline{c}_3^6,\overline{c}_3^6,c_4^6 & \overline{c}_1^6,1,c_2^6 \\ 1,0,c_0^5 & 1,c_1^5,c_2^5 & 1,\overline{c}_1^6,c_2^6 & 1,1,c_0^6 \end{pmatrix}$$

$$\overline{c_i} = 1 - c_i$$

Multiple Extraordinary Vertices

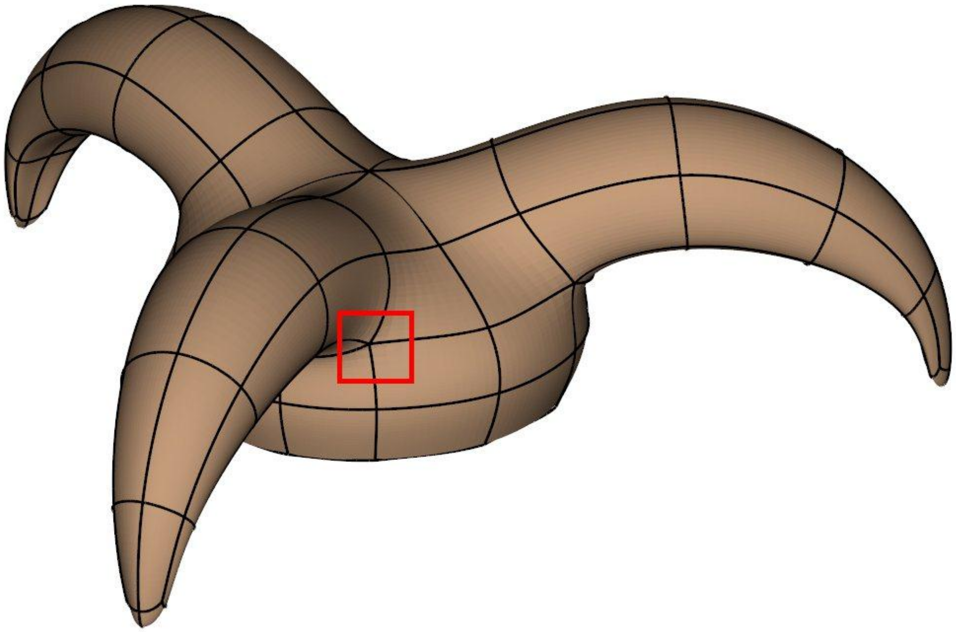
$$C = \begin{pmatrix} (0,0,c_0^n) & (0,c_1^n,c_2^n) & (0,\frac{2}{3},1) & (0,1,1) \\ (c_1^n,0,c_2^n) & (c_3^n,c_3^n,c_4^n) & (\frac{1}{3},\frac{2}{3},1) & (\frac{1}{3},1,1) \\ (\frac{2}{3},0,1) & (\frac{2}{3},\frac{1}{3},1) & (\frac{2}{3},\frac{2}{3},1) & (\frac{2}{3},1,1) \\ (1,0,1) & (1,\frac{1}{3},1) & (1,\frac{2}{3},1) & (1,1,1) \end{pmatrix}$$

Results

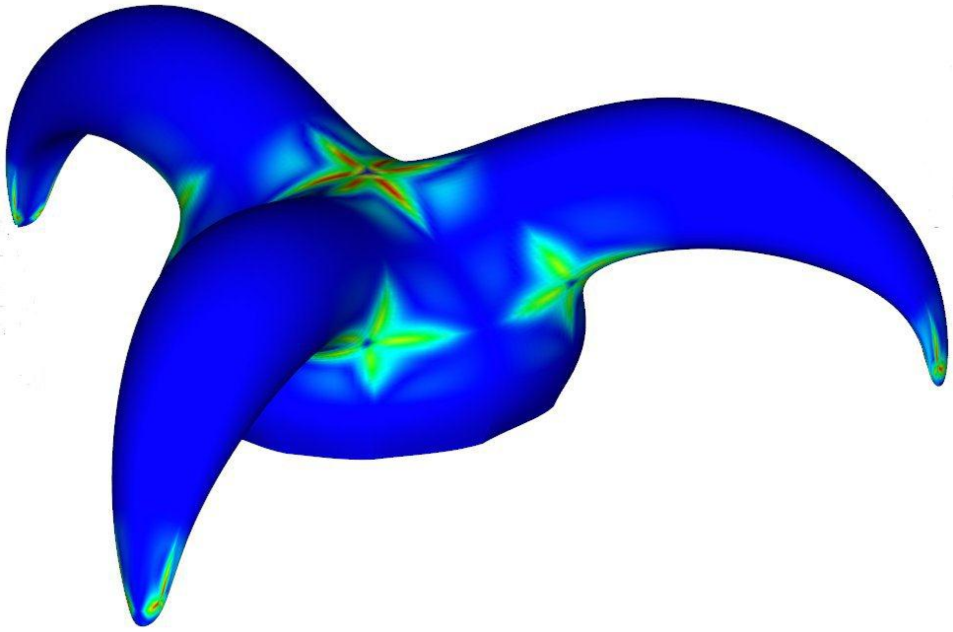
Valence	c_0^n	c_1^n	c_2^n	c_3^n	c_4^n
3	0.0759	0.1014	0.6548	0.2105	0.9240
5	0.3296	0.0850	0.7913	0.3223	0.8958
6	0.4188	0.0759	0.8259	0.3636	0.8768
7	0.4830	0.0686	0.8487	0.3949	0.8595
8	0.5293	0.0629	0.8645	0.4189	0.8451
9	0.5634	0.0586	0.8757	0.4372	0.8335
10	0.5890	0.0553	0.8840	0.4515	0.8242

Valence-dependent precomputed parameters

Results

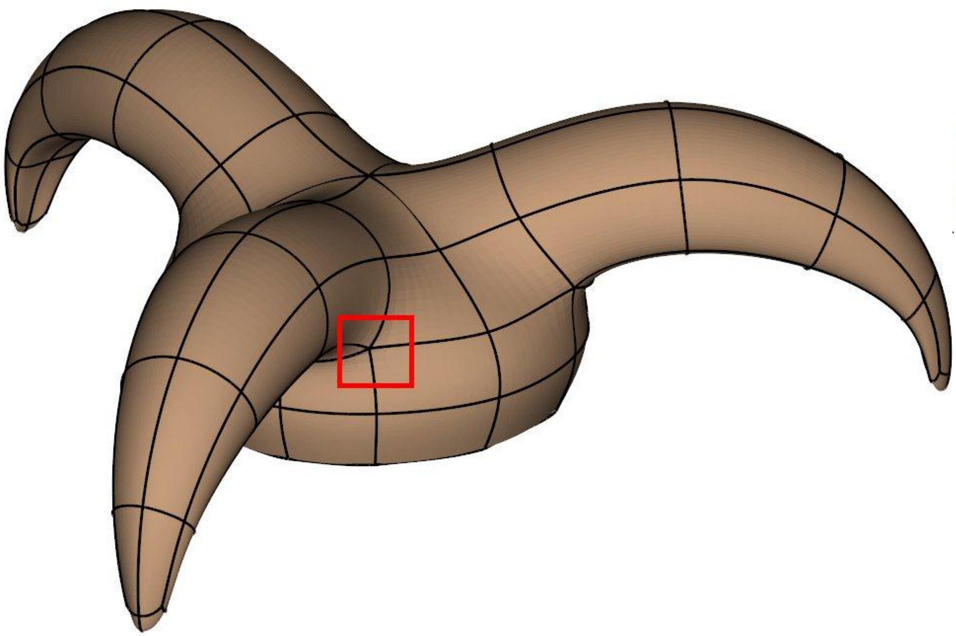


Gregory surface



Original

Results



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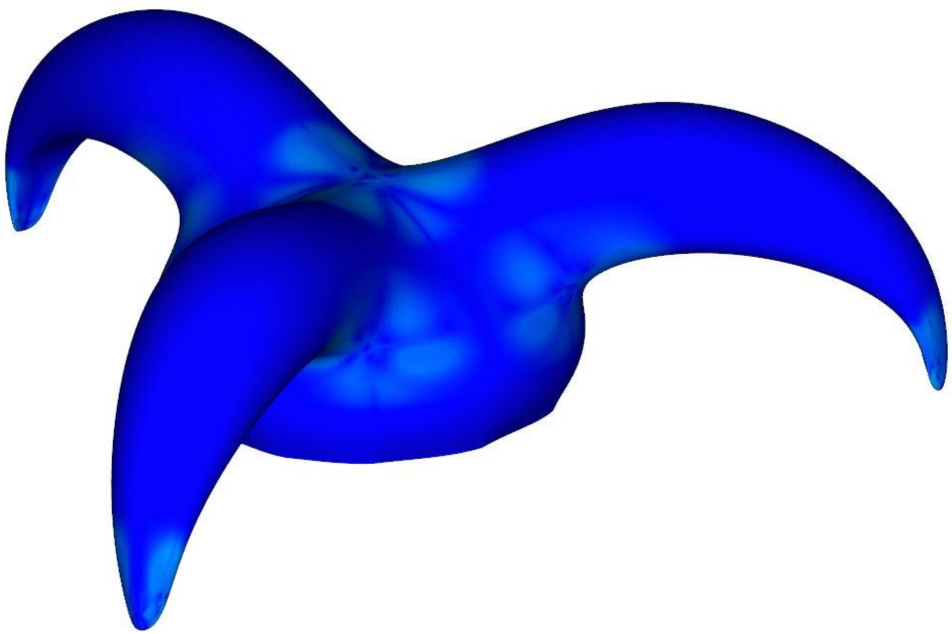
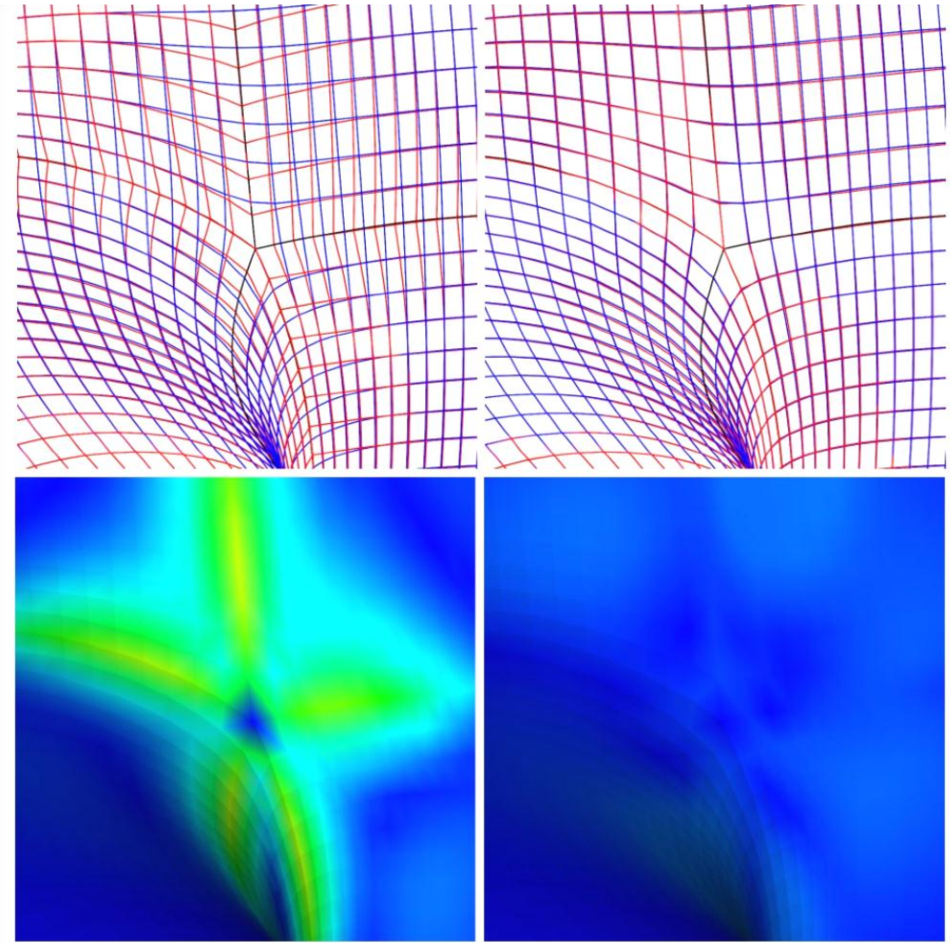


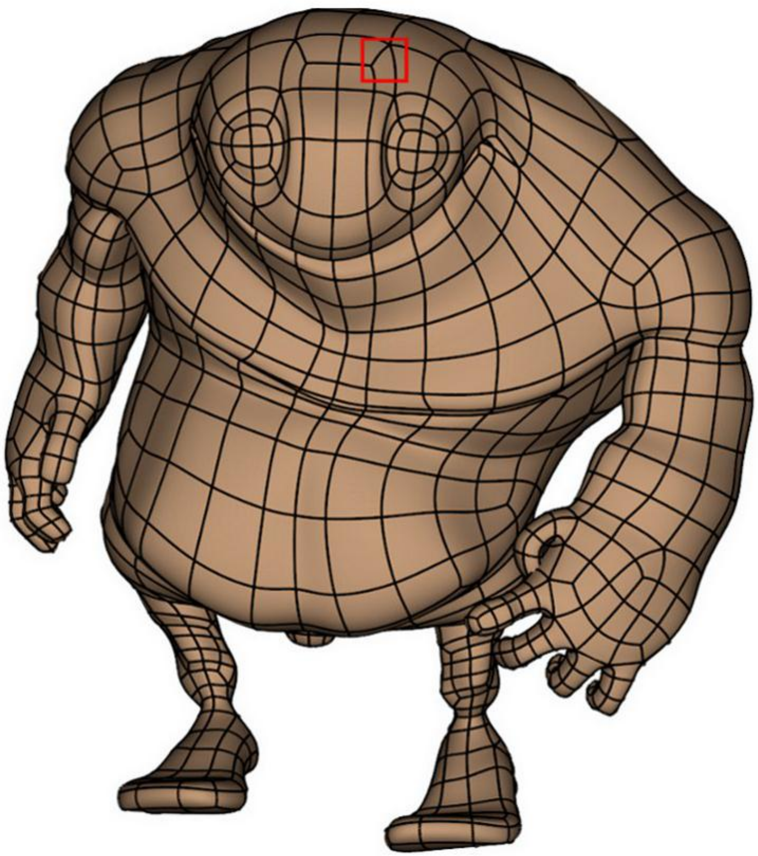
With reparameterization

Results



Original　　　Our method

Results



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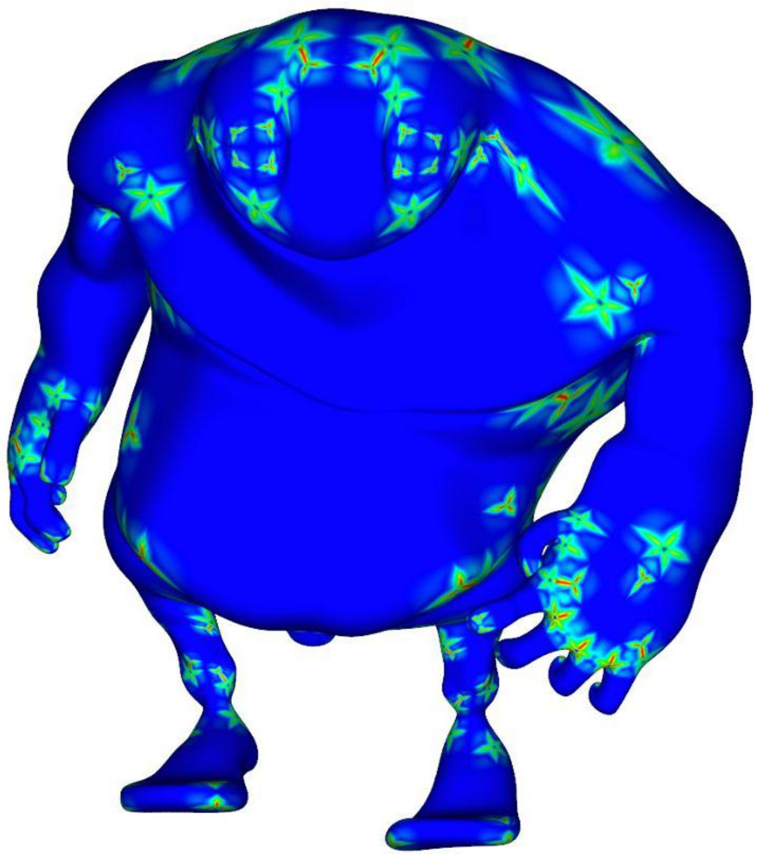

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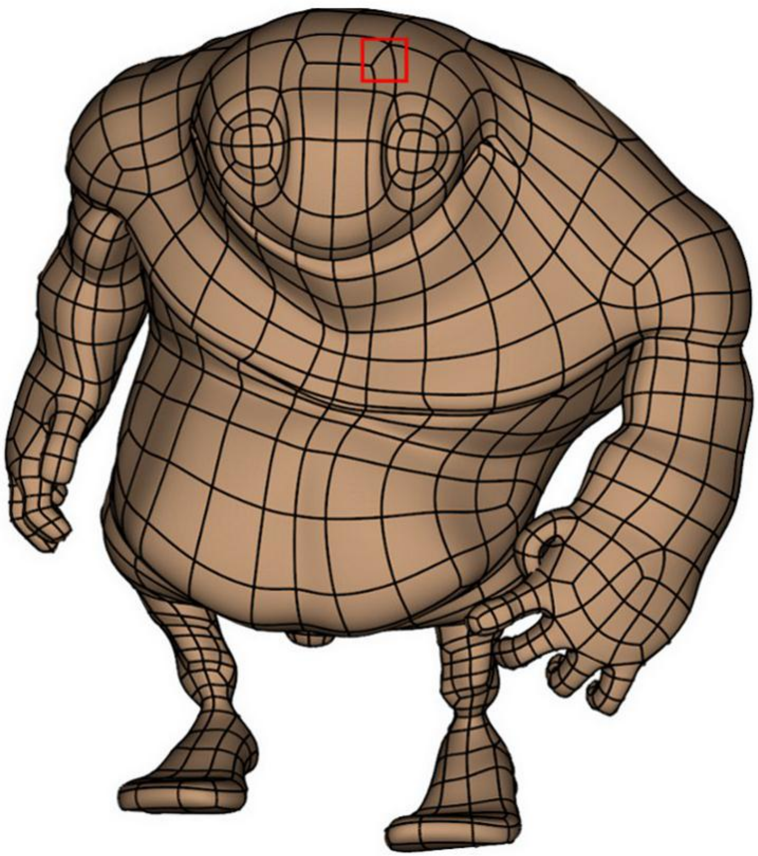

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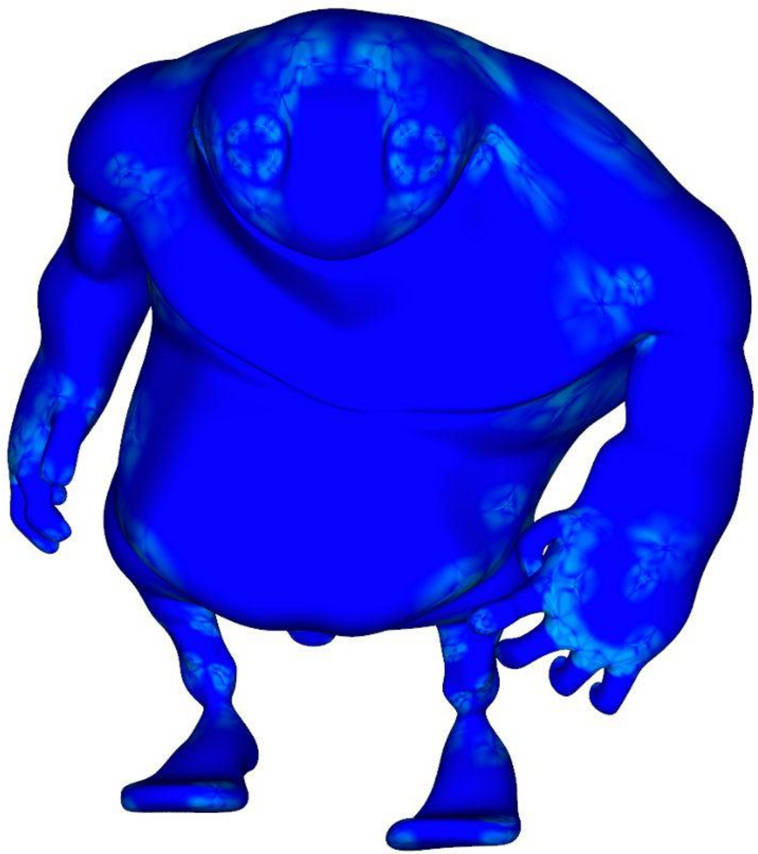
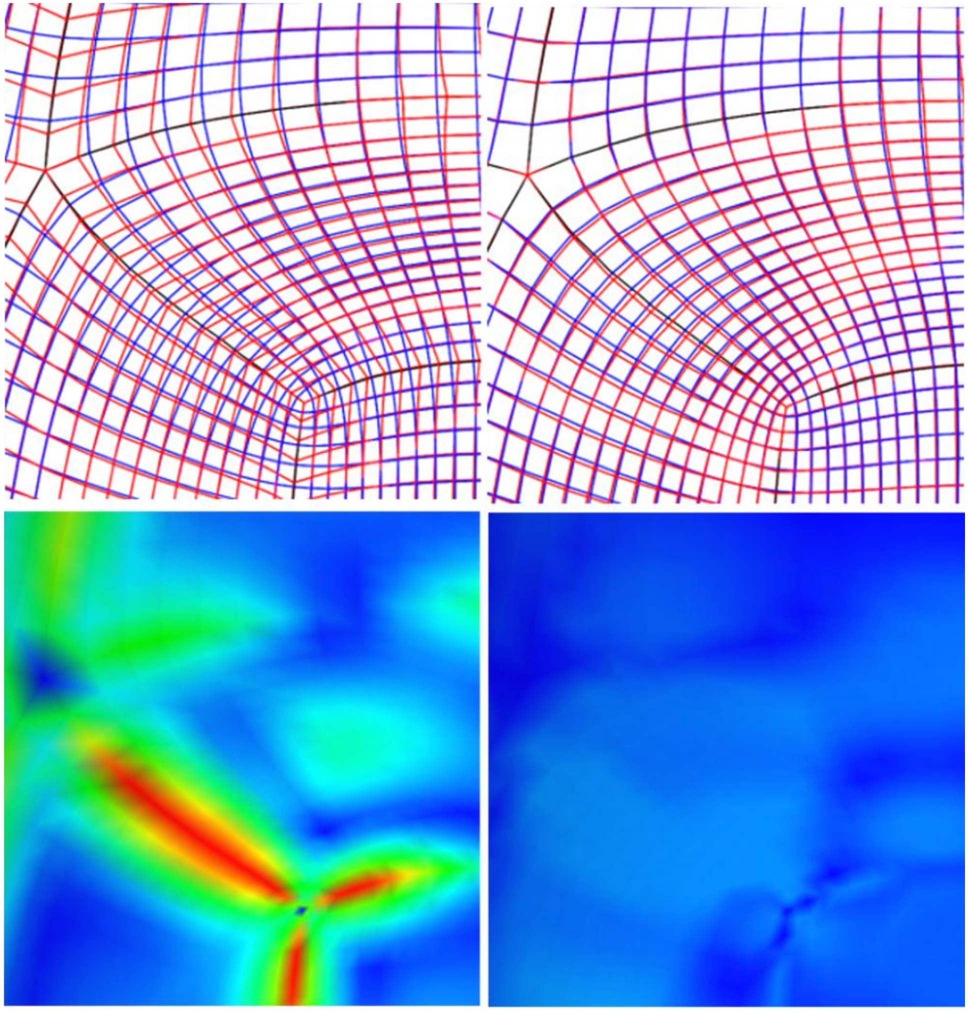


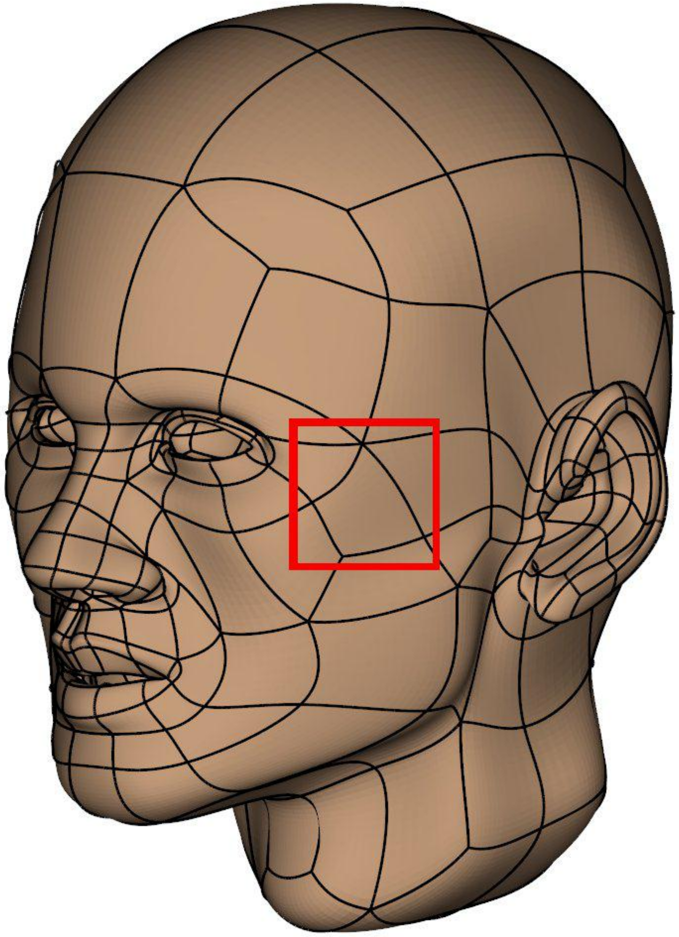
With reparameterization

Results



Original Our method

Results



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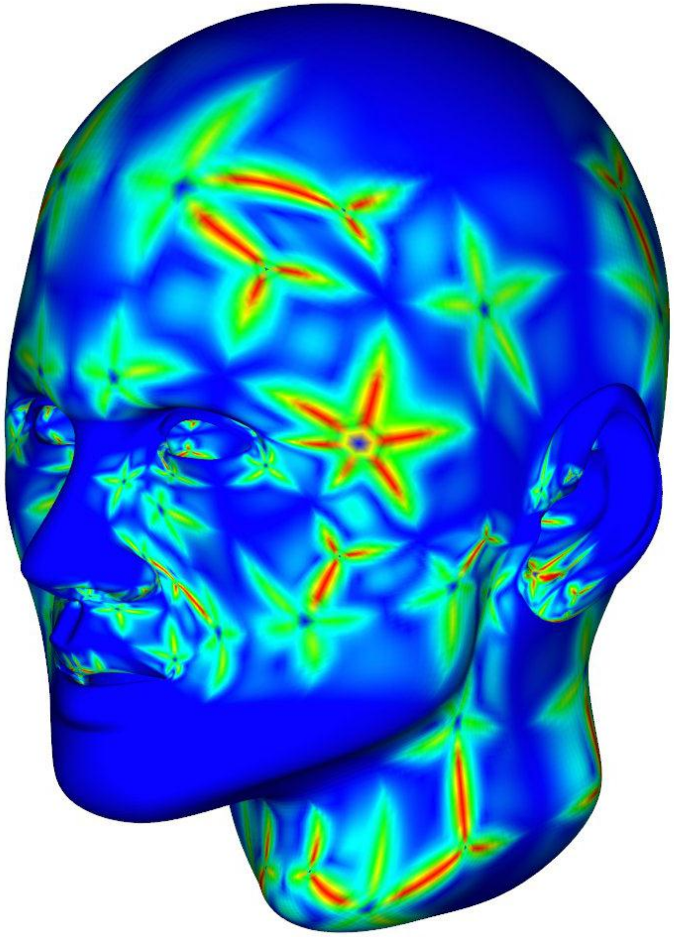

Original

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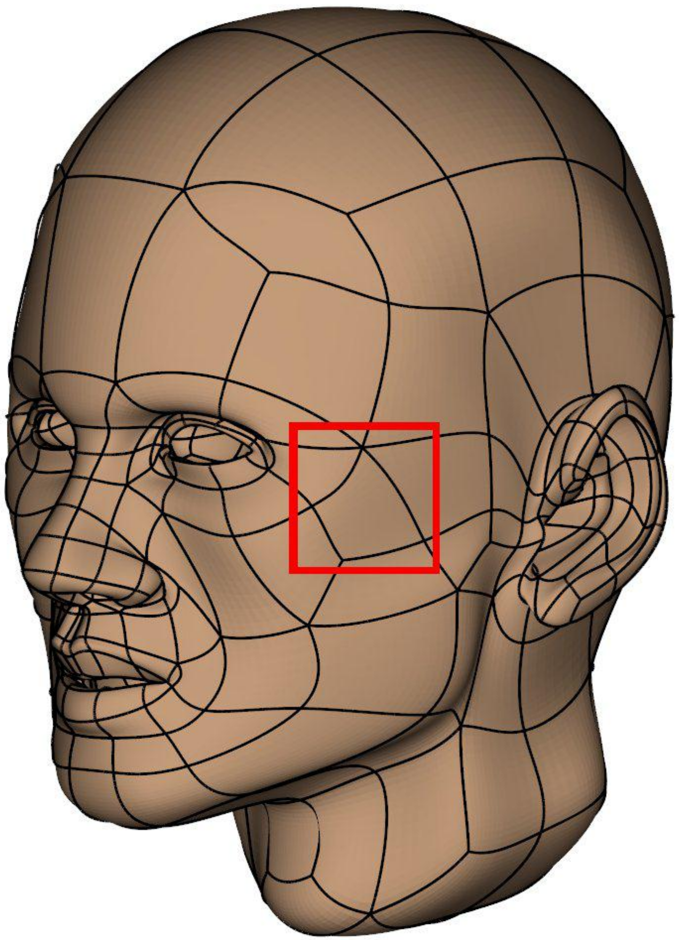

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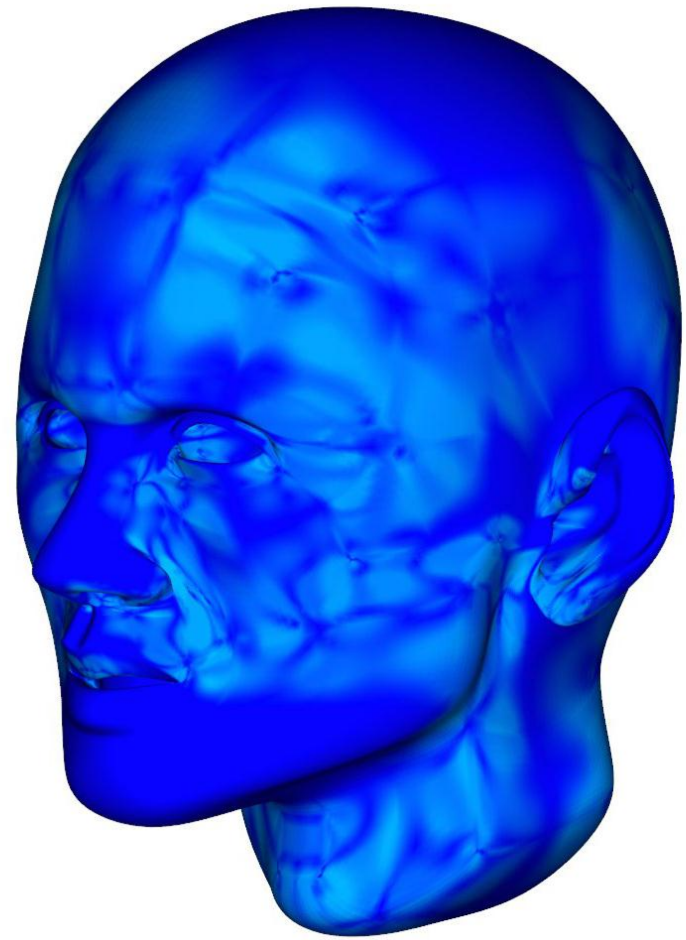
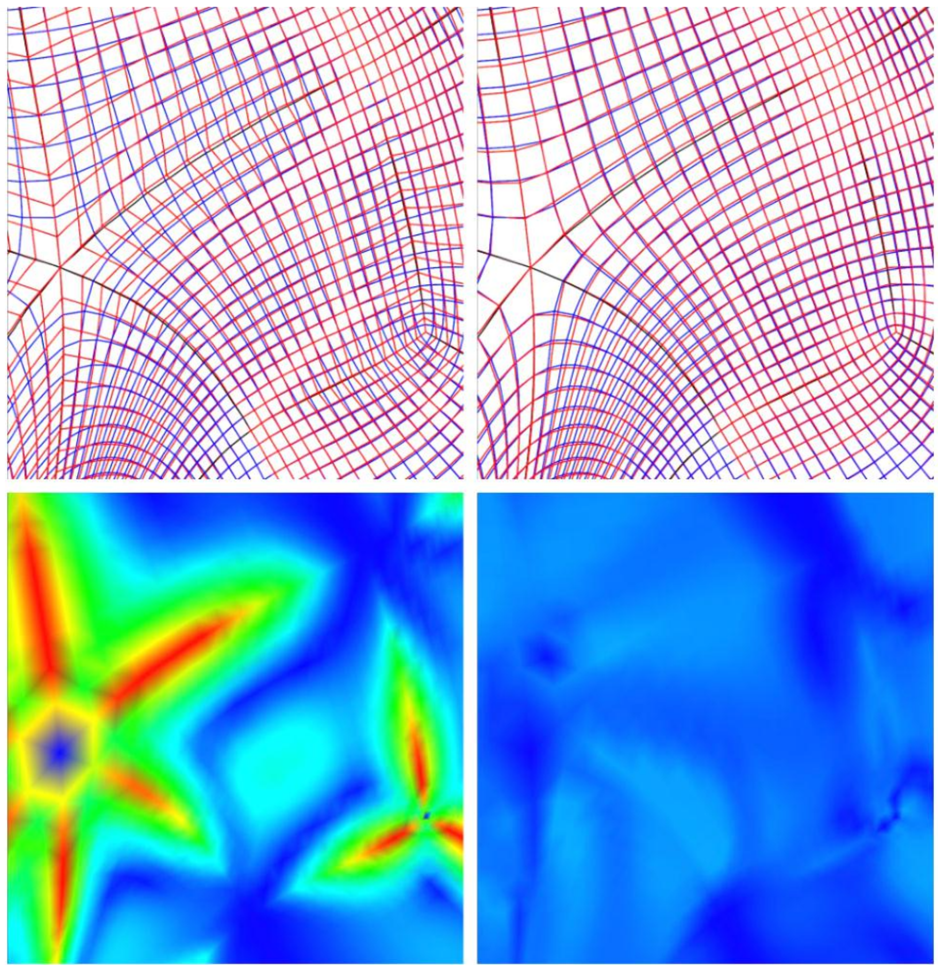


With reparameterization

Results



Original Our method

Subdivision surface

Original

With reparameterization

Conclusion

- Handles arbitrary number of extraordinary vertices per patch
- Geometry independent reparameterization
- Simple, efficient implementation

Thanks!