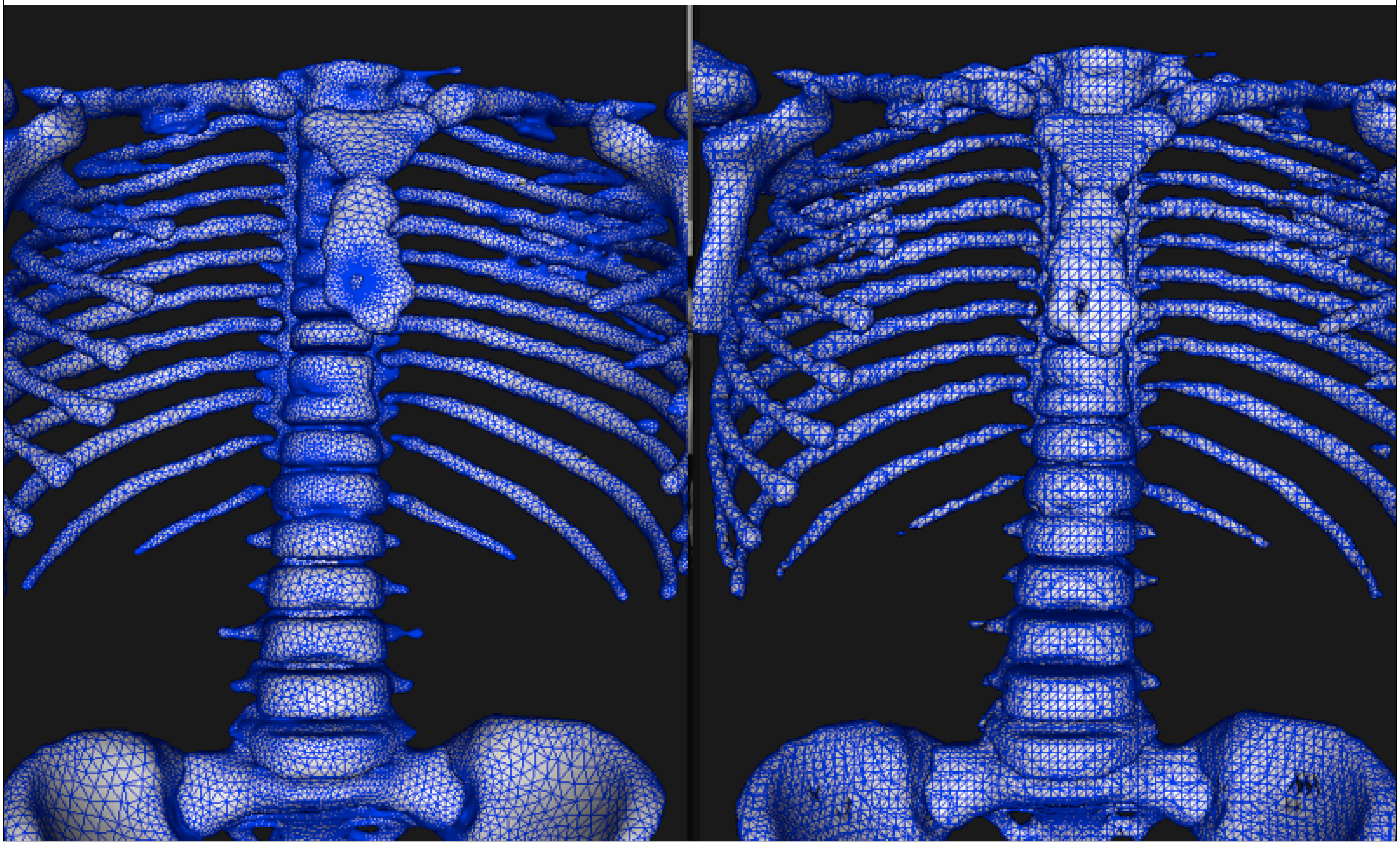
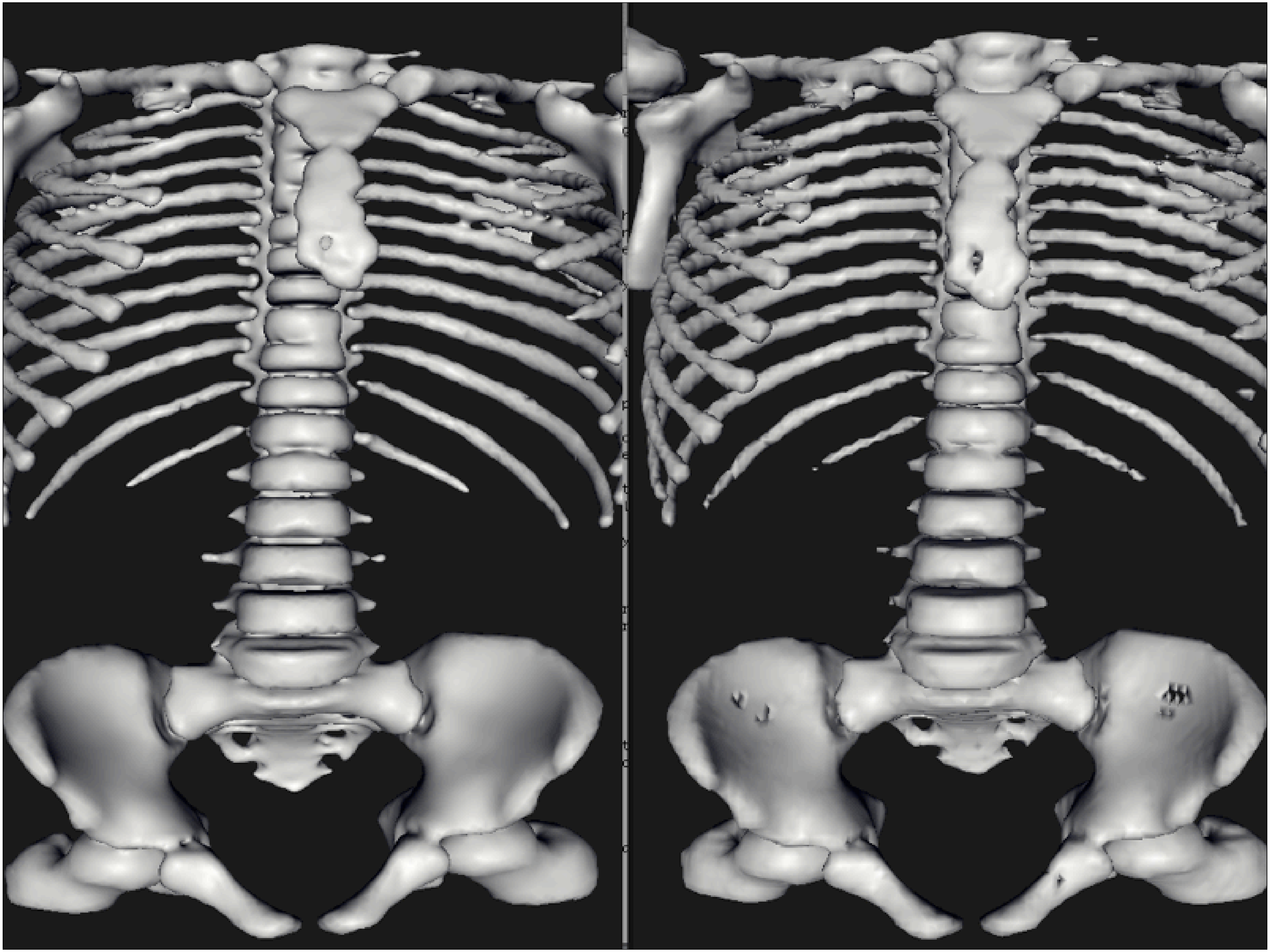
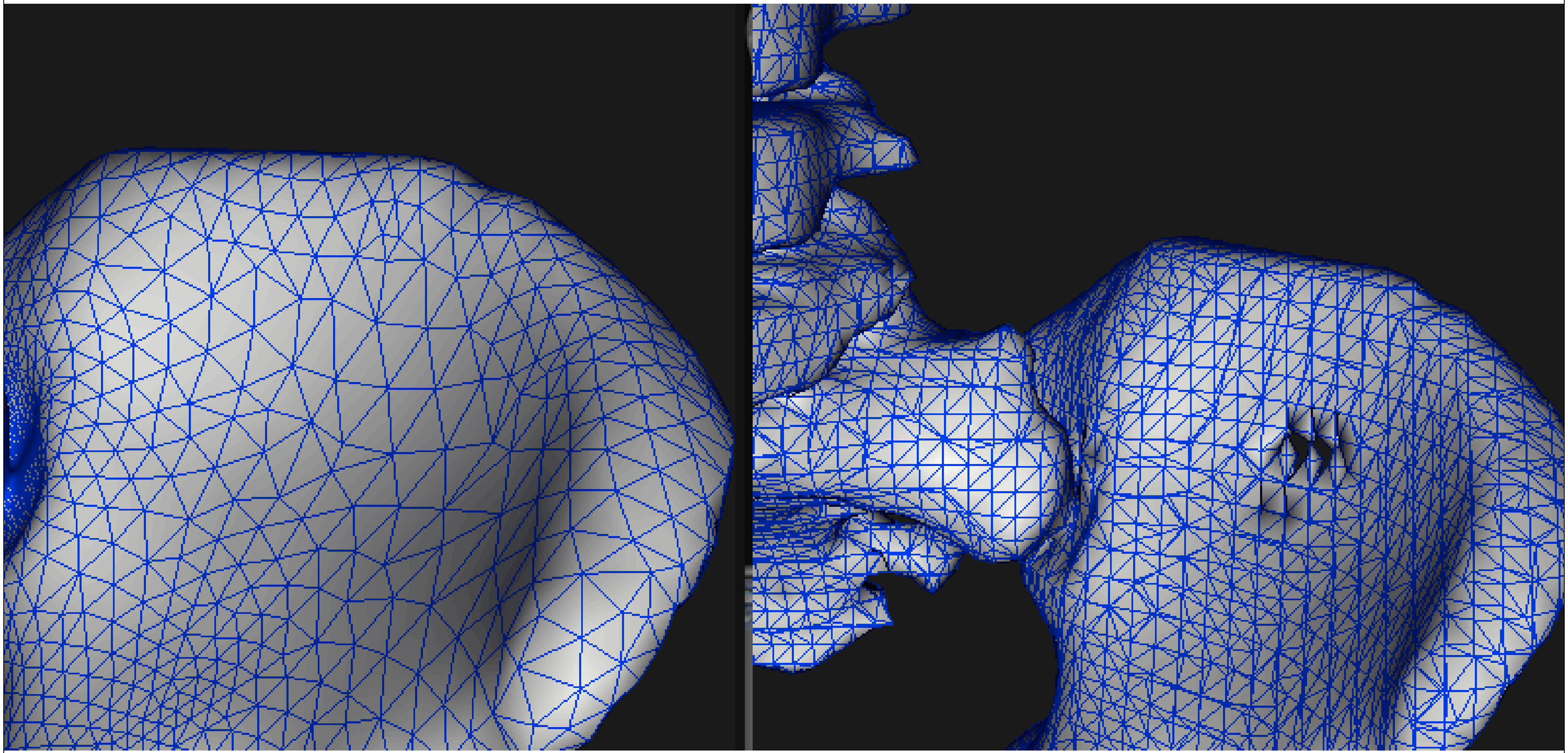
Computing High-Quality Isosurfaces

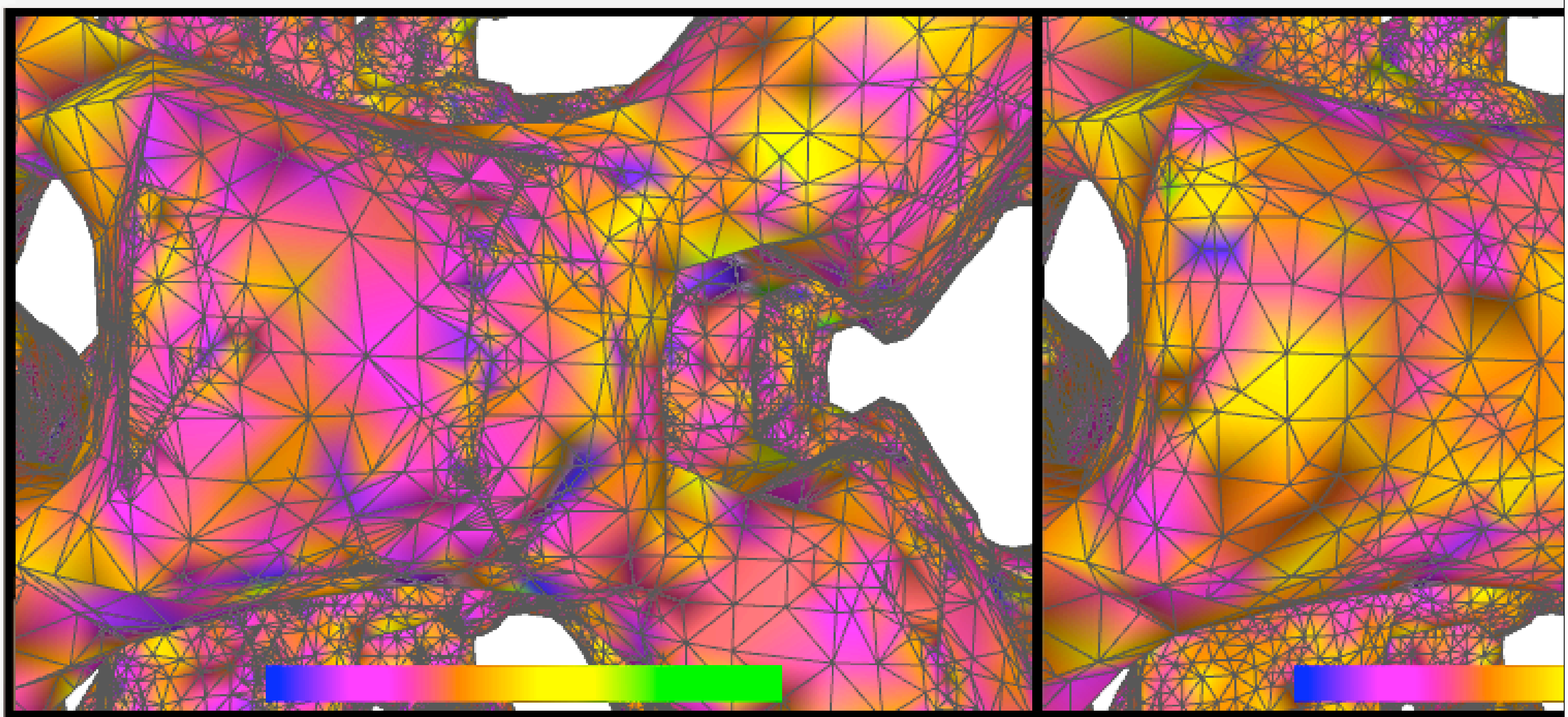
Visualization Algorithm Quality

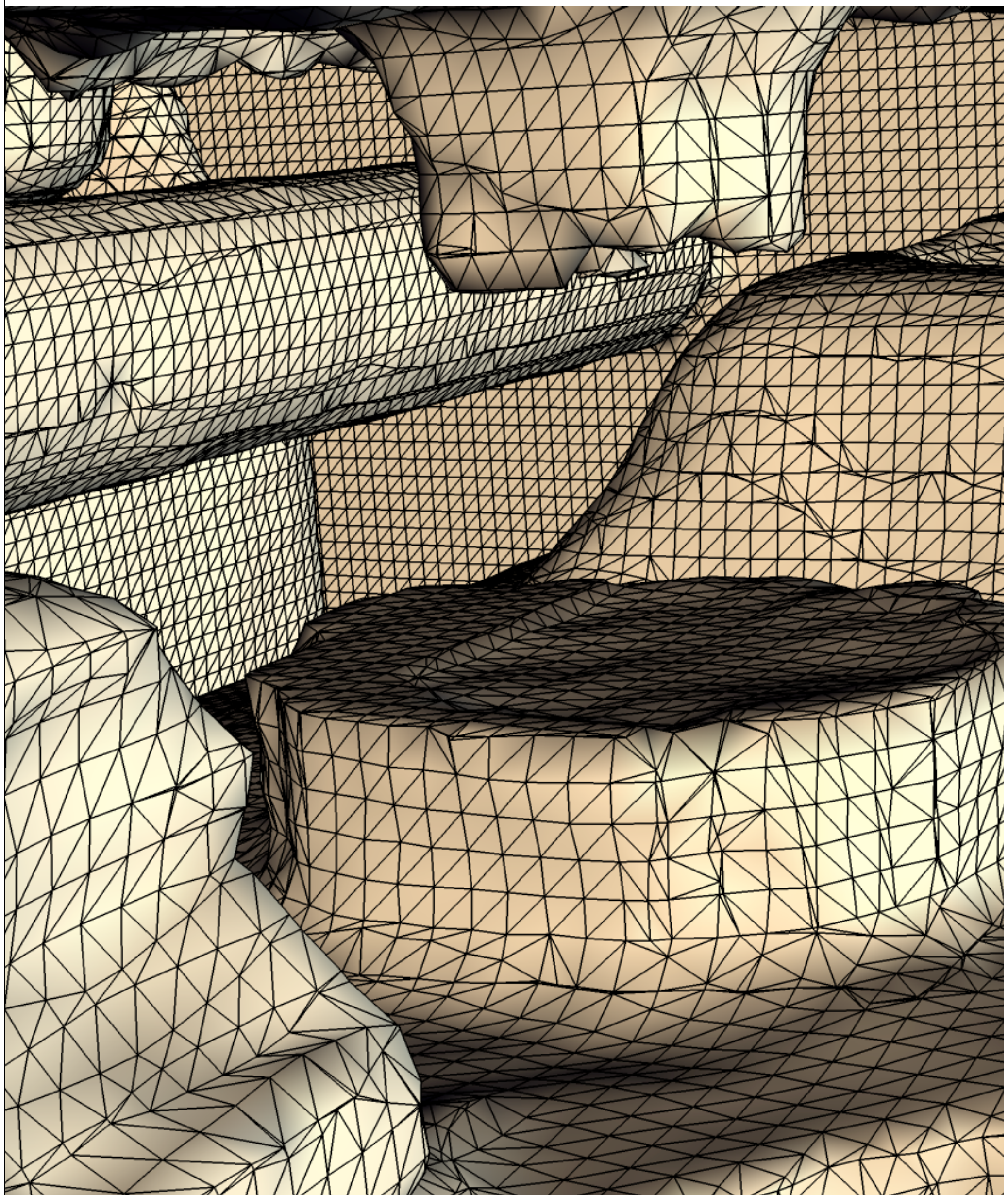






Implications: CDT quality





Isosurface computed by Marching Cubes

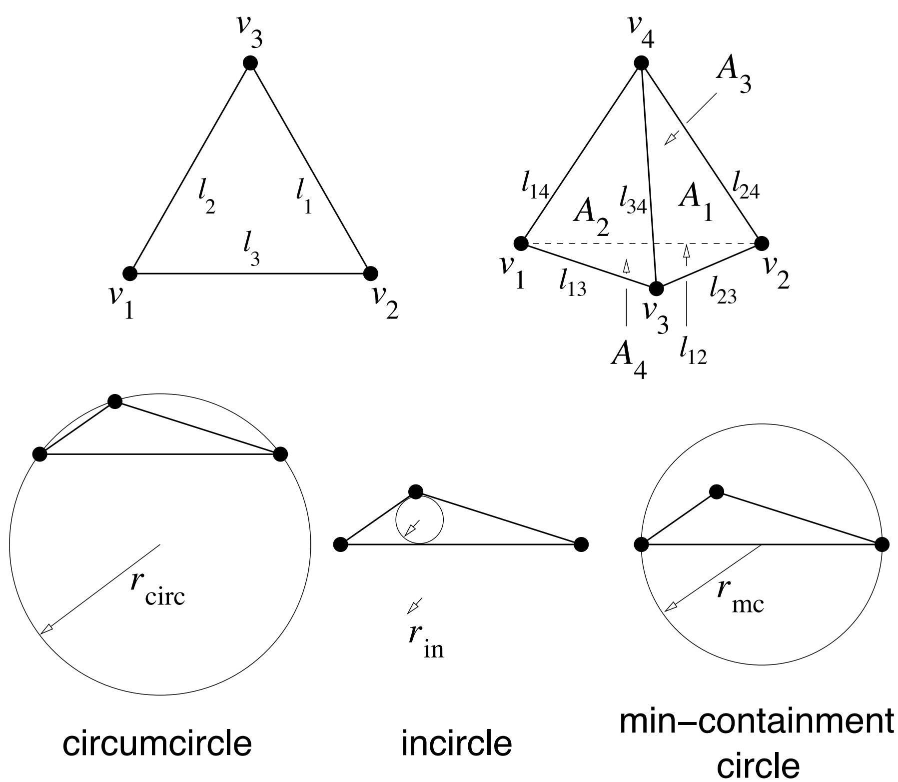
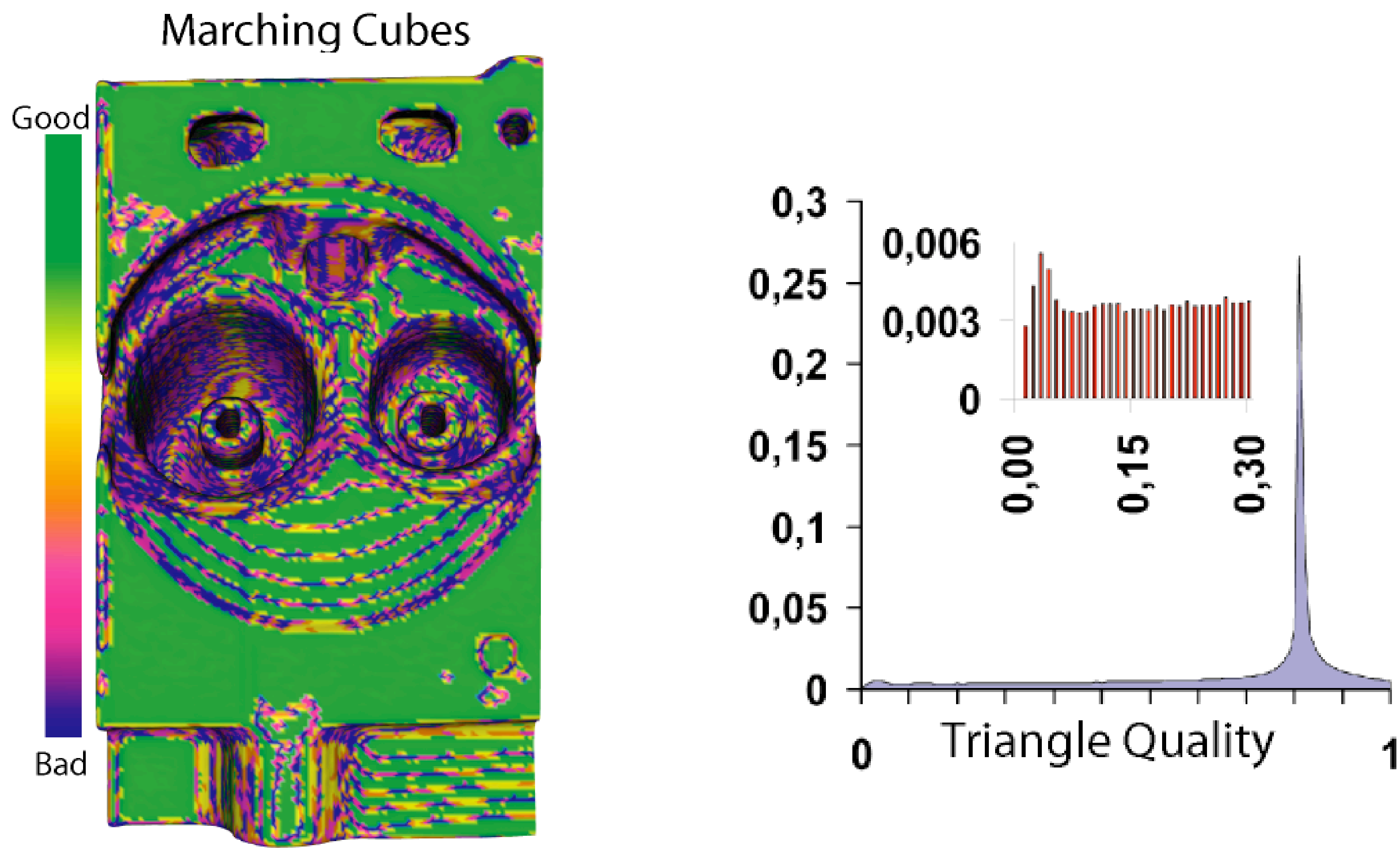
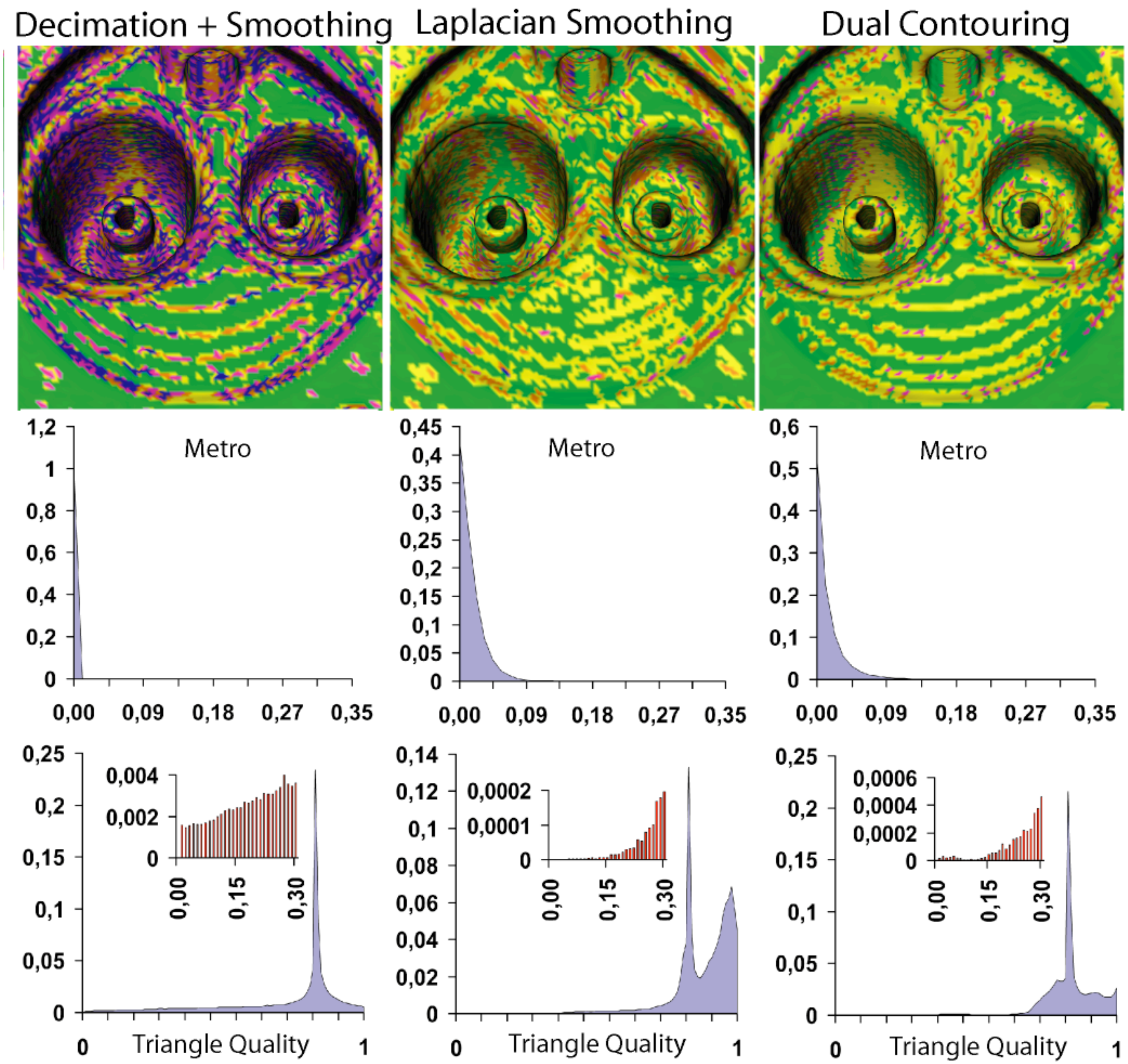


Figure 1: Quantities associated with triangles and tetrahedra.

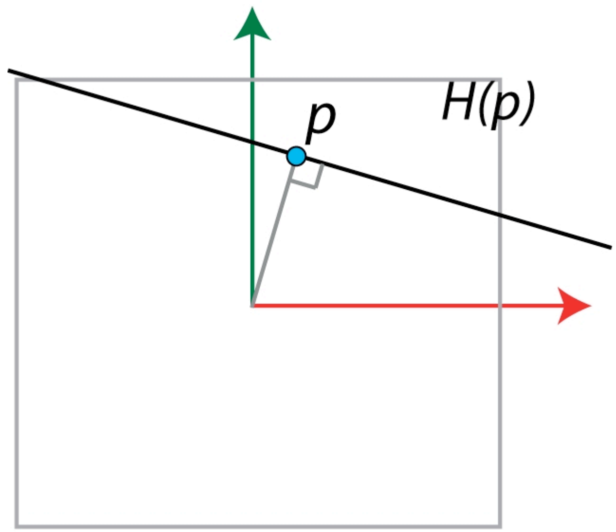


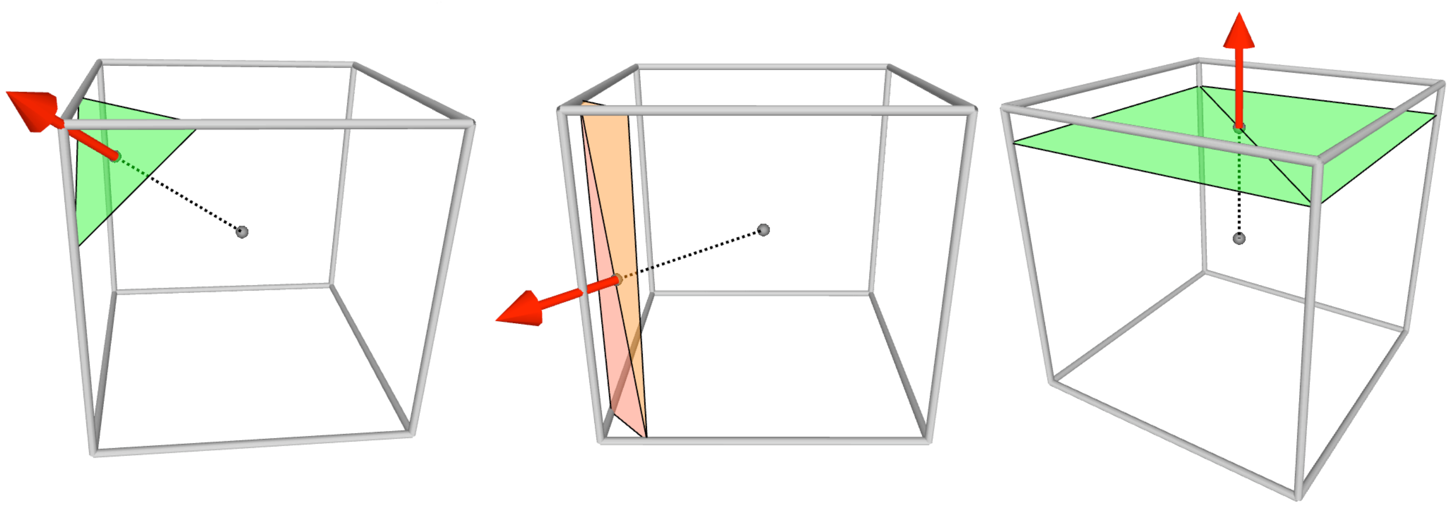
Marching Cubes
Good
Bad
0,3
0,25
0,2
0,15
0,1
0,05
0
0,006
0,003
0
0,00
0,15
0,30
0
Triangle Quality
1



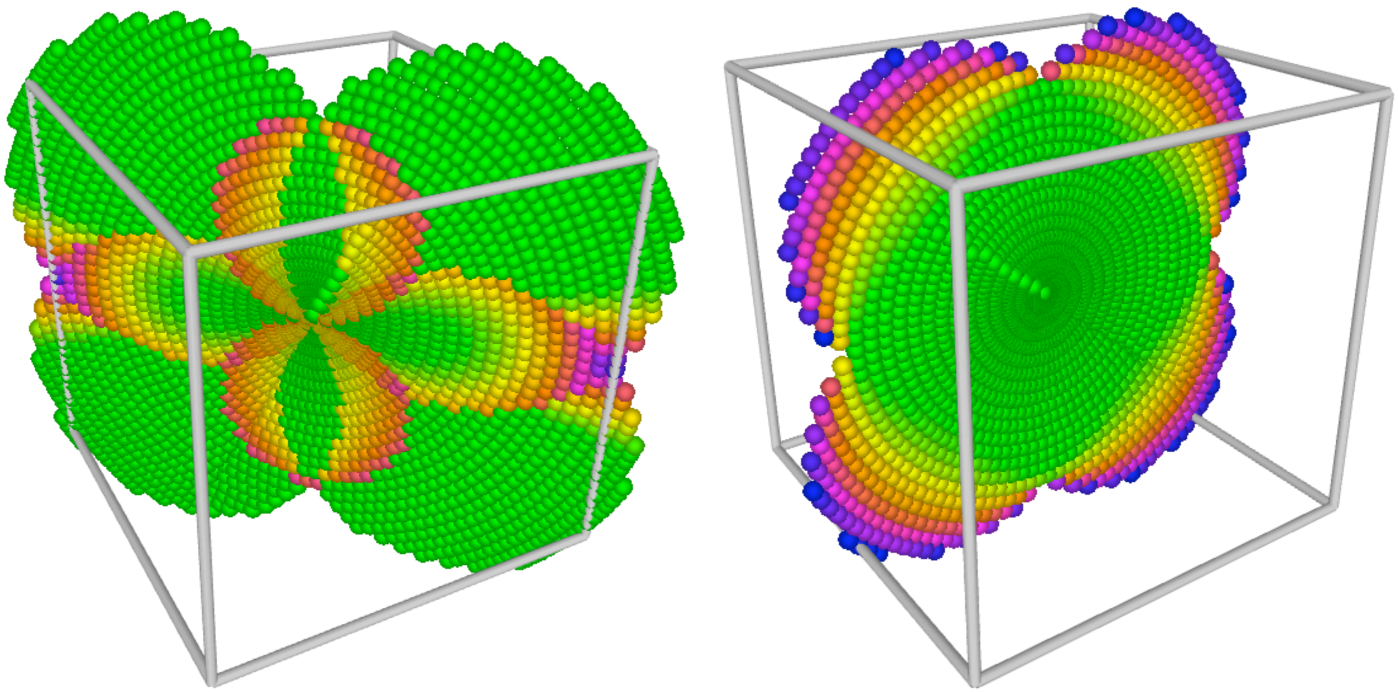
Decimation + Smoothing
Laplacian Smoothing
Dual Contouring
Metro
Metro
Metro
1,2
1
0,8
0,6
0,4
0,2
0
0,00 0,09 0,18 0,27 0,35
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0,00 0,09 0,18 0,27 0,35
0,6
0,5
0,4
0,3
0,2
0,1
0
0,00 0,09 0,18 0,27 0,35
0,25
0,2
0,15
0,1
0,05
0
0,004
0,002
0
0,00 0,15 0,30
0 Triangle Quality 1
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
0,0002
0,0001
0
0,00 0,15 0,30
0 Triangle Quality 1
0,25
0,2
0,15
0,1
0,05
0
0,0006
0,0004
0,0002
0
0,00 0,15 0,30
0 Triangle Quality 1

What is the source of bad triangles in MC?

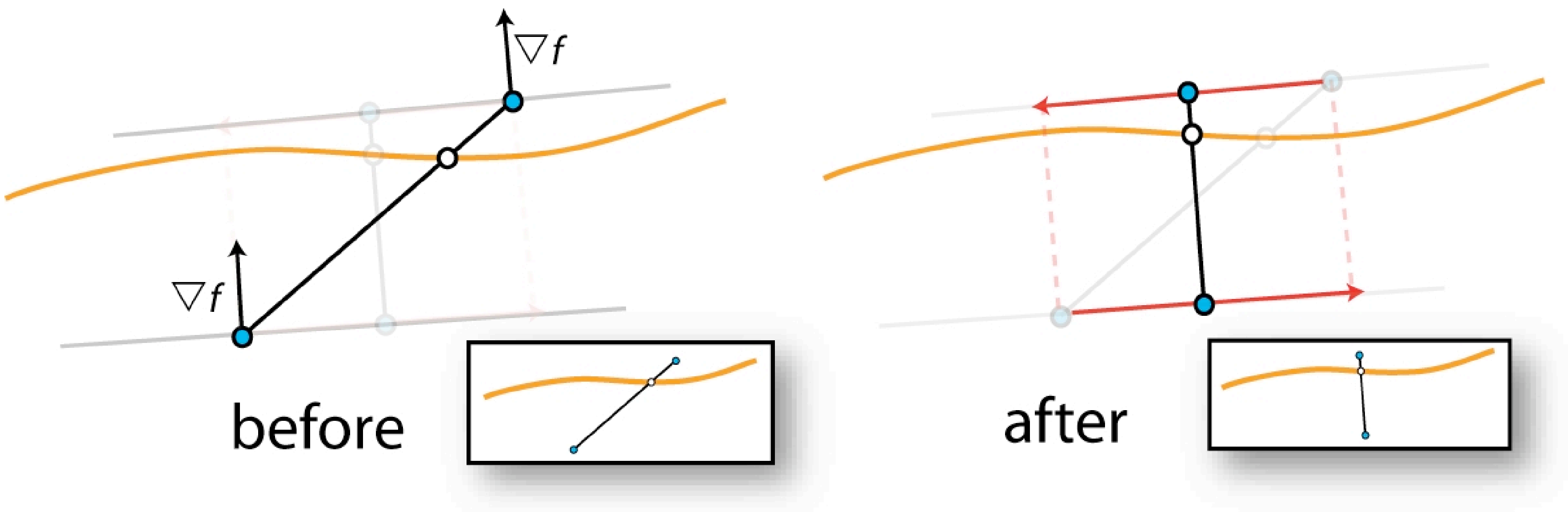




What is the source of bad triangles in MC?

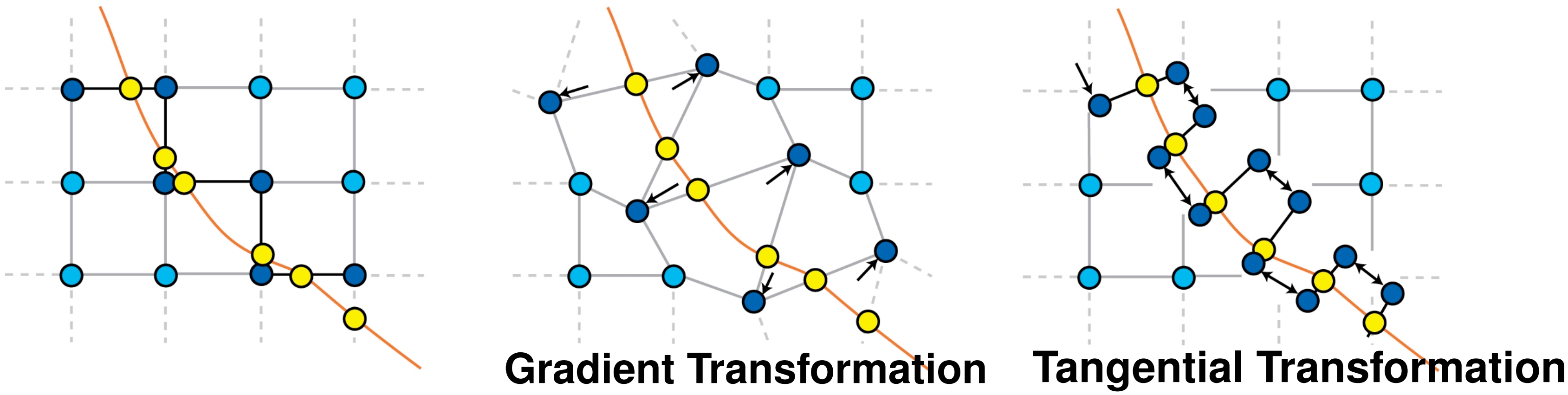


Edge Transformations for Improving Mesh Quality of Marching Cubes

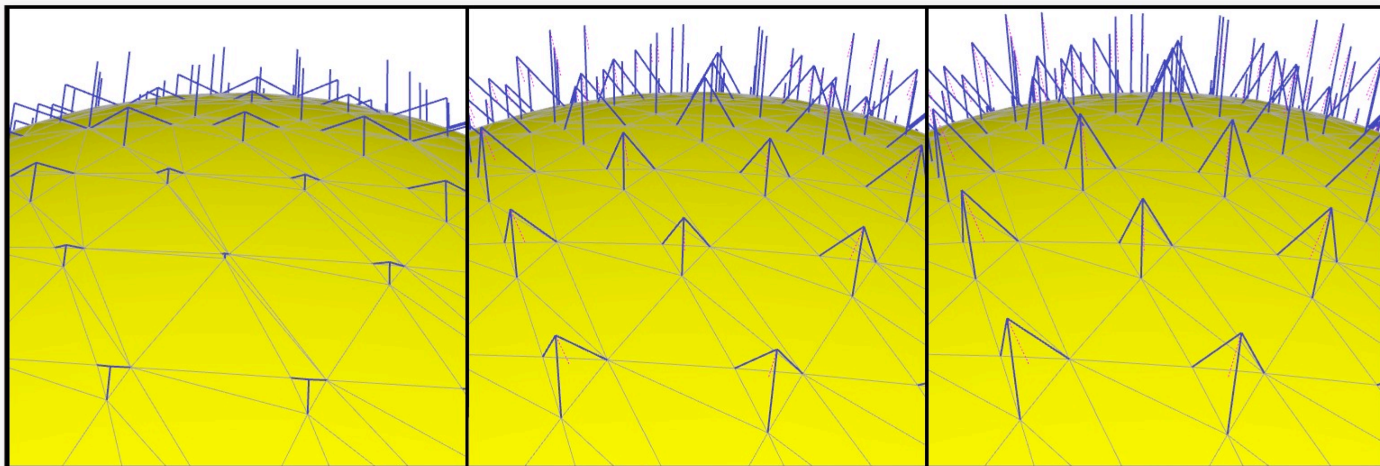


∇f
∇f
before
after

Fixing the problem: MACET

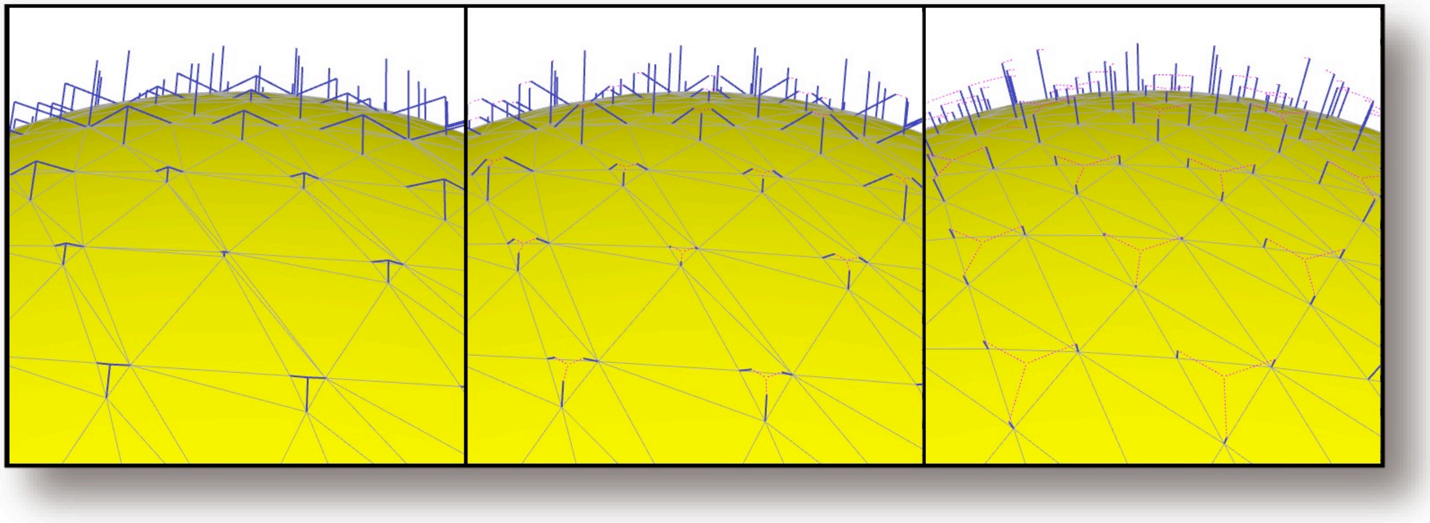


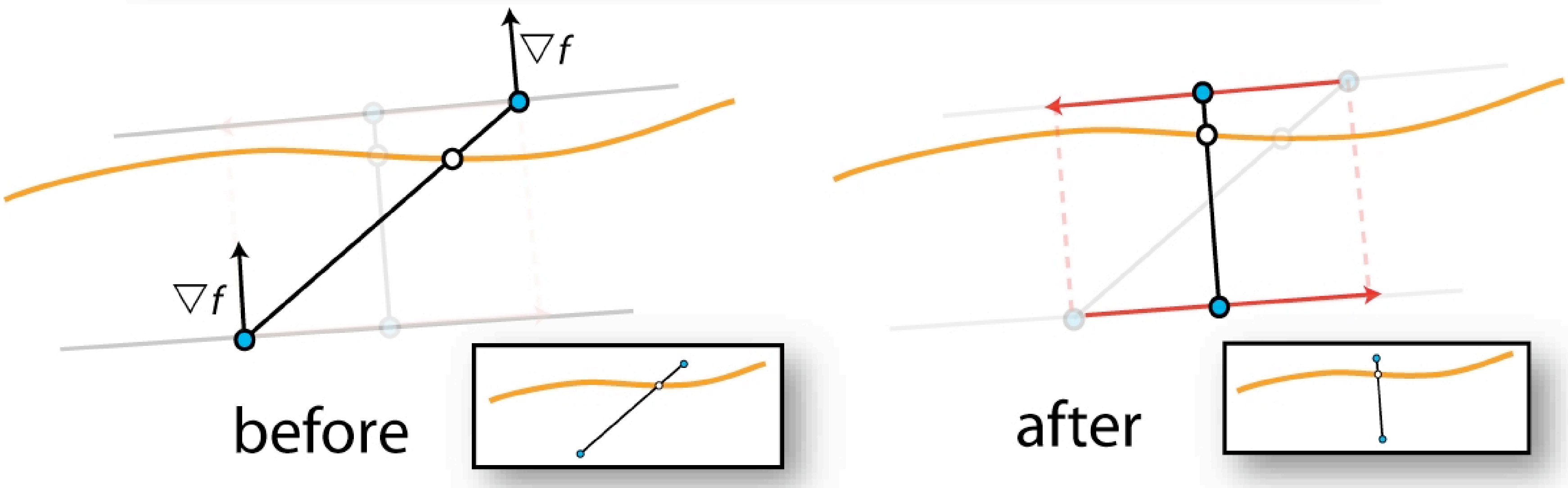
Gradient Transformation



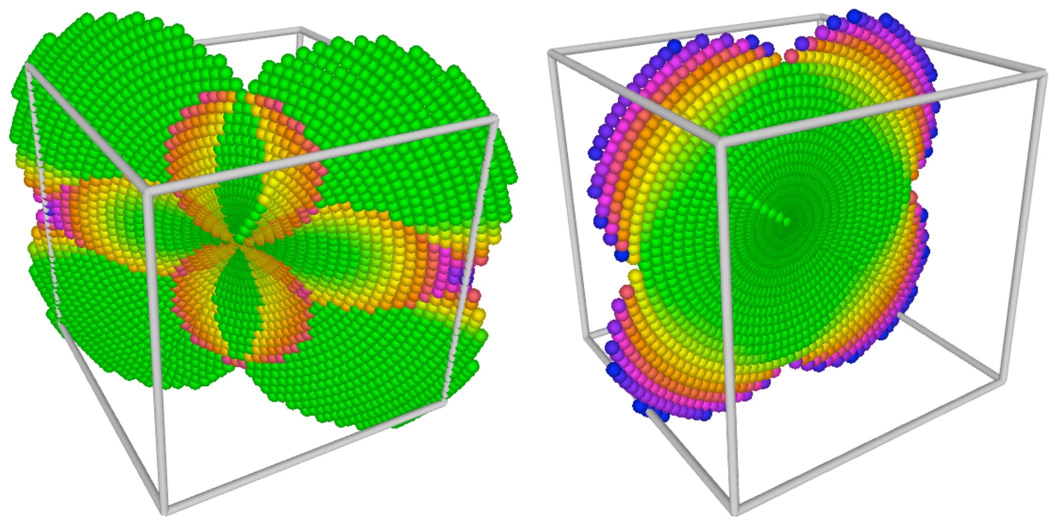
$$p' = p + \alpha \left\langle \nabla f(p'), \nabla f(p) \right\rangle \nabla f(p)$$

Tangential Transformation

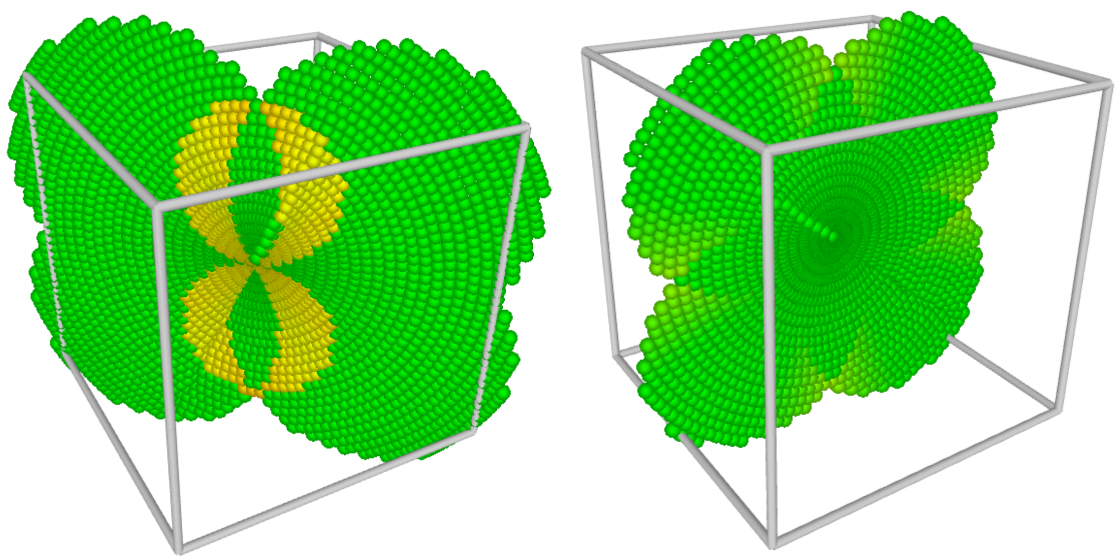


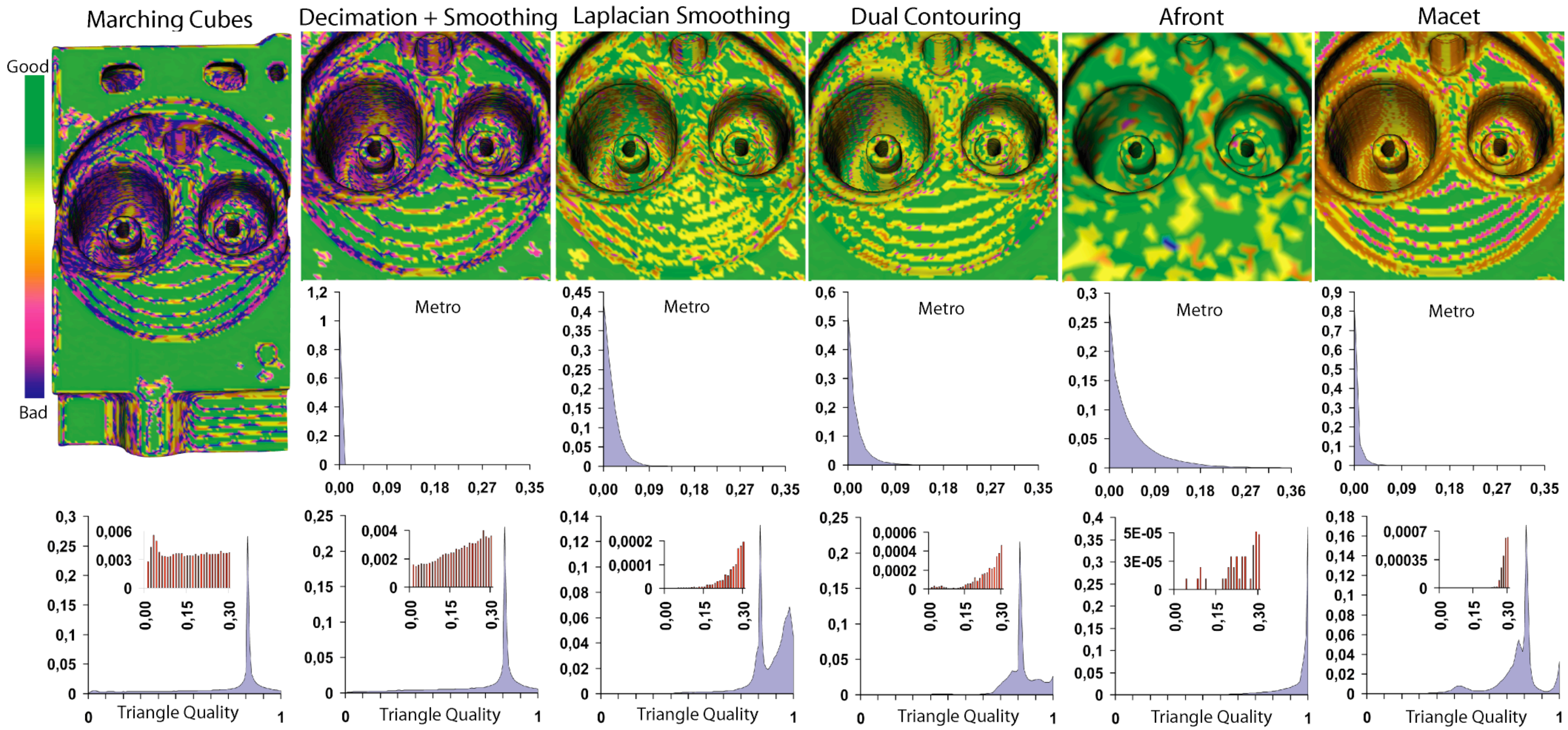


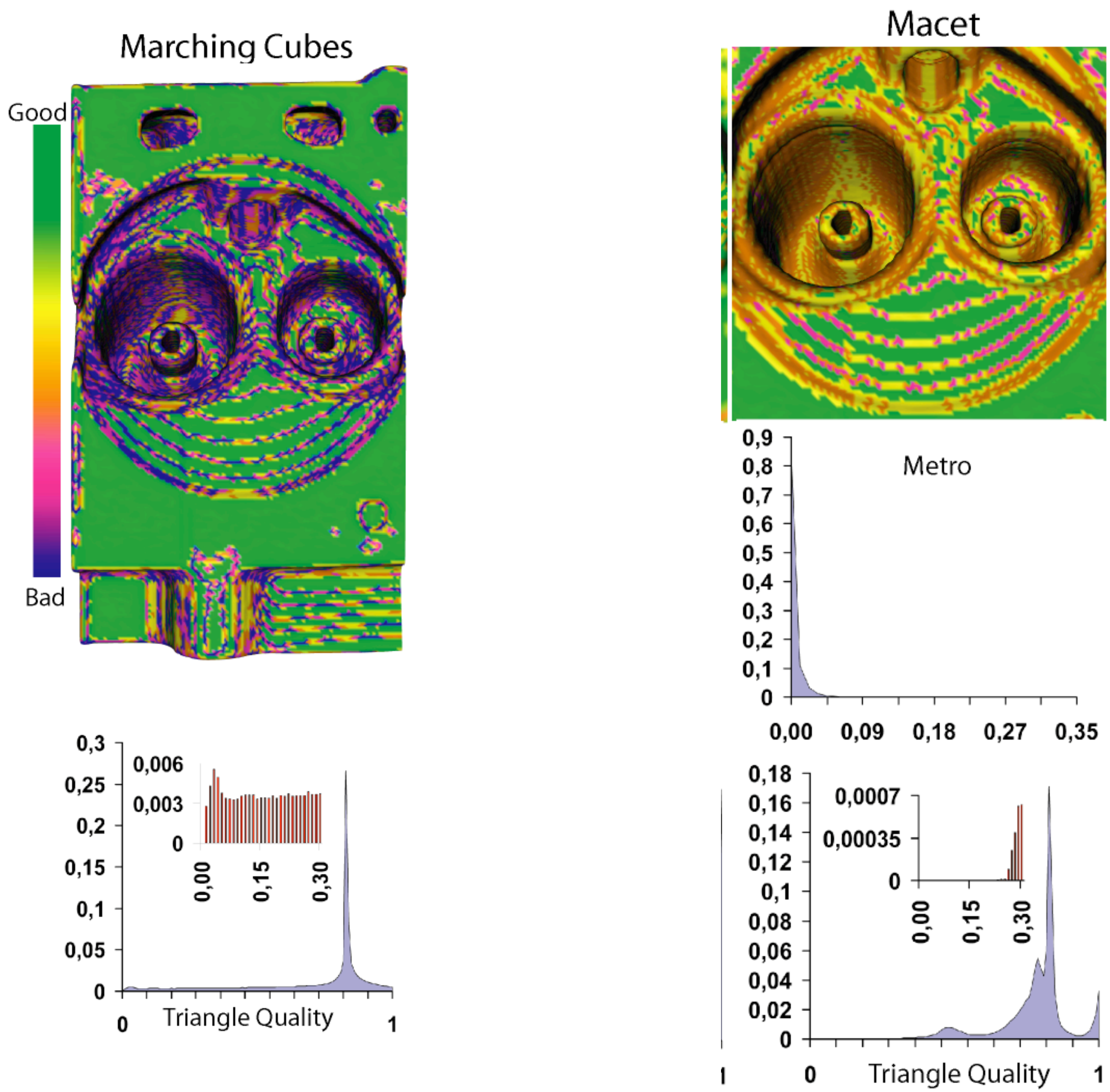
Marching Cubes:



MACET:




Marching Cubes
Decimation + Smoothing
Laplacian Smoothing
Dual Contouring
Afront
Macet
Good
Bad
Metro
Triangle Quality

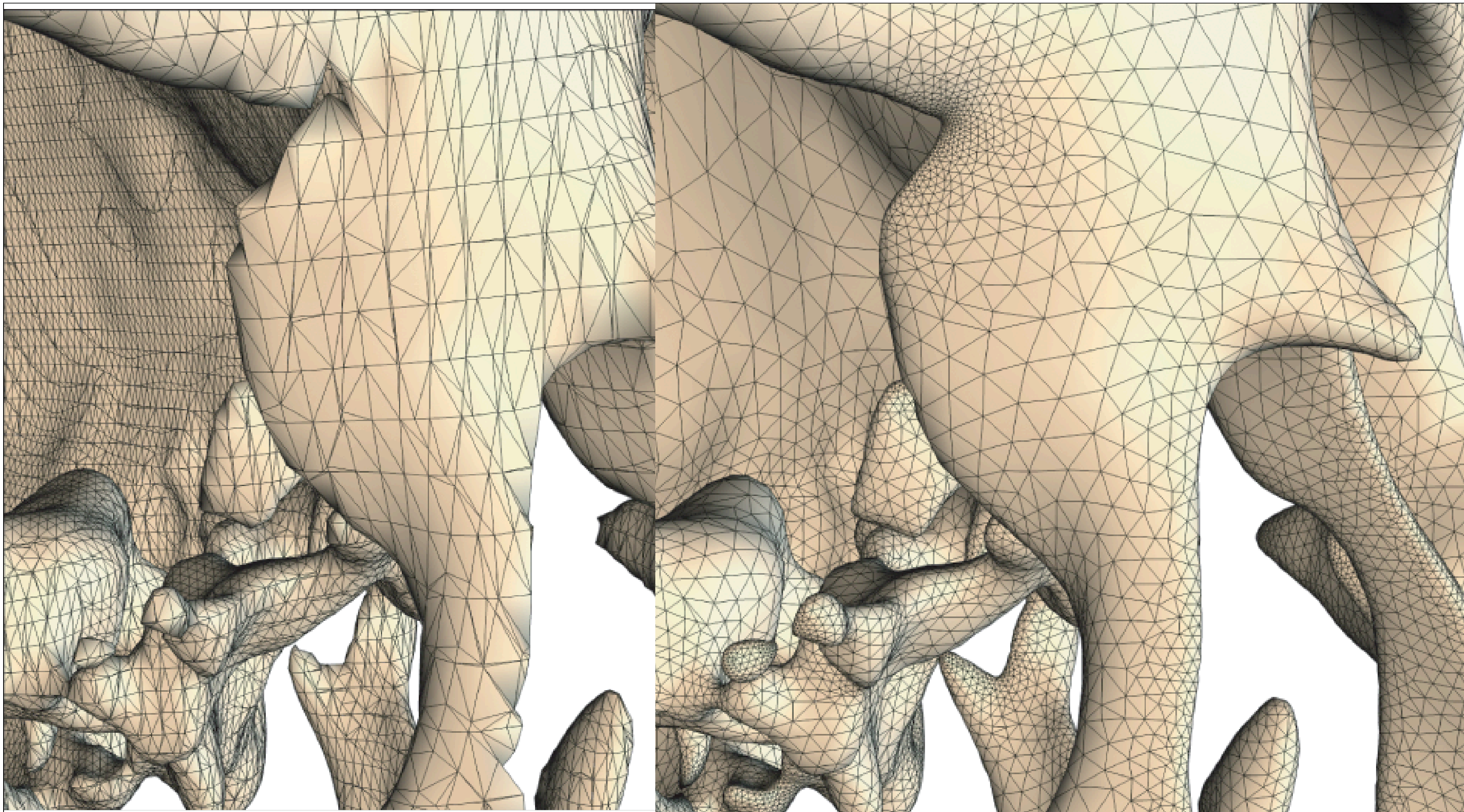


Marching Cubes
Good
Bad
0,3
0,25
0,2
0,15
0,1
0,05
0
0,006
0,003
0
0,00
0,15
0,30
0
Triangle Quality
1
Macet
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Metro
0,00
0,09
0,18
0,27
0,35
0,18
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
0,0007
0,00035
0
0,00
0,15
0,30
0
Triangle Quality
1

Edge Transformations for Improving Mesh Quality of Marching Cubes

Carlos Dietrich, Carlos Scheidegger, and John Schreiner, Joao Comba,, Luciana Nedel, and C. Silva

Submitted for publication

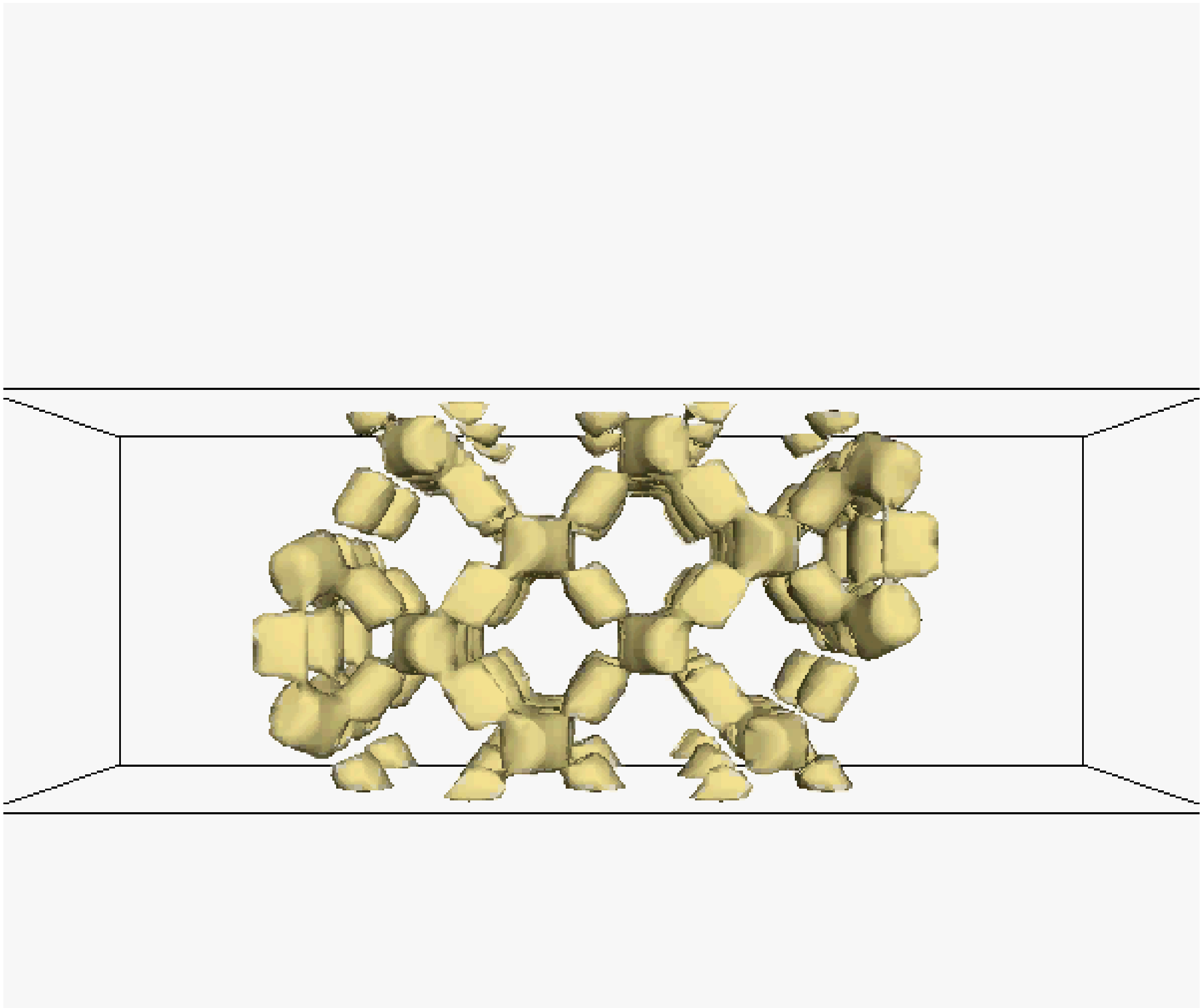


High-Quality Extraction of Isosurfaces from Regular and Irregular Grids

John Schreiner, Carlos Scheidegger, and Claudio T. Silva

IEEE Transactions on Computer Graphics (Visualization 2006)

Video



```
TRIANGULATE(f, ∇f, H(f), k, ρ, η)
let 𝒮 be defined by all x such that f(x) = k
g ← GENERATE-SAMPLES(𝒮, ∇f, H(f)) (see Section 4.1)
CULL(g, ρ, η) (see Section 4.2)
Active ← SEED-FRONTS(𝒮) (see Section 3.2)
while |Active| > 0
      do front ← GET-ANY-FRONT(Active)
           if OK-TO-ADD-TRIANGLE(front, ρ, η)
              then ADD-TRIANGLE-TO-FRONT(front, ρ, η)
              else  other ← GET-INTERFERING-FRONT(front)
                    if other = front
                       then (f1,f2) ← SPLIT(front)
                            REMOVE-FRONTS(Active, {front})
                            ADD-FRONTS(Active, {f1, f2})
                       else  new-front ← MERGE(front, other)
                            REMOVE-FRONTS(Active, {front, other})
                            ADD-FRONTS(Active, {new-front})
```

Triangulation Constraints - I

$$\iota_{\mathcal{S}} : \mathcal{S} \longrightarrow \mathbb{R}^{+}$$ (ideal edge size length)

$$\iota_{\mathcal{S}}(x) = \frac{2\sin(\rho/2)}{\kappa_{\max}}$$

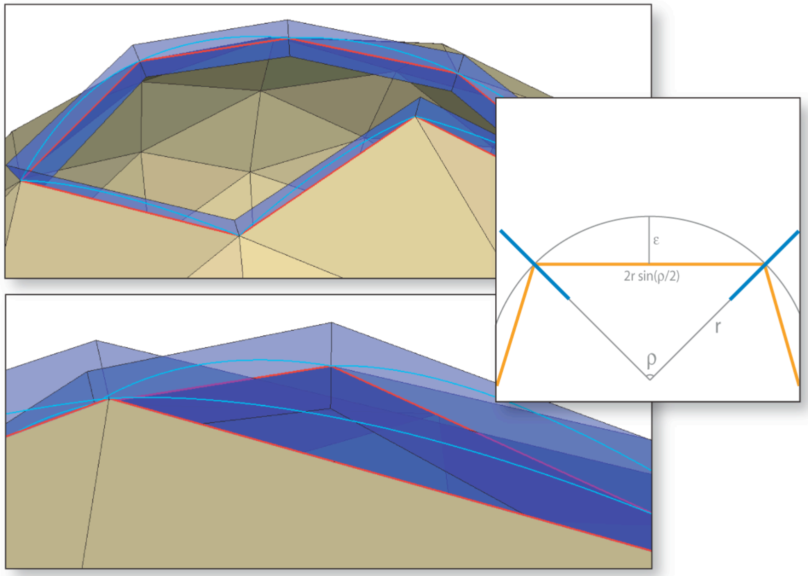
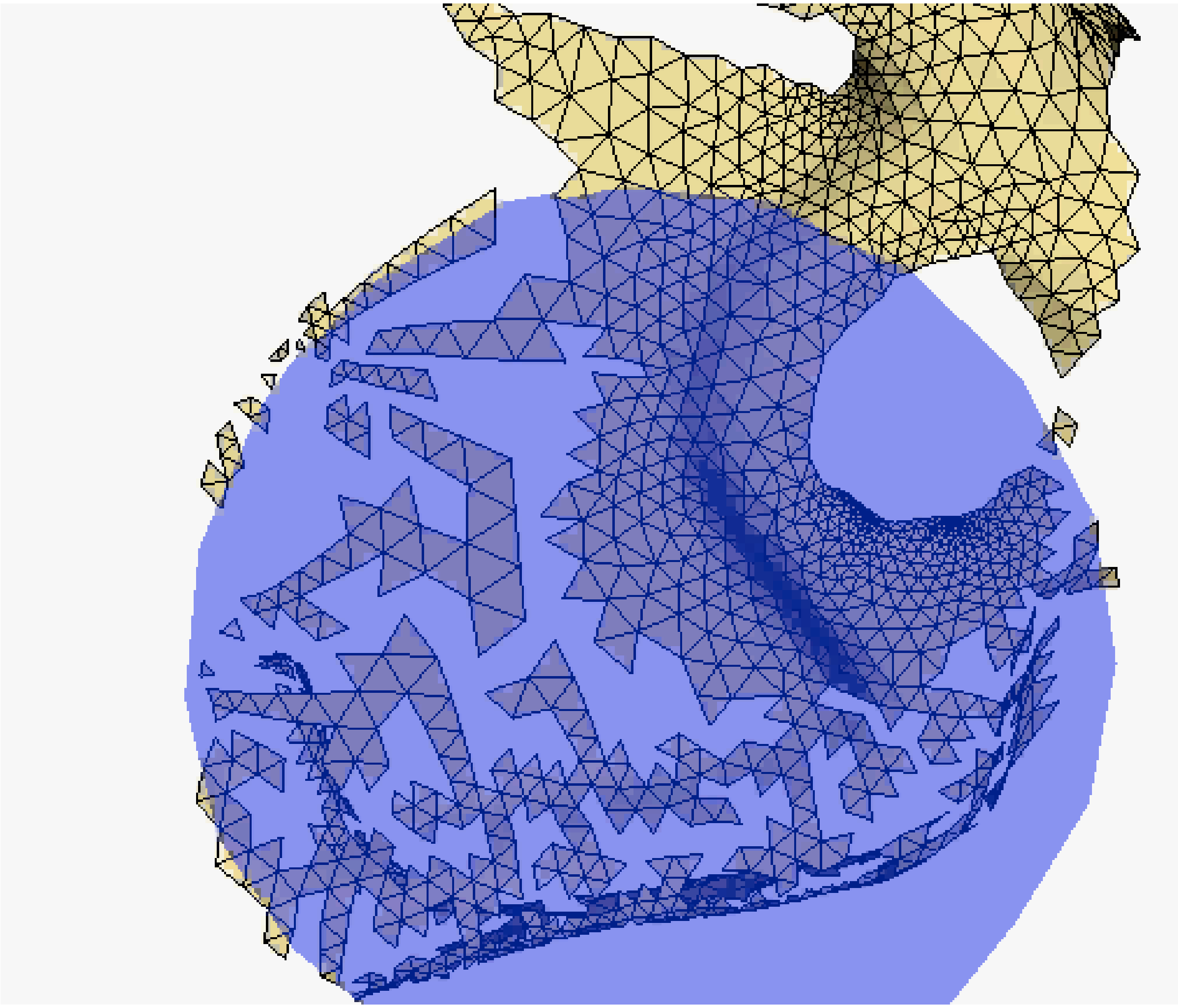


Figure 4: *To robustly detect front interference, we use a set of* fences*: extensions of the front curve in the normal direction of the surface. We exploit the bound on the Hausdorff error to determine the correct fence height – the inset on the right shows the argument in two dimensions.* $r = \kappa_{\max}^{-1}$.

The need for the guidance field



Triangulation Constraints - II

1. The triangles placed over a patch of surface must be a good approximation for the surface. In other words, the triangle edge size at s_i should be at most ι_i.
2. Triangle quality throughout the triangulation must be adequate. Specifically, we require that any two edges e_i and e_j incident to a common vertex have a ratio bounded by a user-defined parameter η:

$$\eta^{-1} \leq |e_i|/|e_j| \leq \eta \tag{1}$$

We have two user-defined parameters

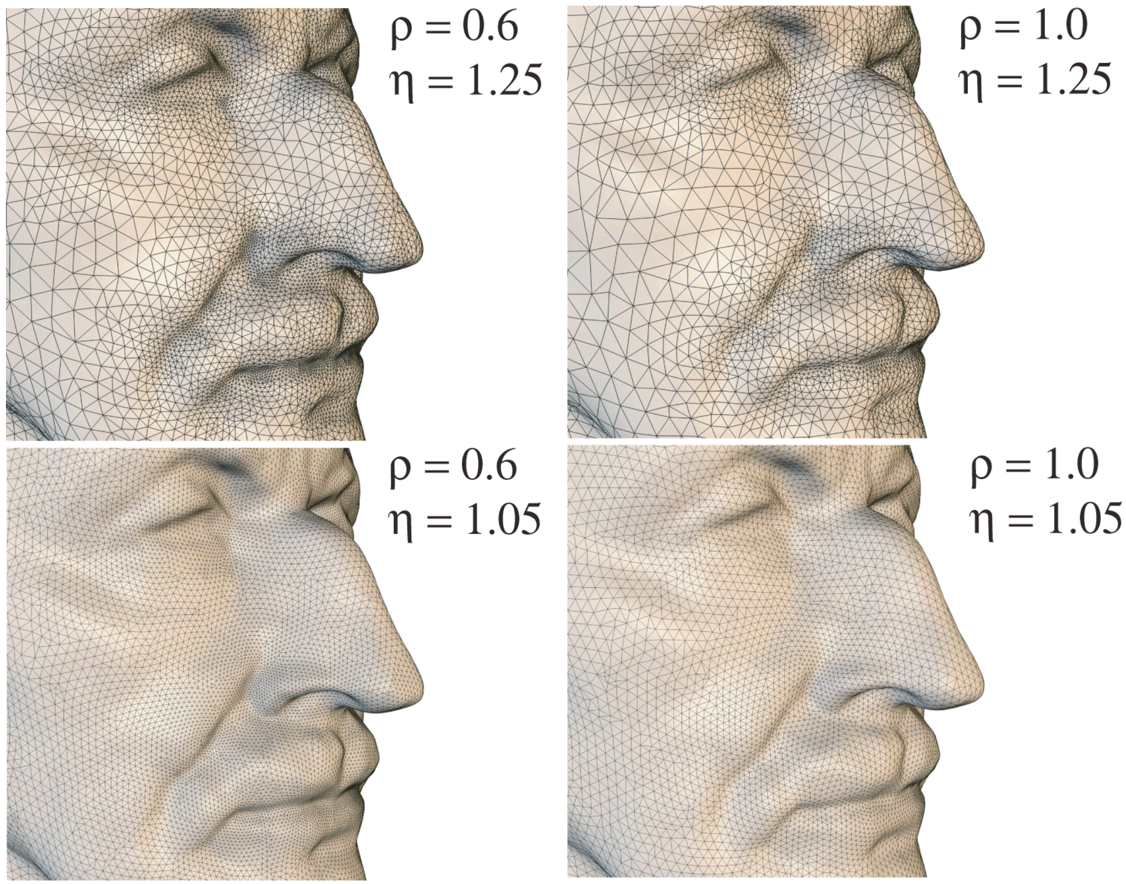
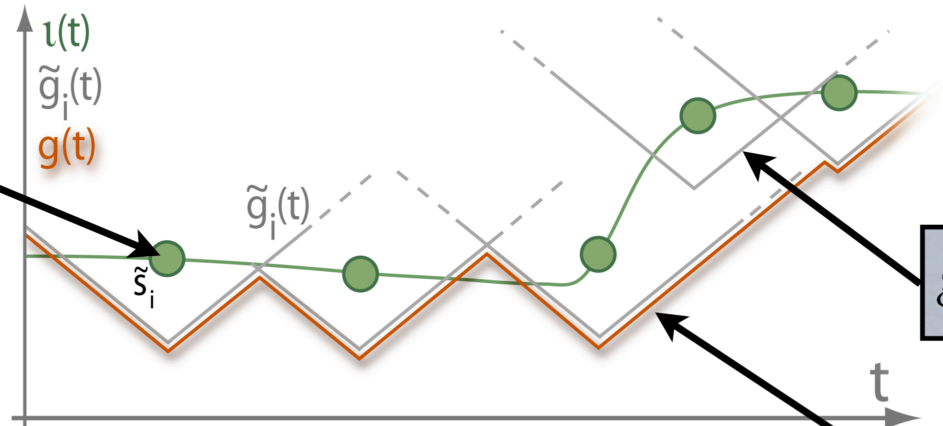


Figure 8: *The effects of* ρ *and* η *on the resulting mesh.* ρ *controls the approximation accuracy: a bigger* ρ *will result in a coarser triangulation.* η *controls triangle grading: a larger* η *will result in more adaptive triangulations.*

Defining the Guidance Field

$$g_{\mathcal{S}}(x) : \mathbb{R}^3 \to \mathbb{R}^+ \quad \text{(guidance field)}$$

$\hat{g}_i(\iota_i) = \iota_i.$



$\tilde{g}_i(x) = \hat{g}_i(|\tilde{s}_i - x|)$

$g_{\mathcal{S}}(x) = \min_i \tilde{g}_i(x)$

Figure 3: *The guidance field $g(t)$ on a curve $t : \mathbb{R} \to \mathcal{S}$. $g(t)$ is the minimum over all $\tilde{g}$. At the sample points $\tilde{s}_i$, $\tilde{g}_i$ is minimum, and it grows linearly as the distance from $\tilde{s}_i$ increases. Note that if the sampling is too coarse, $g(t)$ might not bound $\iota(t)$, and that some of the samples might be unnecessary. Since each $\tilde{g}_i$ is Lipschitz, so is $g(t)$.*

$\hat{g}_i(x) = (1 - \eta^{-1})x + \eta^{-1}\iota_i$

(see paper for complete details)

Results

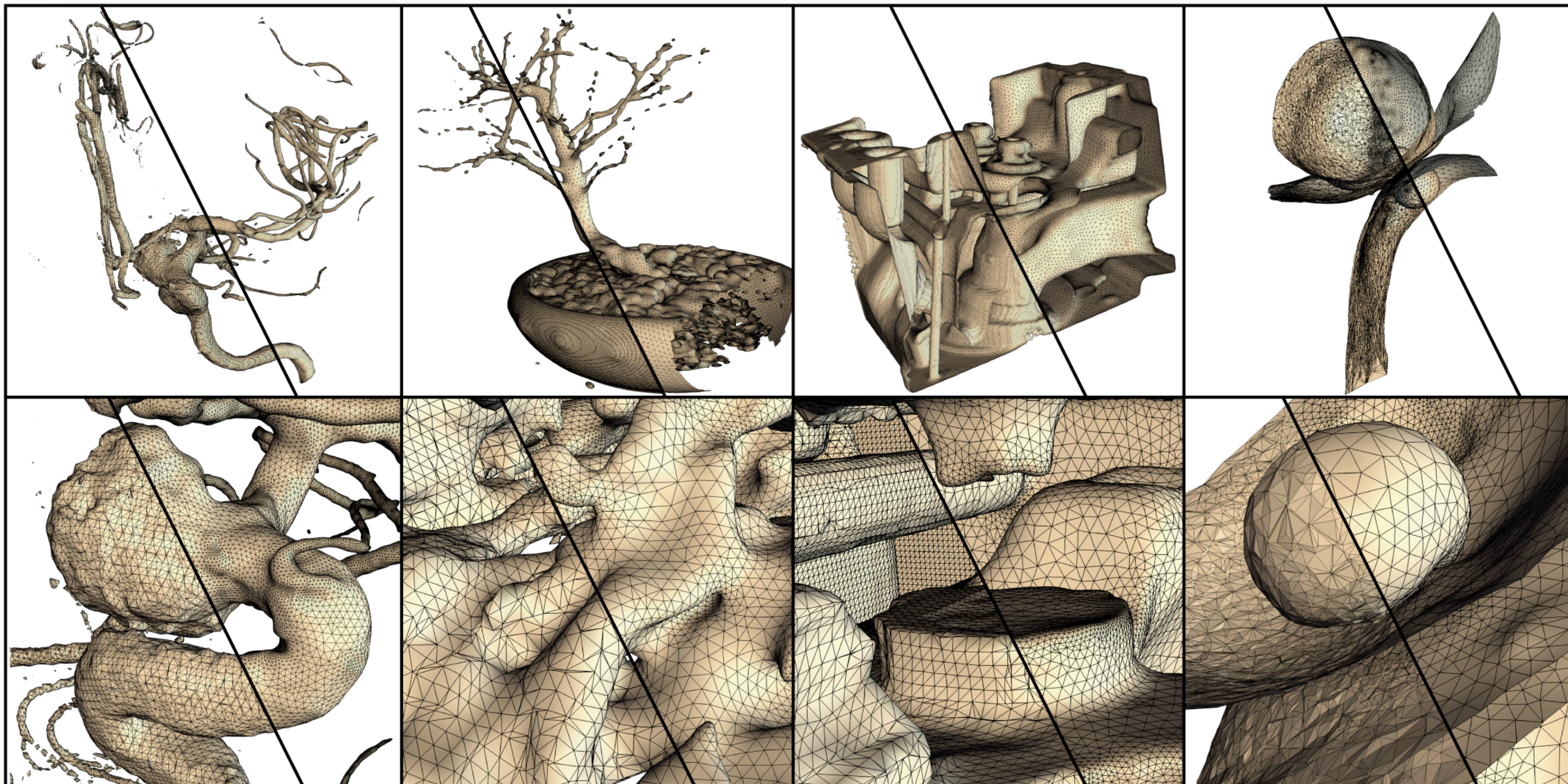


Figure 6: Some results of our algorithm, compared to MC and MT. From left to right: CT scans of an aneurism, a bonsai and an engine block, and isopotential surfaces of a human torso simulation. The first three datasets are regular grids, while the last one is a tetrahedral mesh.

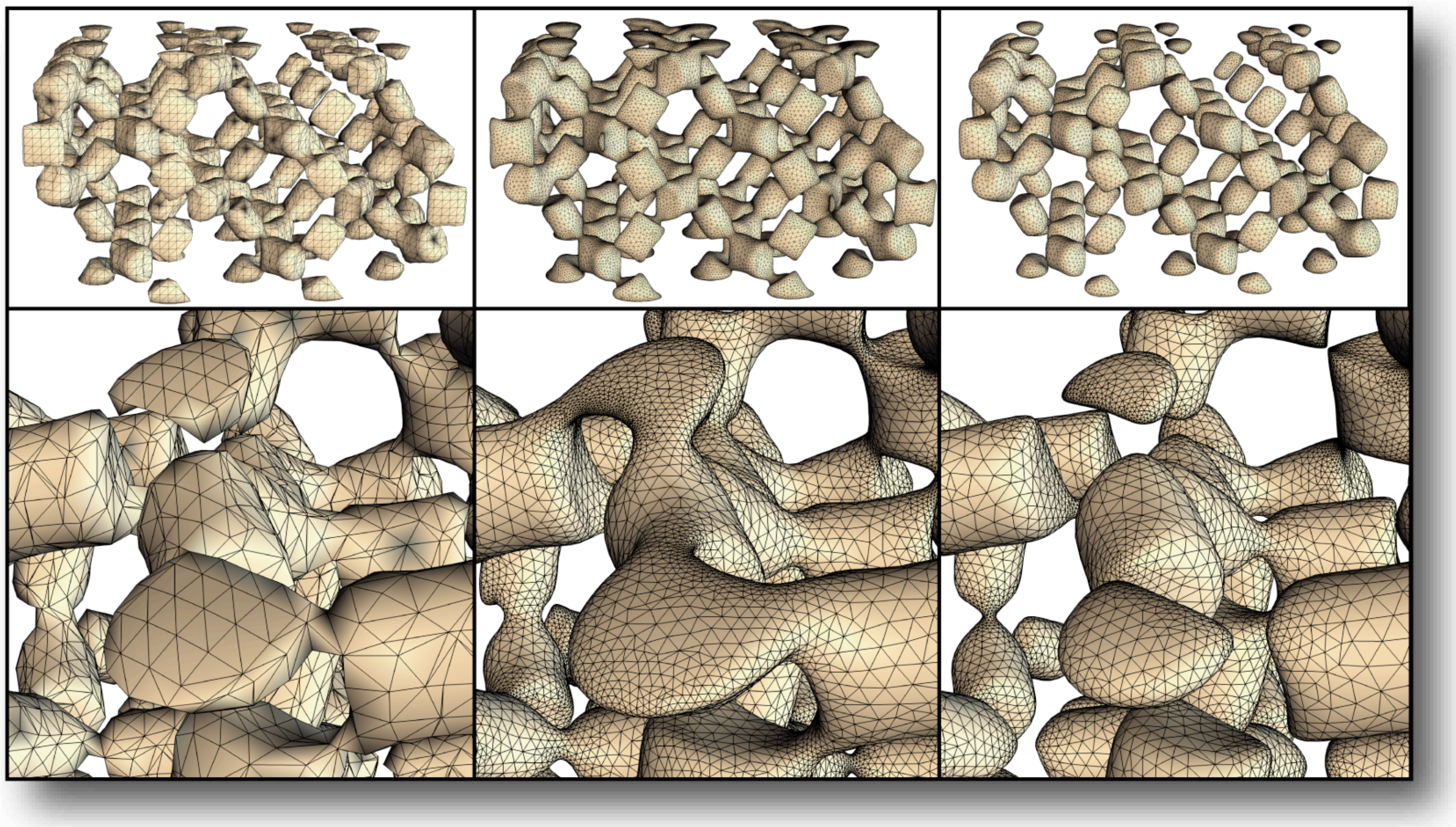


Figure 4: Isosurfacing a structured grid of a silicium lattice simulation. From left to right: marching cubes output, and our method for $\rho = 0.3$, using respectively Catmull-Rom and B-splines for reconstruction.

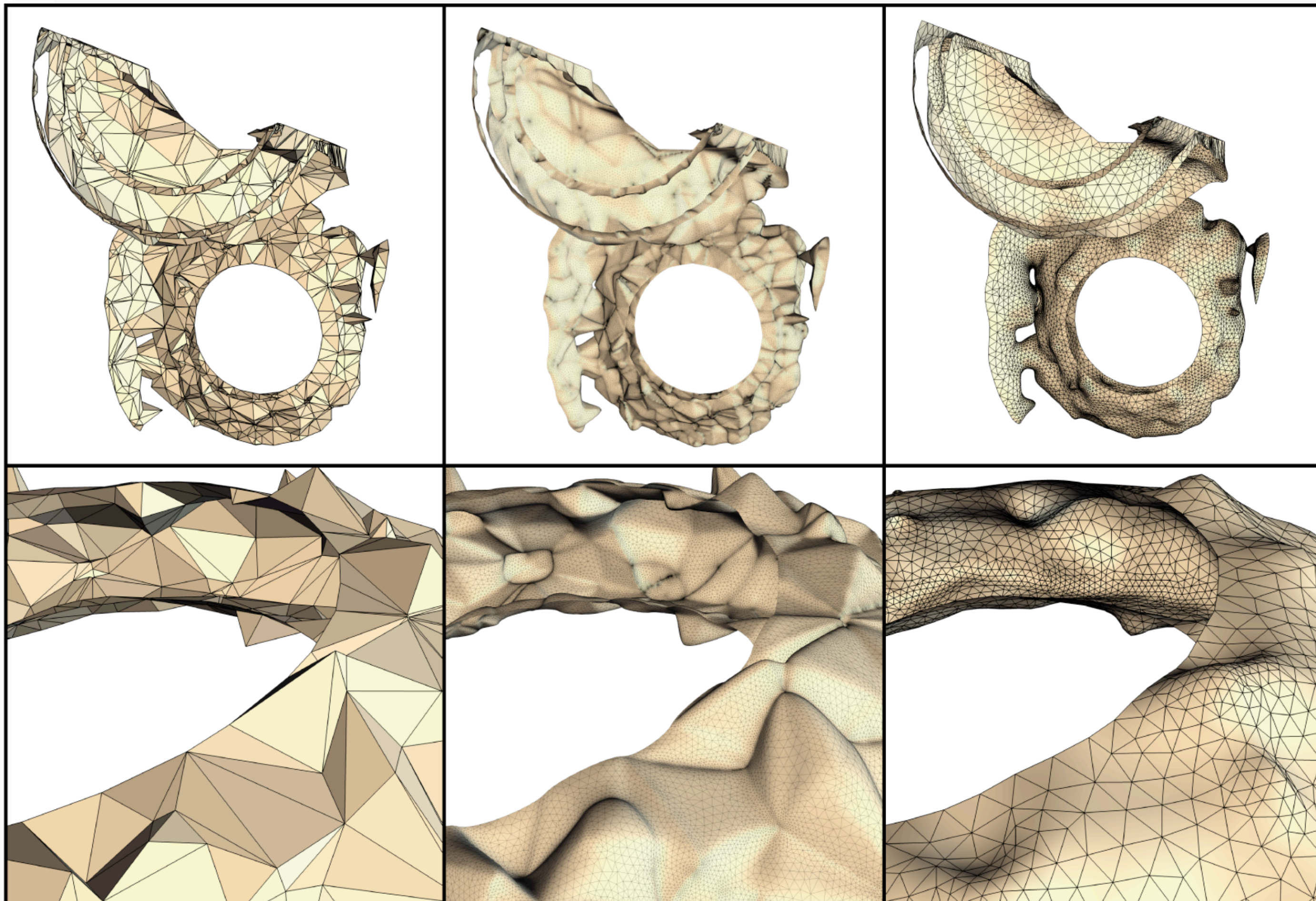
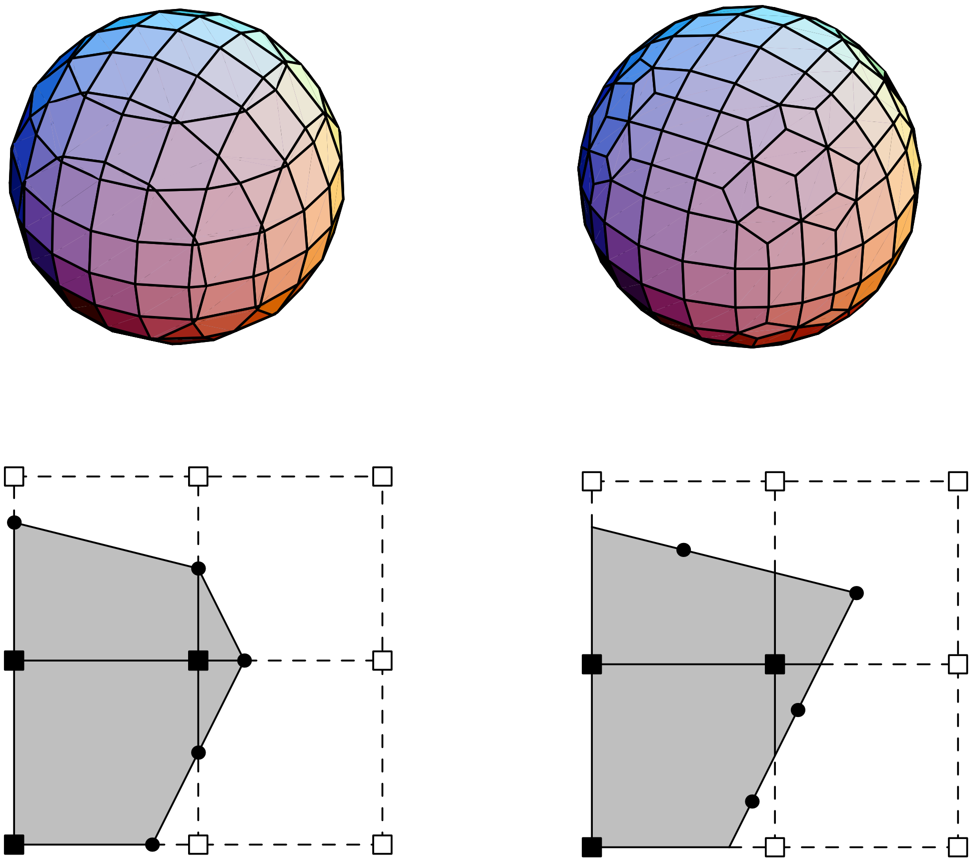


Figure 5: Isosurfacing unstructured grids. From left to right: MT output, and our method for $\rho = 0.5$, using respectively Nielson interpolation and Moving Least Squares for reconstruction.

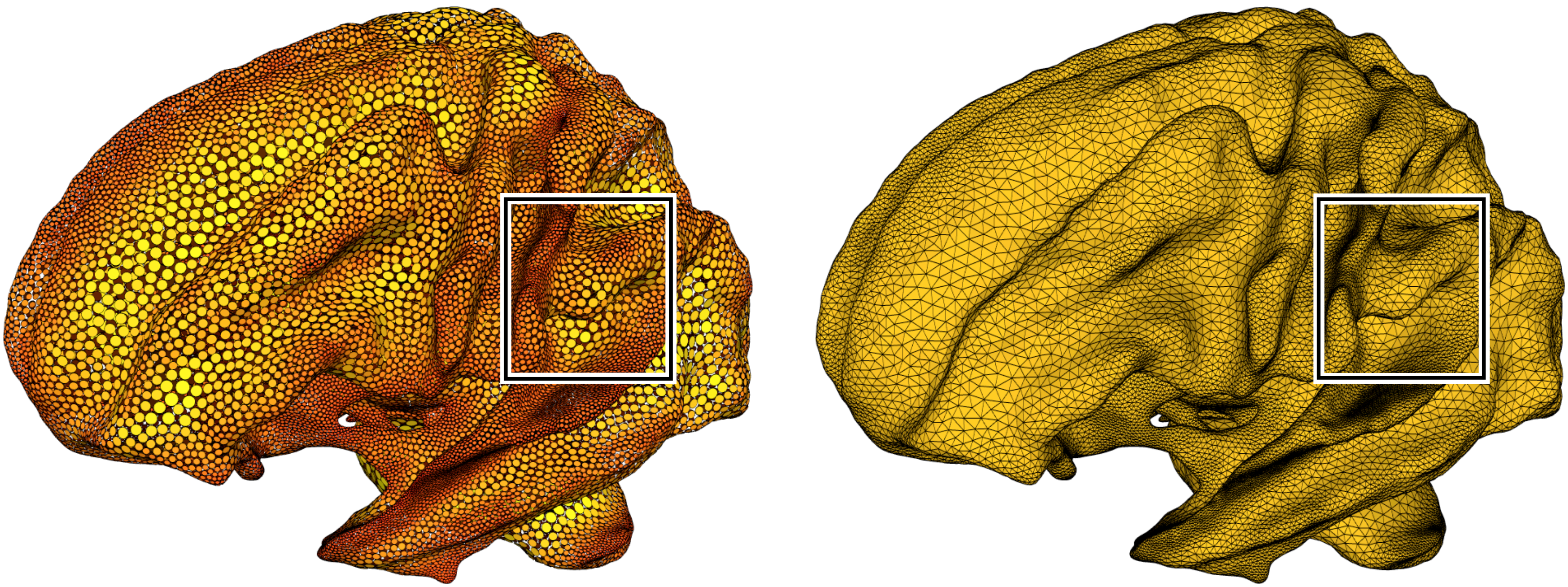
Dual Contouring



Dual Contouring of Hermite Data

Tao Ju, Frank Losasso, Scott Schaefer, Joe Warren
Rice University*

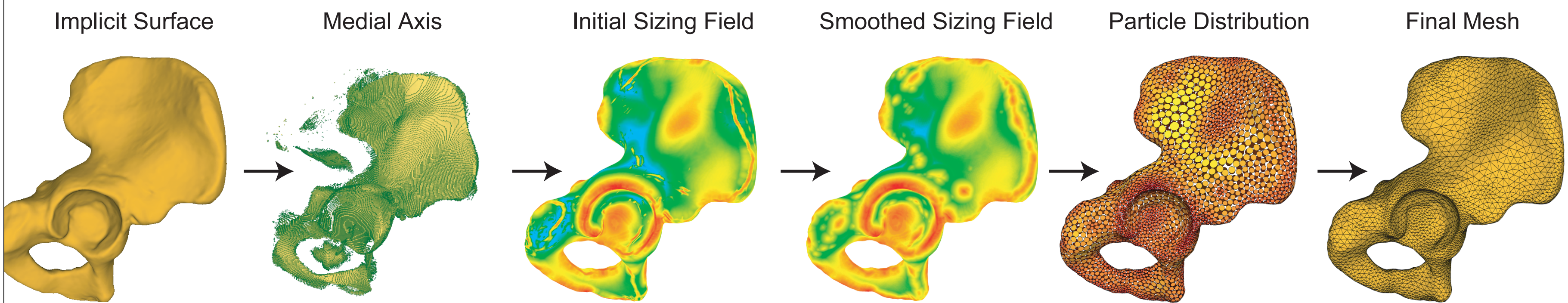
Particle Systems



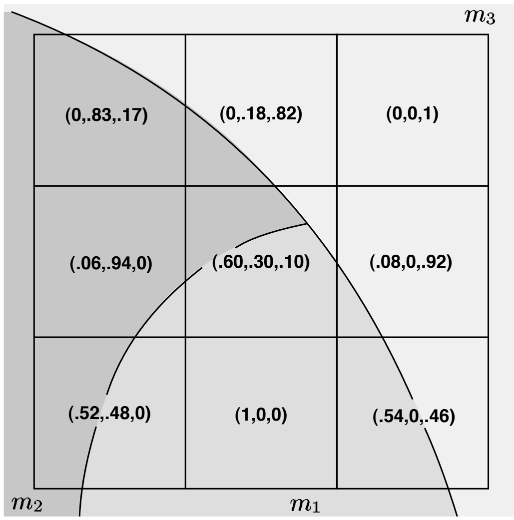
Topology, Accuracy, and Quality of Isosurface Meshes Using Dynamic Particles

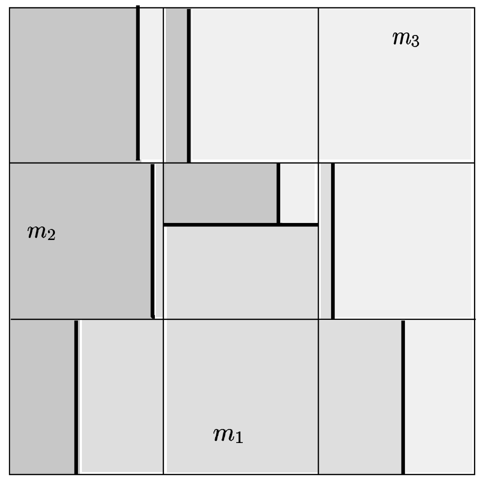
Miriah Meyer, *Student Member, IEEE*, Robert M. Kirby, *Member, IEEE*, and Ross Whitaker, *Member, IEEE*

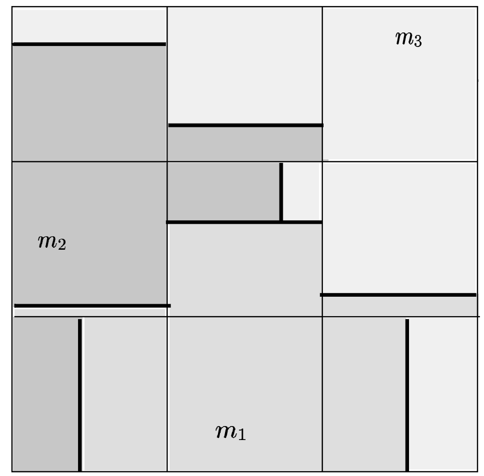
Particle Systems



MATERIAL INTERFACE RECONSTRUCTION







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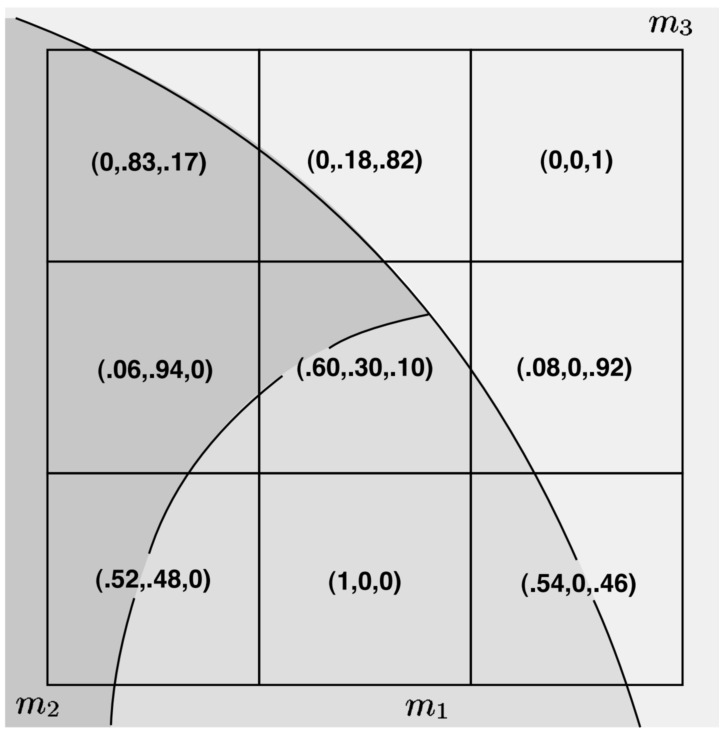
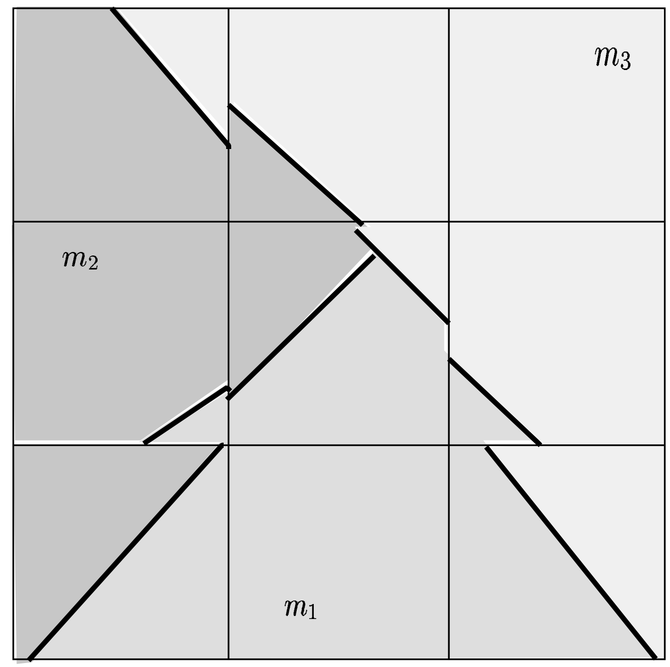
Bernd Hamann[4]

Kenneth I. Joy[5]



m_3
(0,.83,.17)
(0,.18,.82)
(0,0,1)
(.06,.94,0)
(.60,.30,.10)
(.08,0,.92)
(.52,.48,0)
(1,0,0)
(.54,0,.46)
m_2
m_1



m_3
m_2
m_1