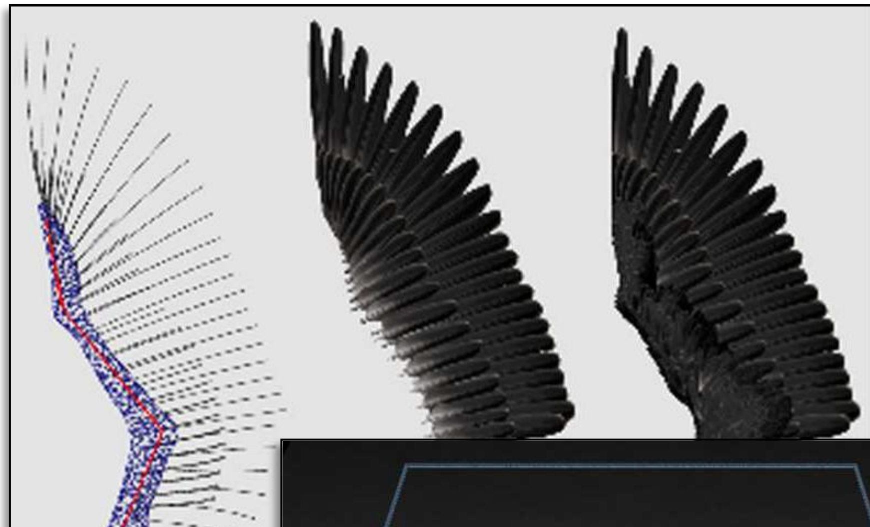
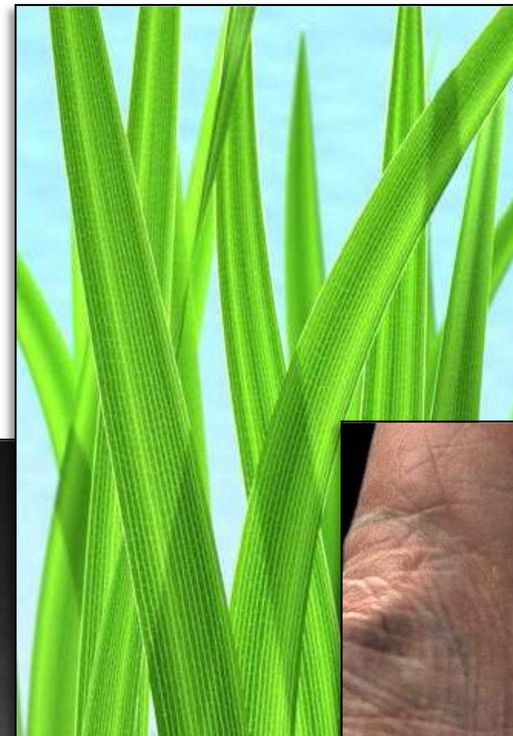
Scales and Scale-like Structures

Eric Landreneau Scott Schaefer
Texas A&M University

Introduction: Natural Phenomena

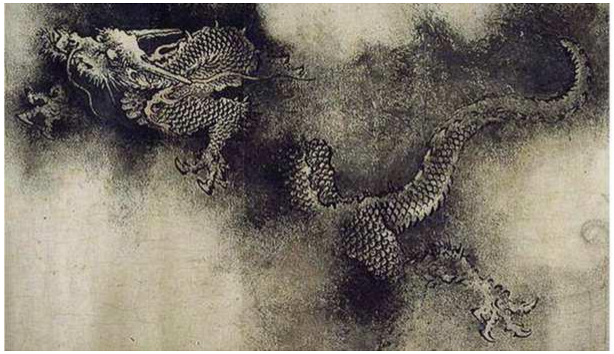


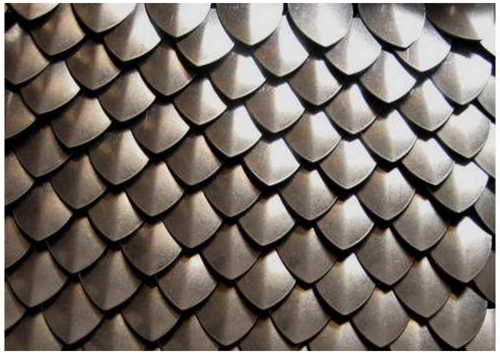


Introduction: Scales

Introduction

Examples of scales in artwork





Usually modeled/painted manually or with ad hoc techniques

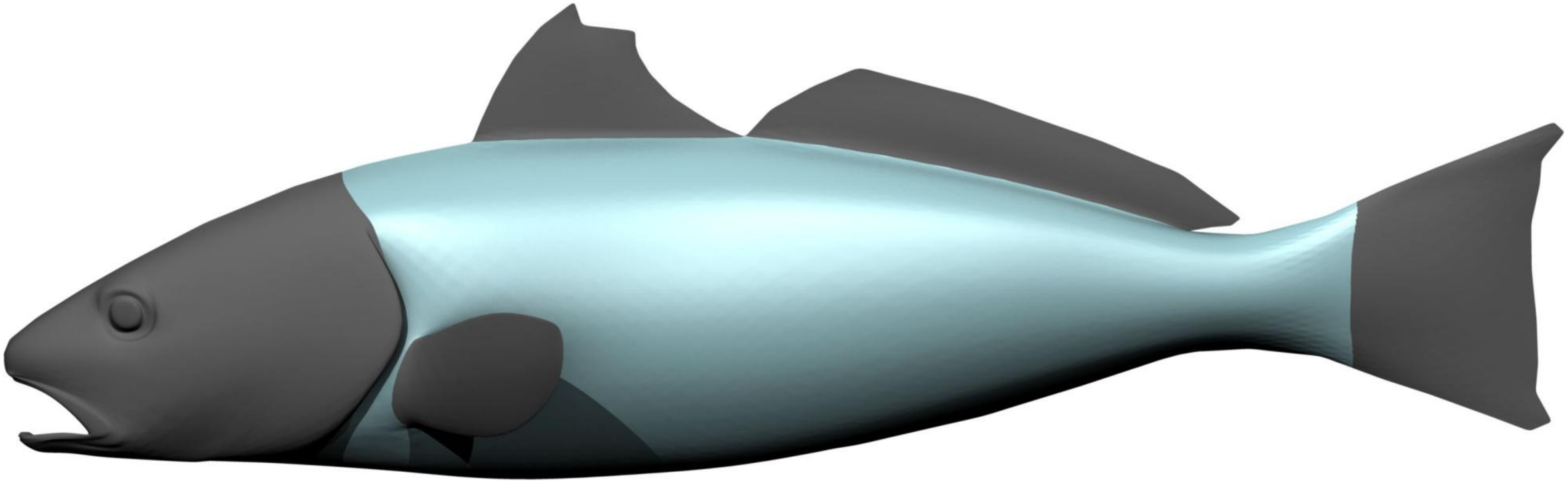
Previous Work

- **Direct modeling of scales** – artist creates scales manually (slow and painstaking)
- **Models** – places a scale shape at each position, no connectivity between scales
- **Displacement maps** – artist paints scales on a model, displaces height
- **Shell maps/mesh quilting** – can create 3d geometry, but problems with borders, seams (based on 2D parameterization)

Objectives

Main Objective

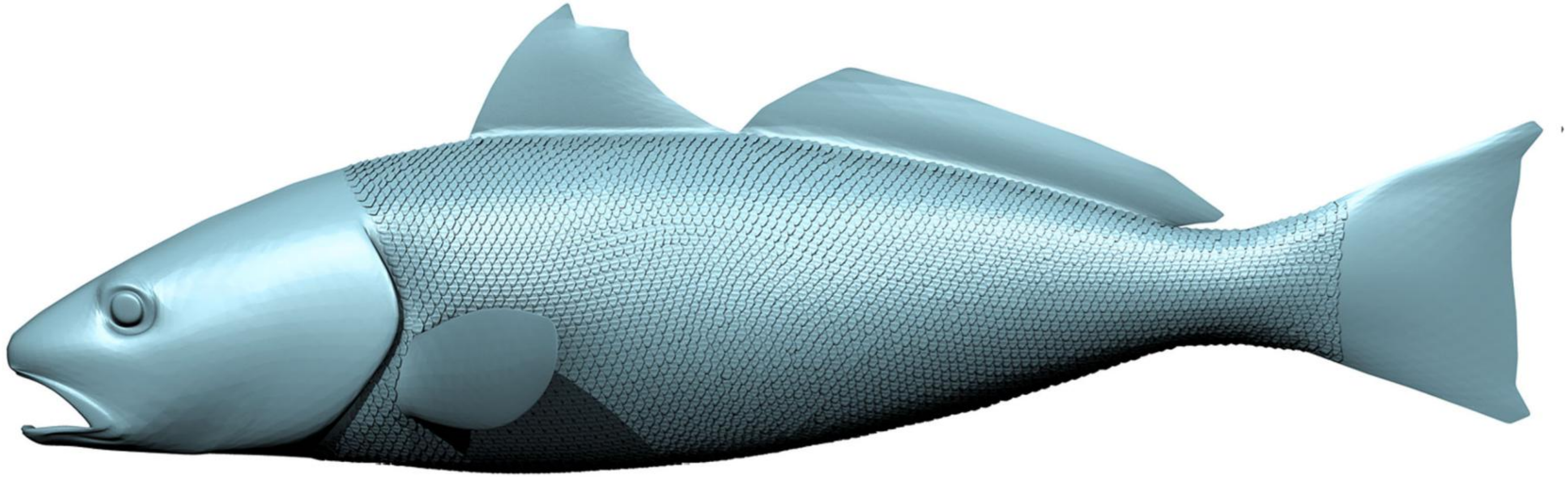
Given a mesh



Objectives

Main Objective

Grow scales on the surface



Scale Placement

Part 1:

Scale Placement

Scale Placement

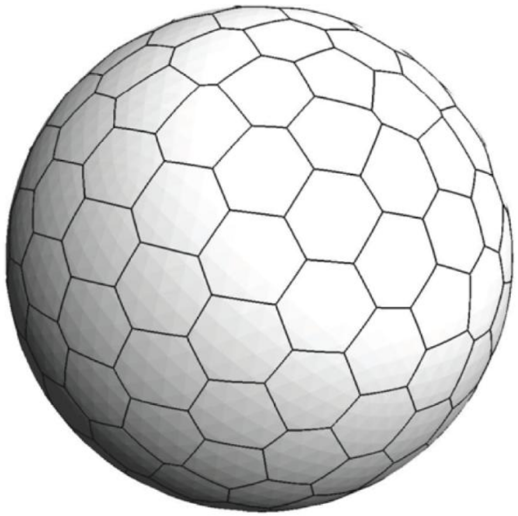
Scale Placement

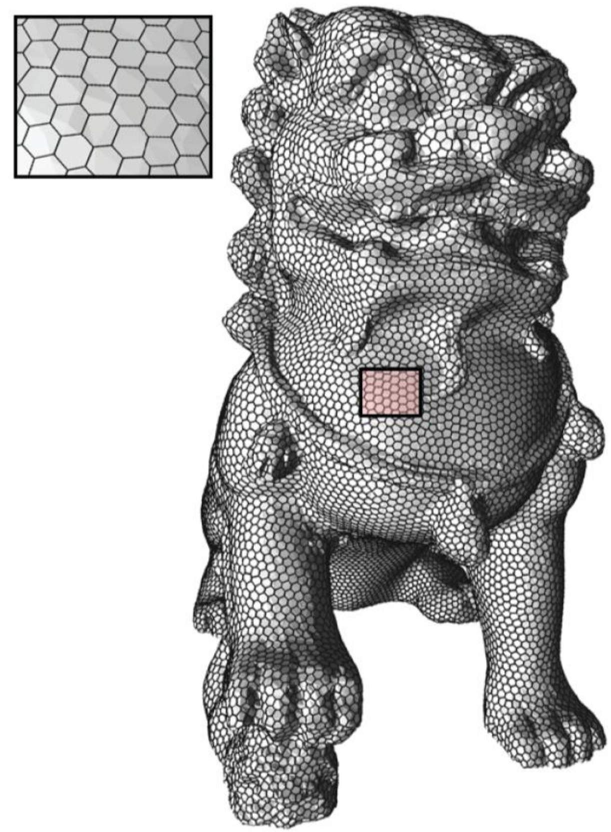
- Segment surface into per-scale regions
- Want evenly spaced scales
- Hexagonal arrangement [1]
- Scales need orientation

[1] Kenneth V. Kardong, *Vertebrates: Comparative Anatomy*, Function, Evolution, McGraw-Hill, 1998.

Scale Placement

Solution? CVTs (Centroidal Voronoi Tessellations[2])





[2] Liu, Y., Wang, W., Lévy, B., Sun, F., Yan, D., Lu, L., and Yang, C. 2009. On centroidal voronoi tessellation—energy smoothness and fast computation. *ACM Trans. Graph.* 28, 4 (Aug. 2009)

Scale Placement

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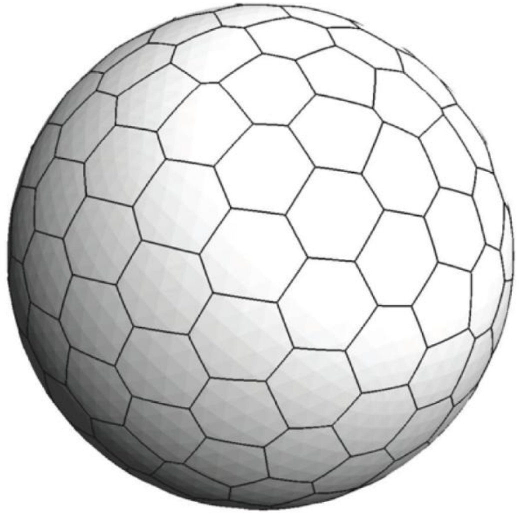
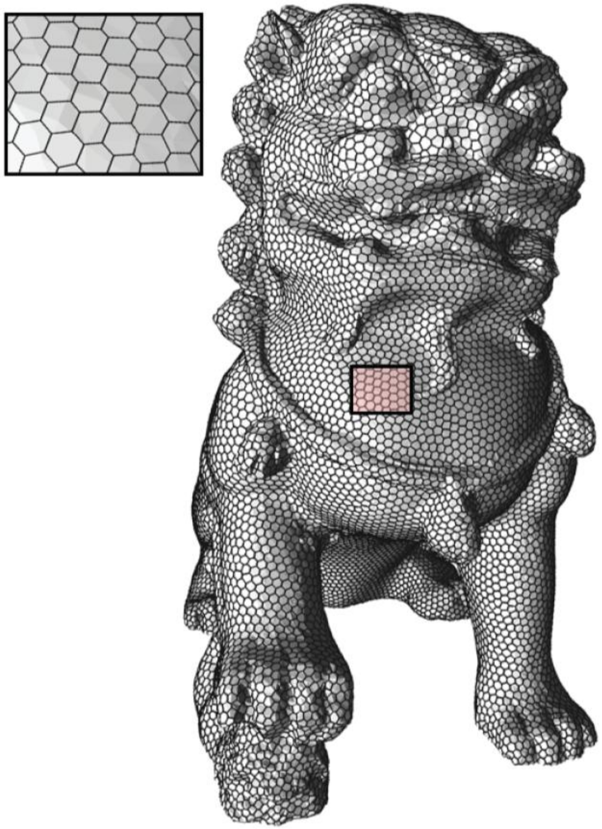


Even distribution of sites



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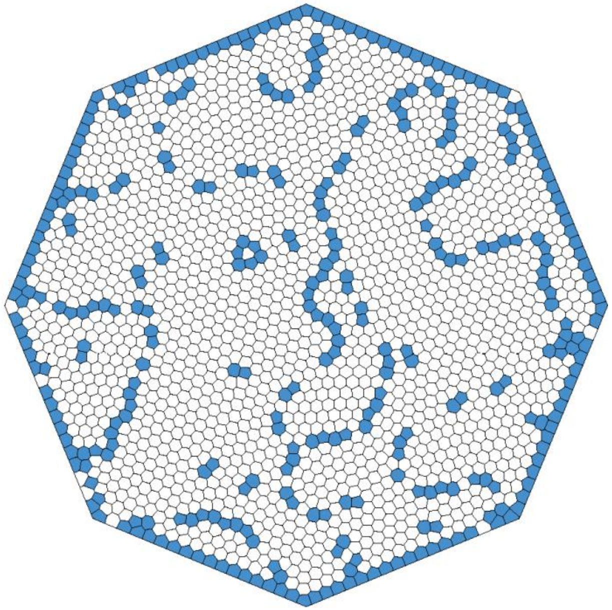
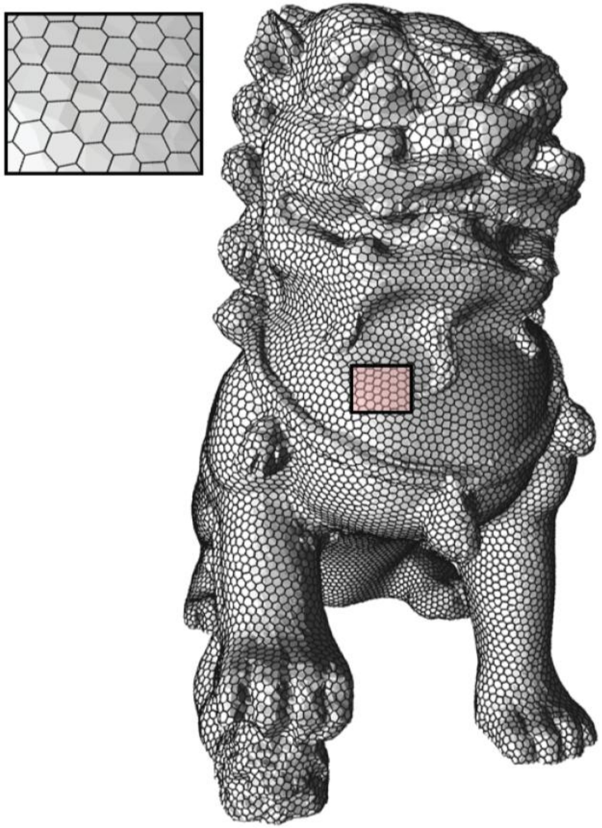


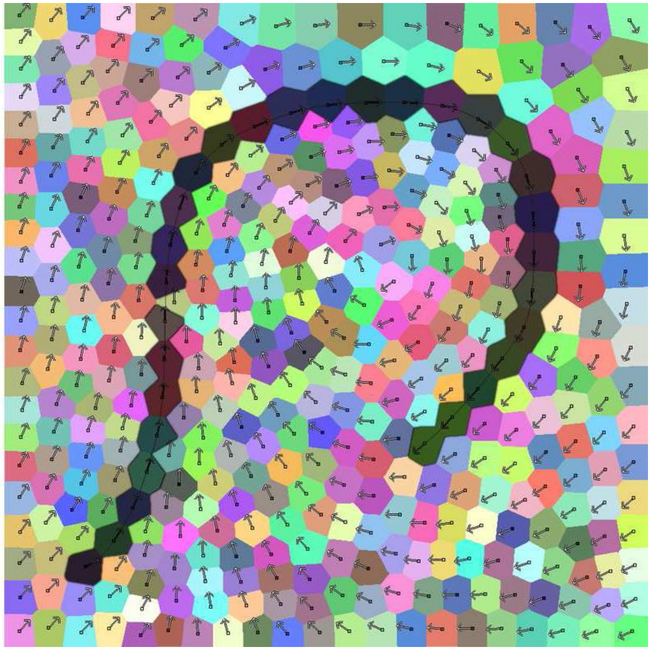


Produces mostly hexagons

[2] Liu, Y., Wang, W., Lévy, B., Sun, F., Yan, D., Lu, L., and Yang, C. 2009. On centroidal voronoi tessellation—energy smoothness and fast computation. *ACM Trans. Graph.* 28, 4 (Aug. 2009)

Scale Placement

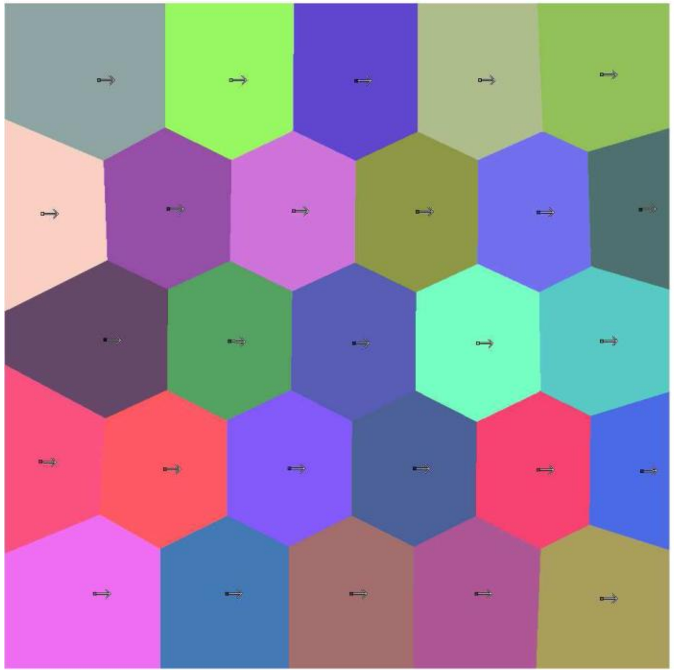
Orientation

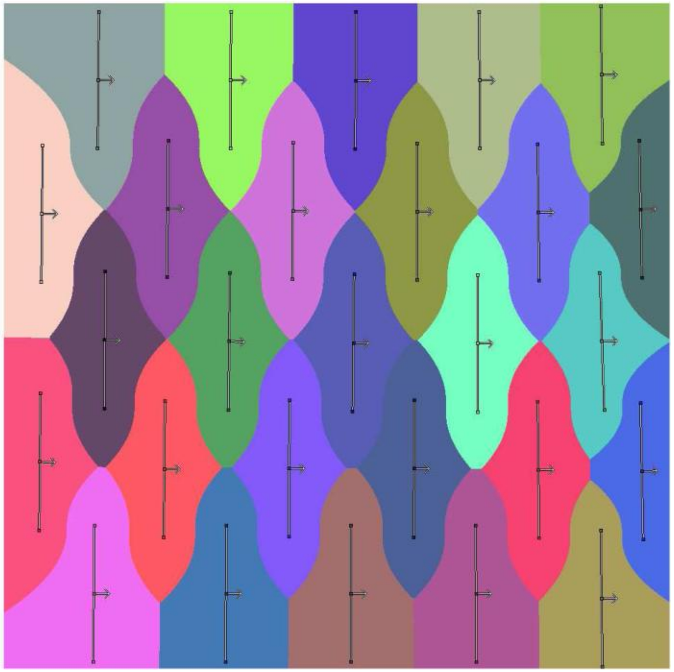


Determine vector field on surface, and propagate to the Voronoi Tessellation

Scale Placement

Orientation





Orientations allow for anisotropy

Scale Placement

How do we guide the CVT?

Scale Placement

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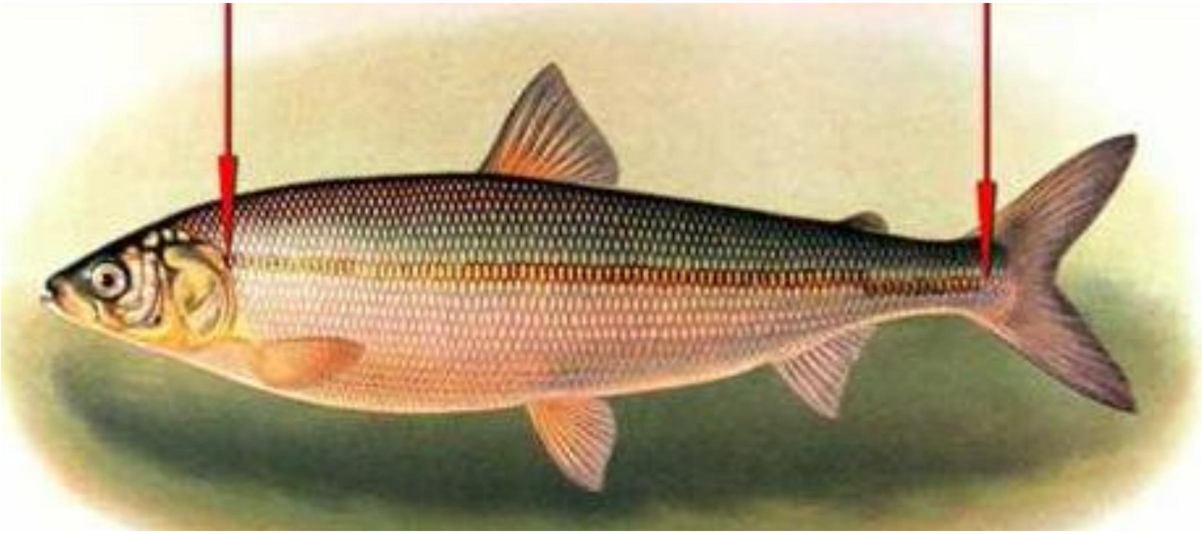
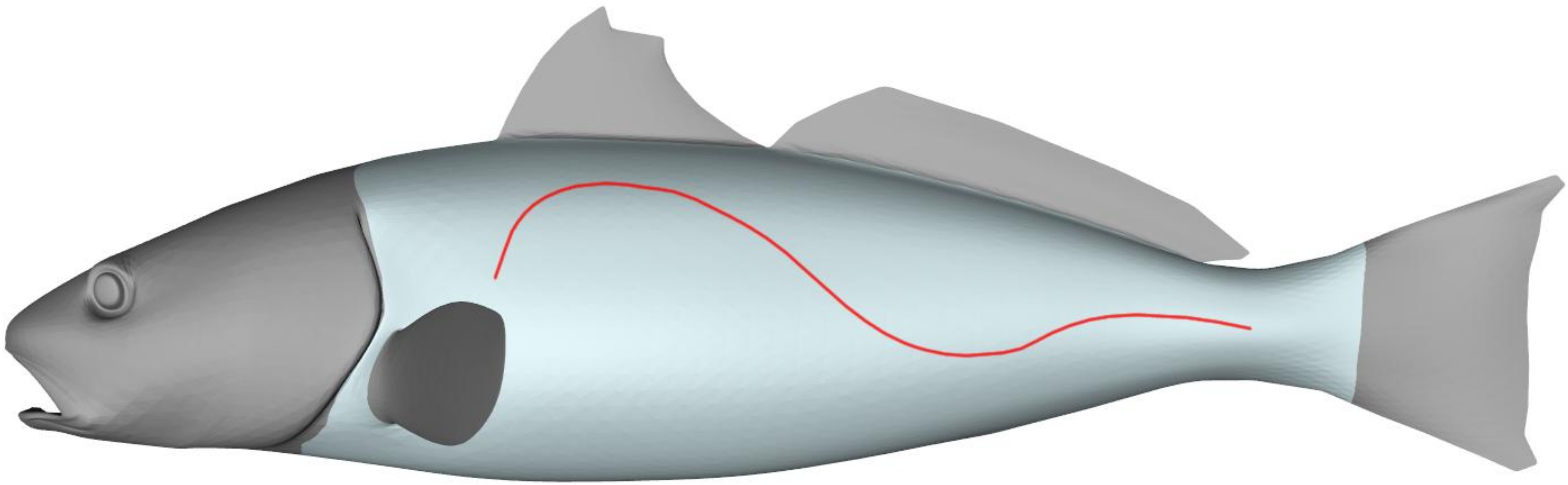


Solution – use a *lateral line*

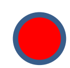
Scale Placement

The artist draws the lateral line



Scale Placement

Scale-sites spawn from the lateral line



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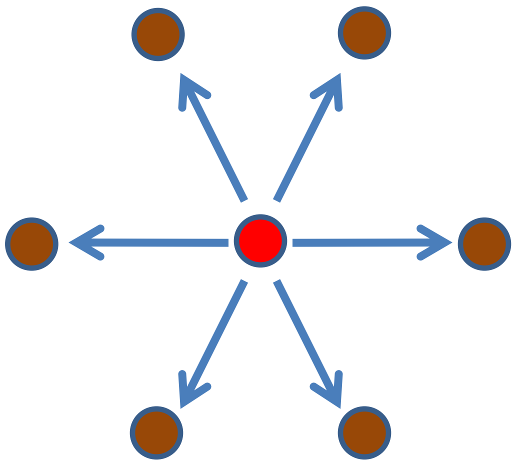

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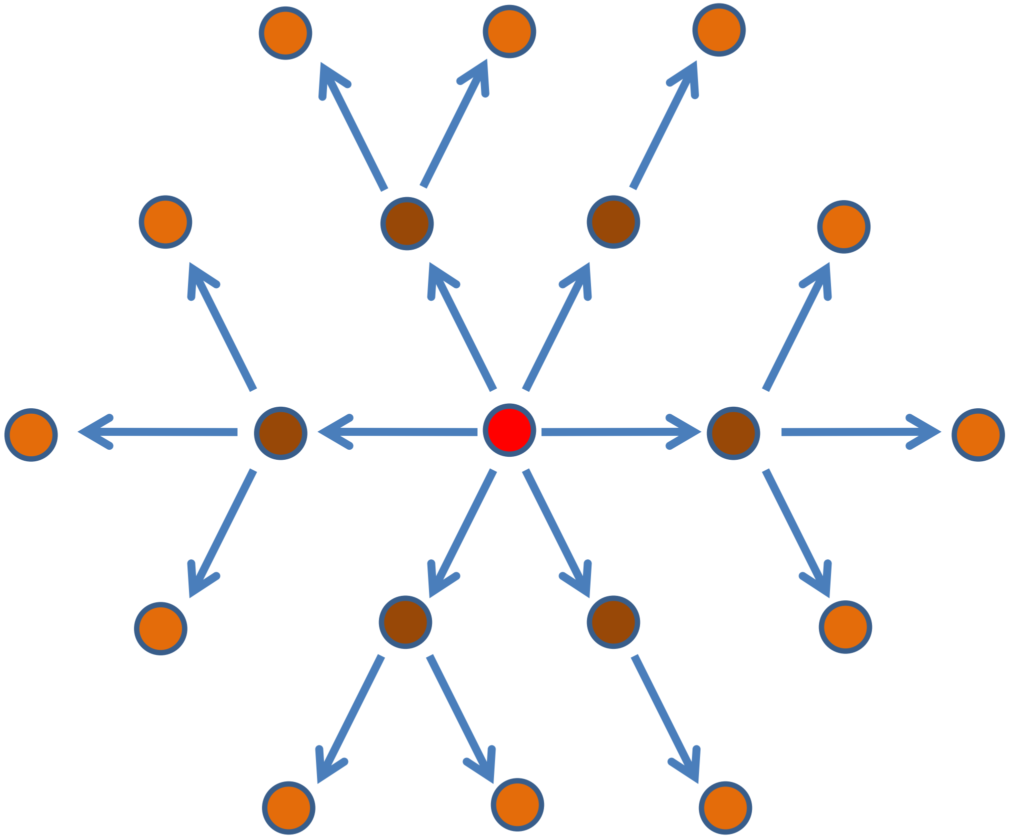
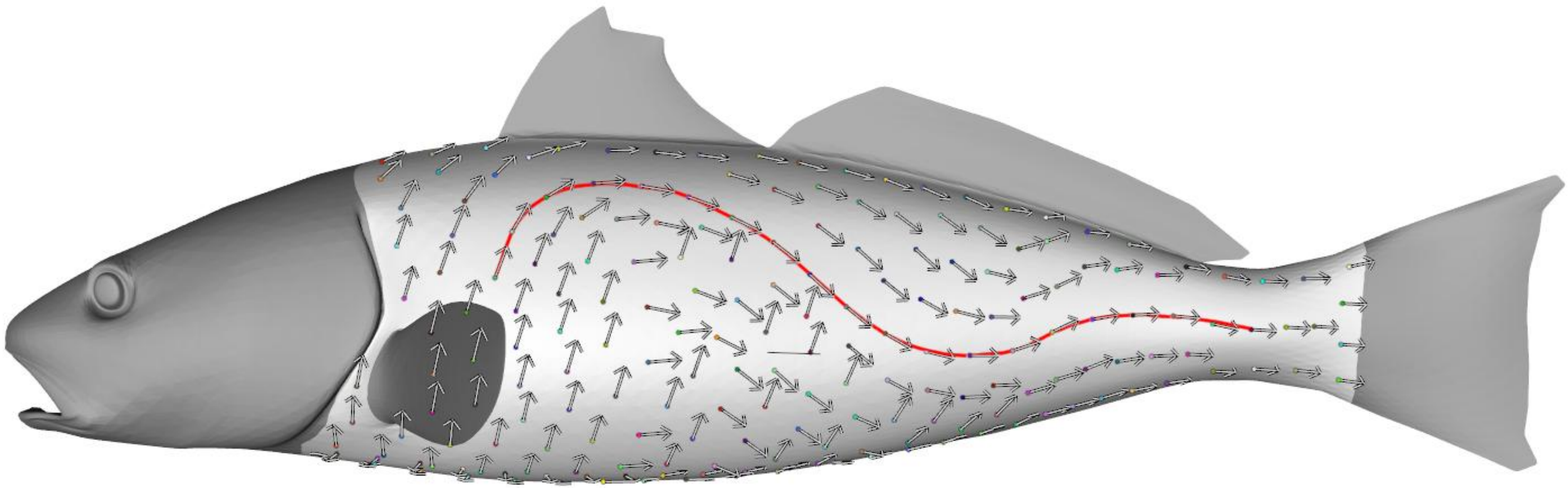
Scale-sites spawn from the lateral line



Scale Placement

Vector field initialized from the lateral line's tangents



Scale Placement

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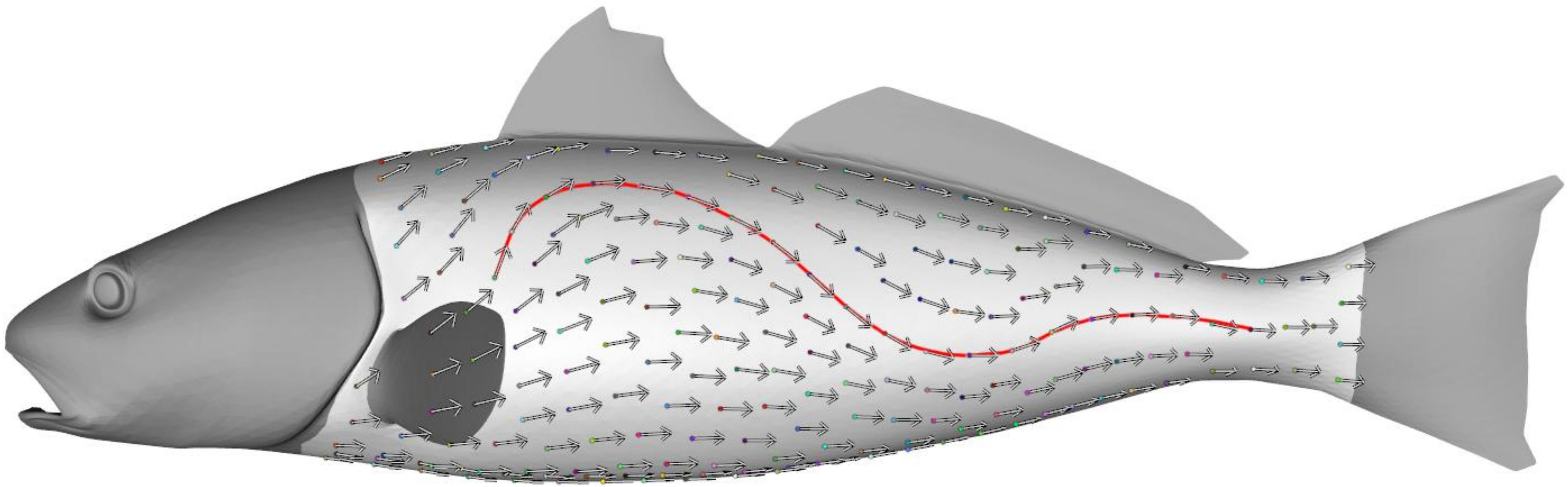
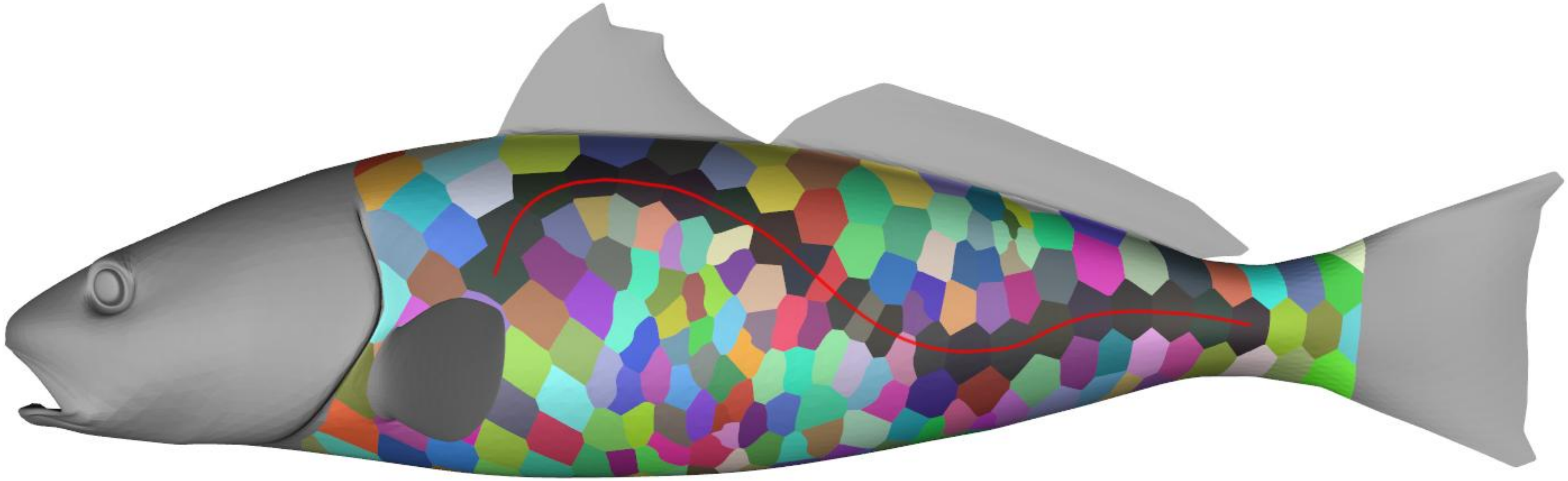


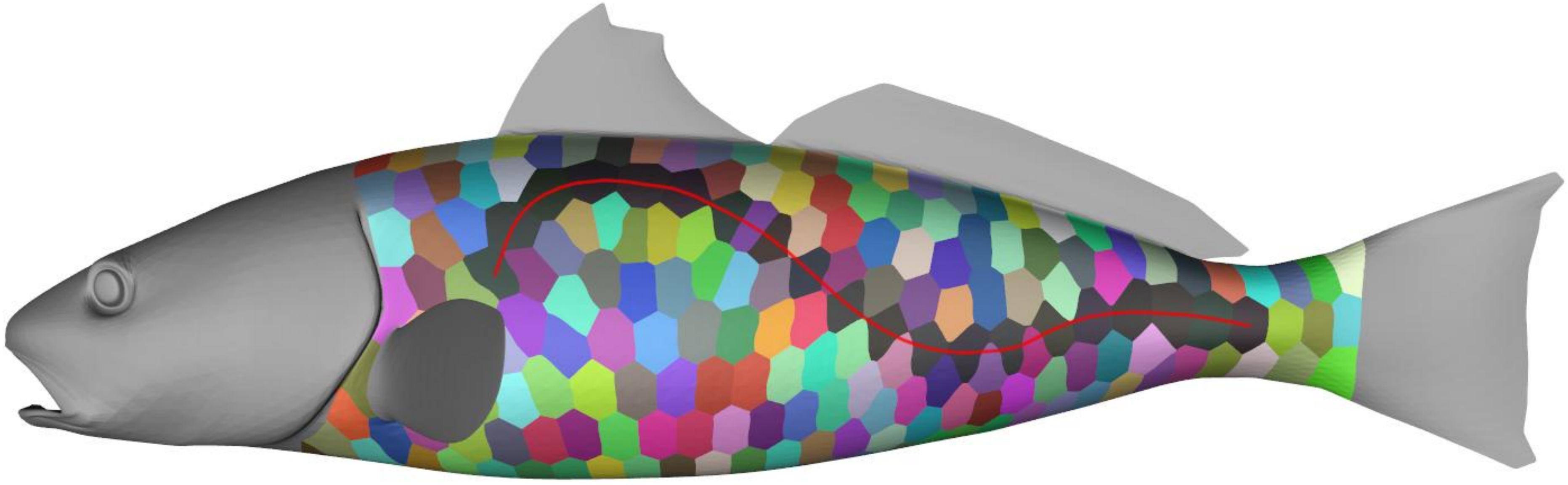
Scale Placement

Initial scale distribution



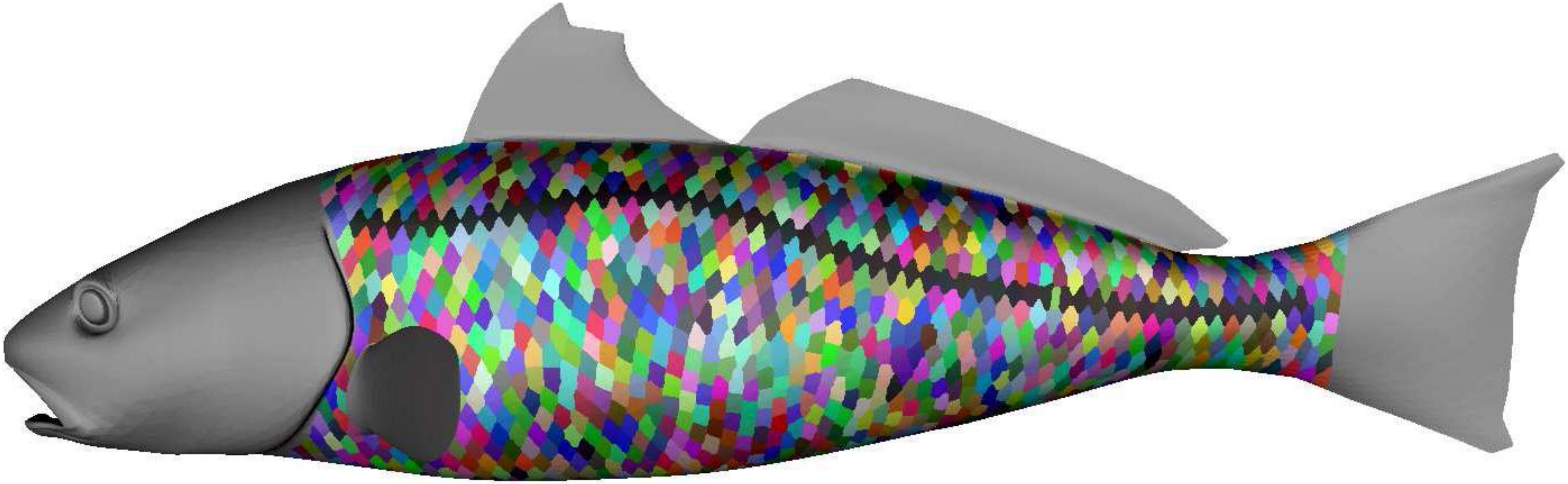
Scale Placement

Applying anisotropic Lloyd's algorithm



Scale Placement

Example of dense CVT



Scale Synthesis

Part 2:

Scale geometry synthesis

Scale Synthesis

- Replace scale regions with artist-provided geometry
- Connect geometry together in a watertight fashion
- Conform geometry to original surface

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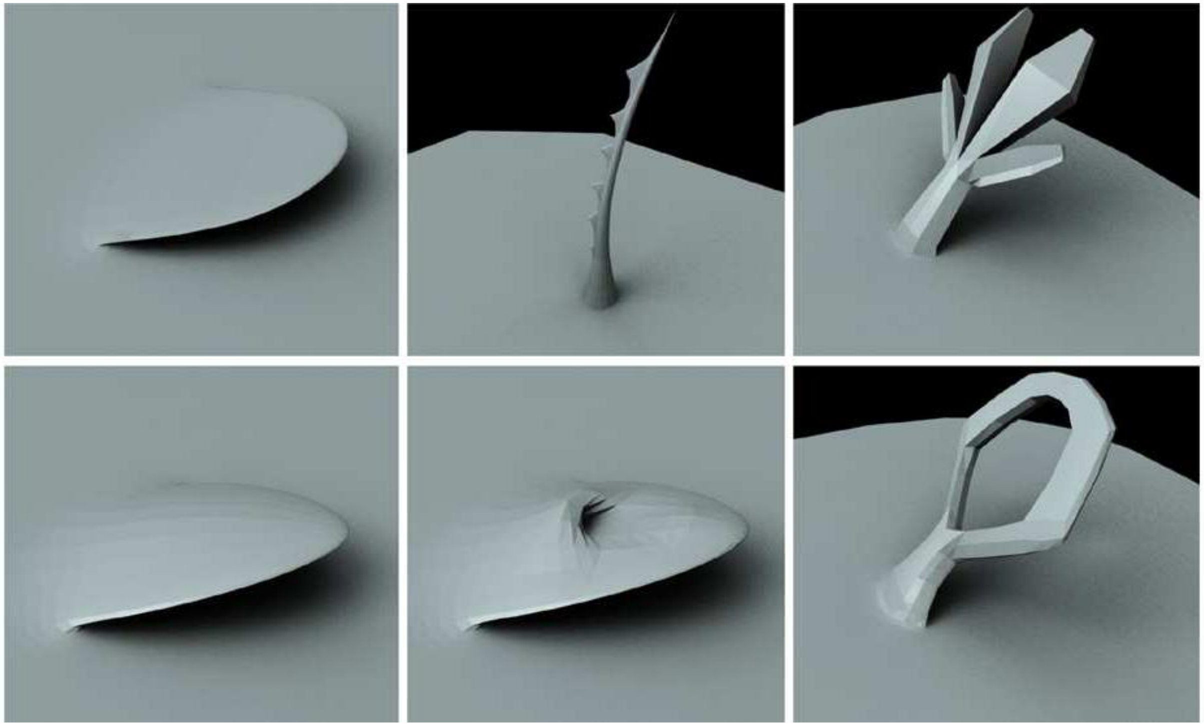
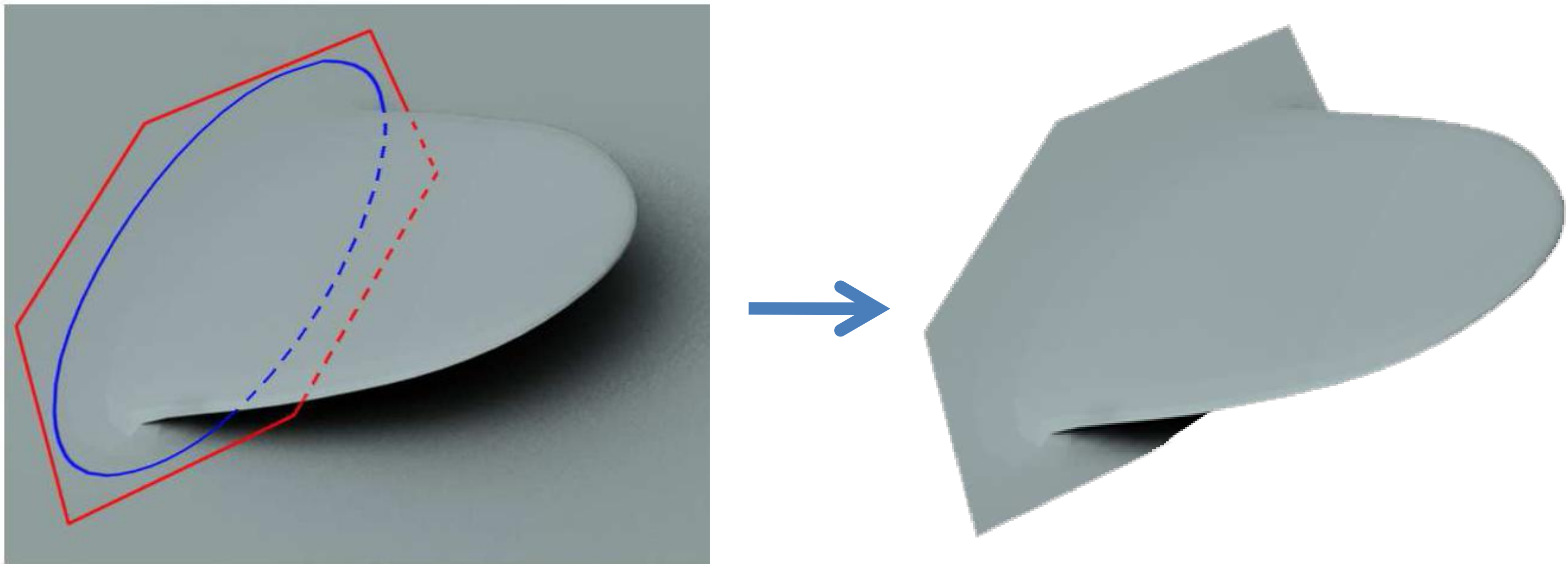
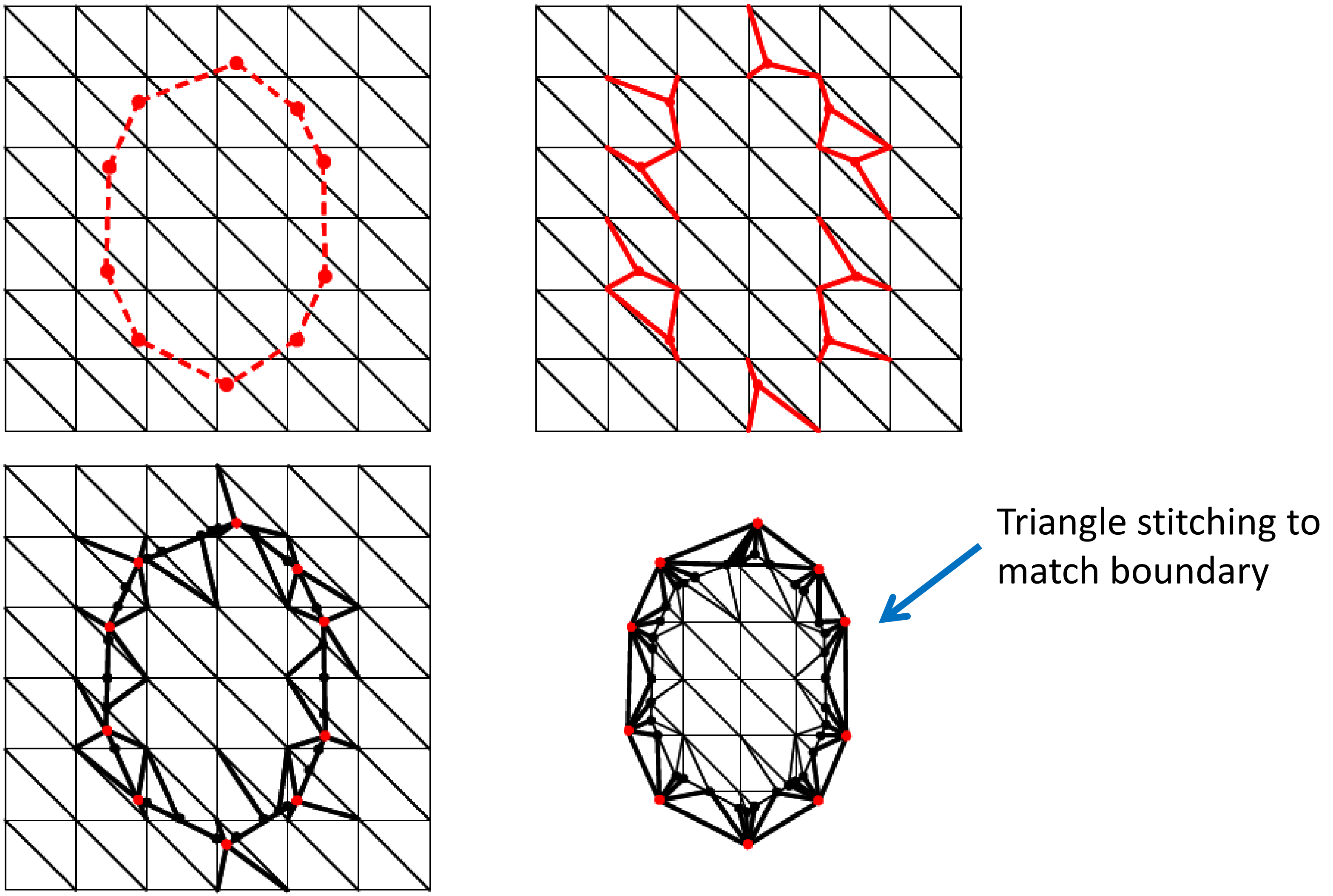


Scale Synthesis

Cut the proxy model using the boundary of the scale region

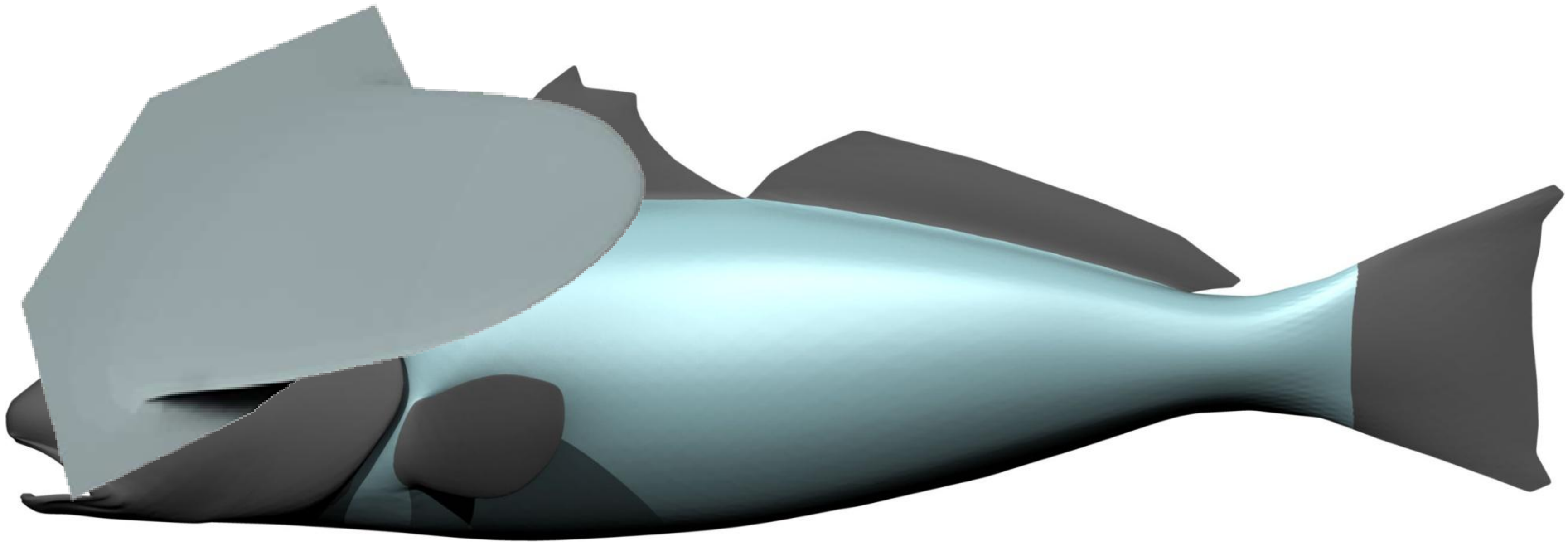


Scale Synthesis



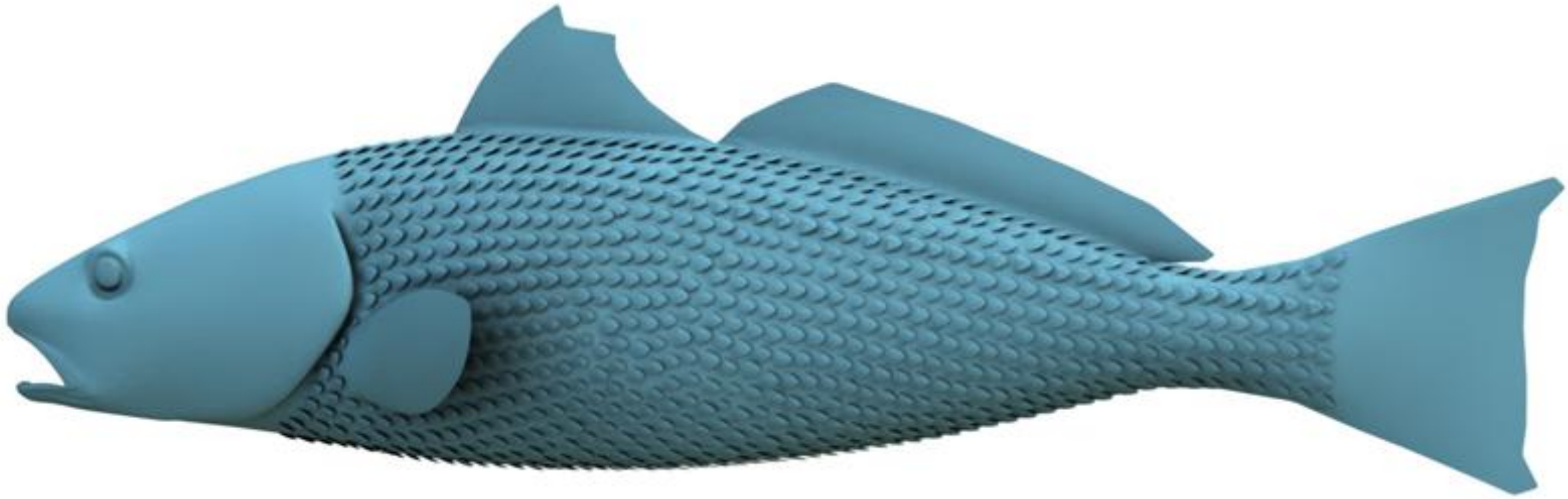
Scale Synthesis

Move the cut proxy-model to the mesh, and deform it to fit the surface

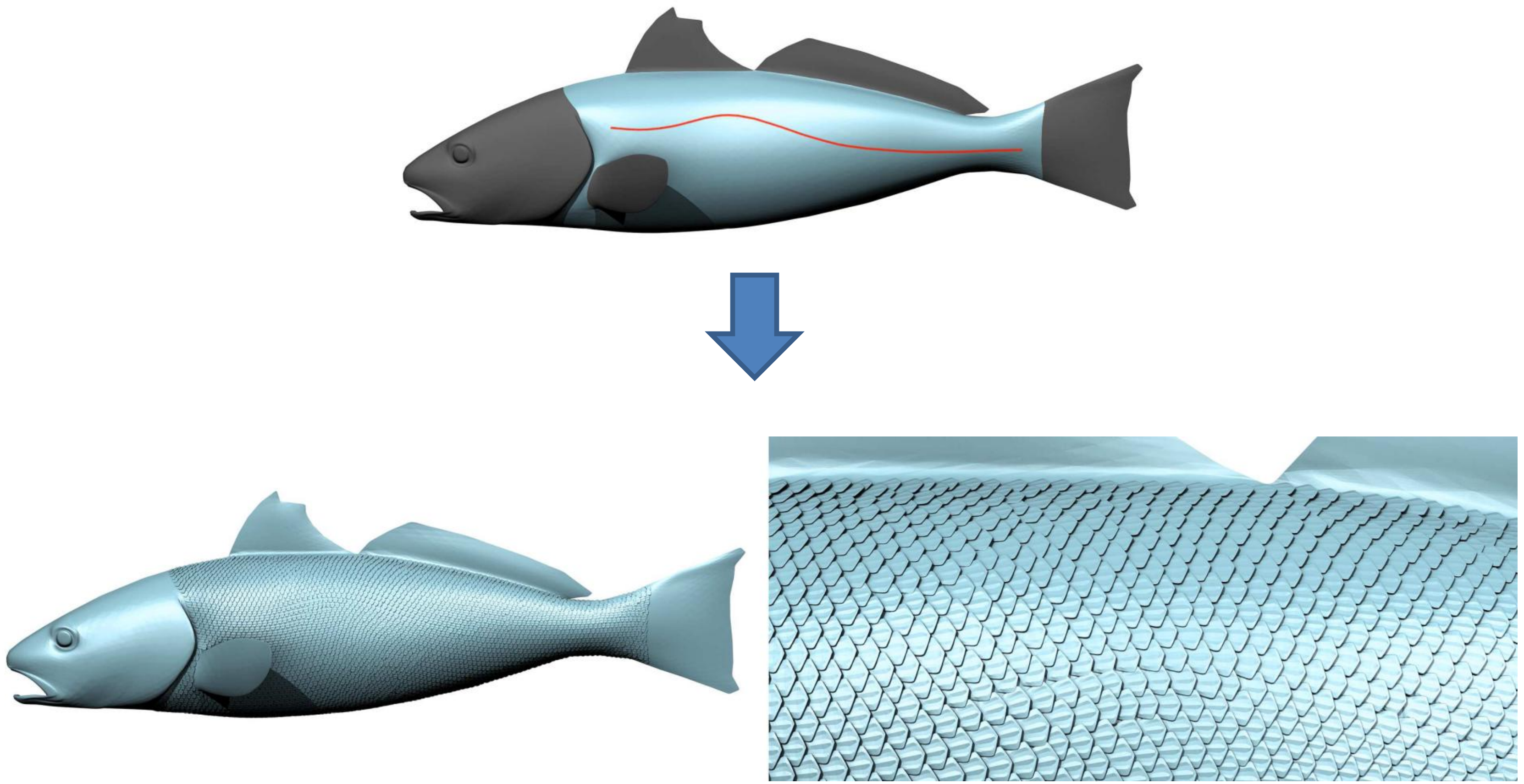


Scale Synthesis

Repeat for each scale region, then connect together to form a watertight network of scales



Results



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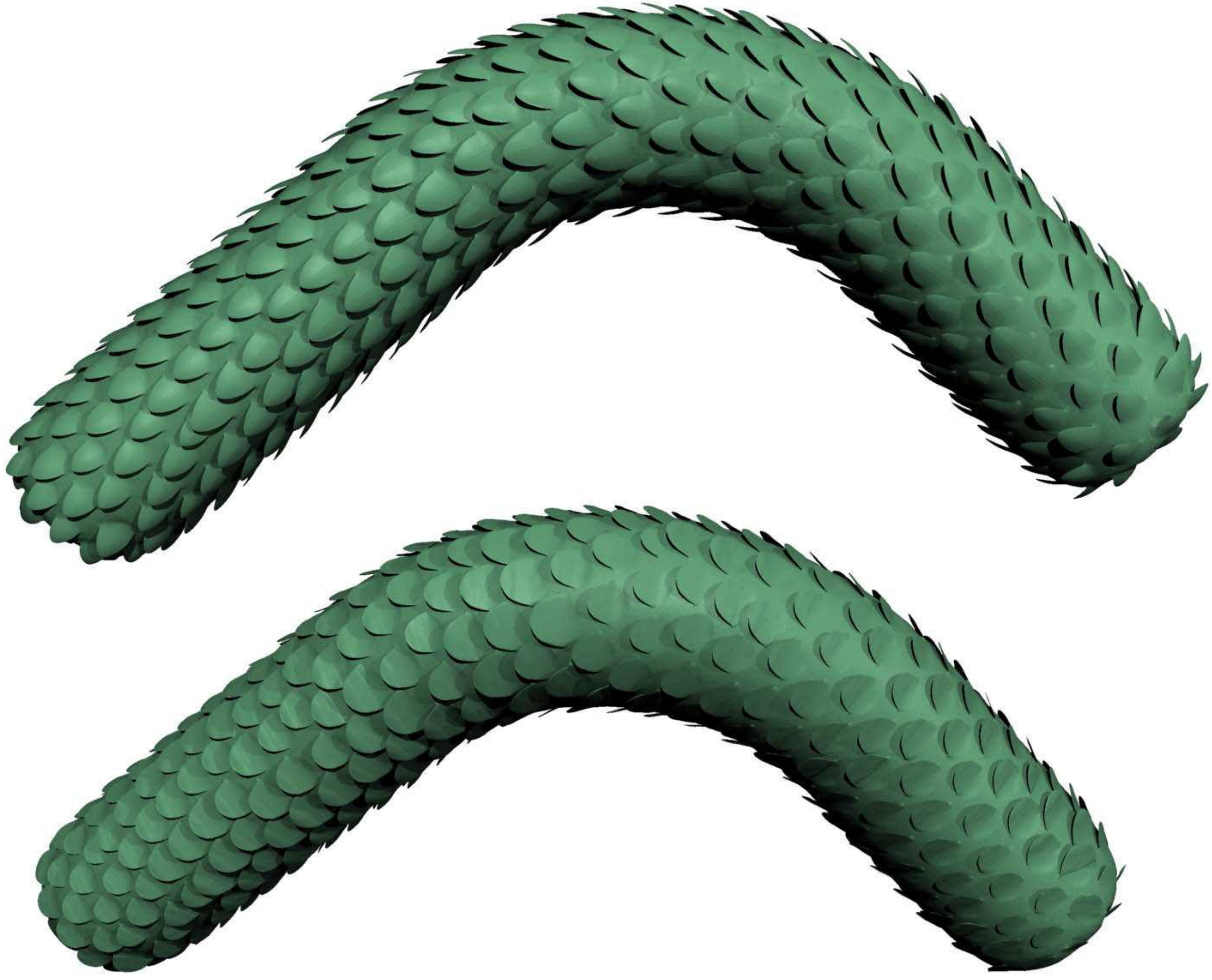

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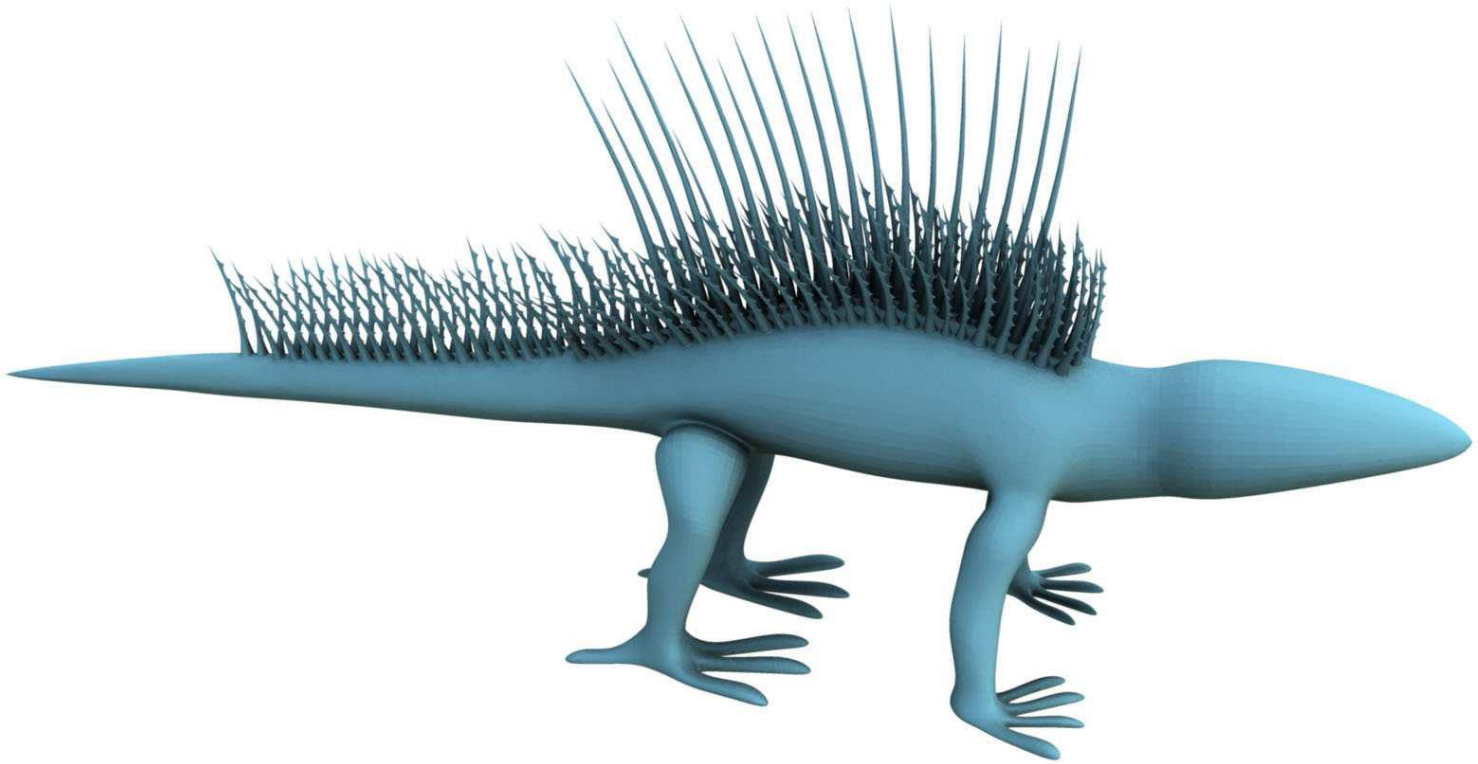
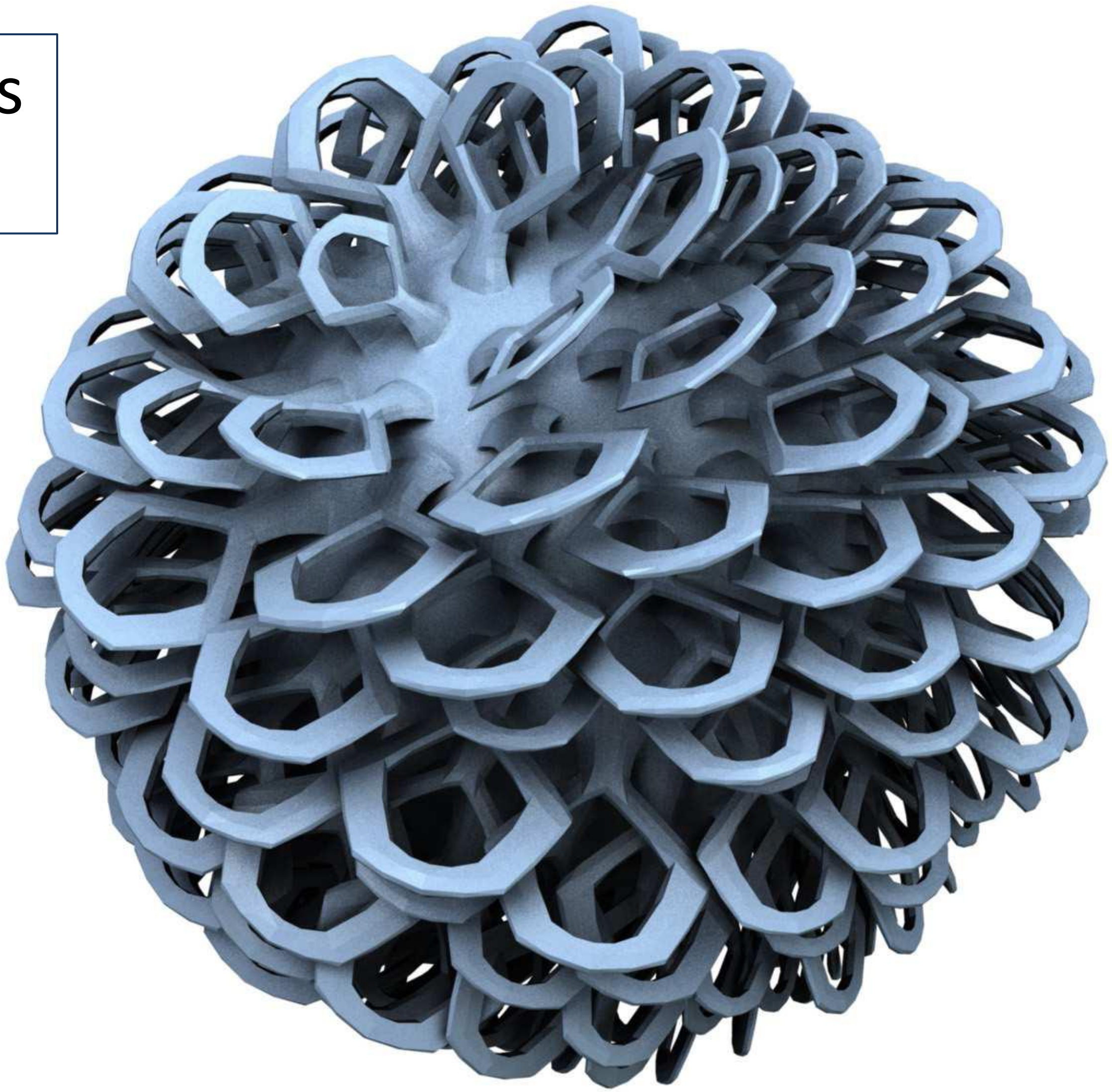


Results

High genus scales



Conclusions

- Does not require a global 2D mesh parameterization
- Allows for arbitrary scales including high-genus or long/thin shapes incompatible with displacement mapping
- Allows intuitive control through the lateral line
- Provides a watertight, topologically 2-manifold surface well suited for post-processing such as subdivision and simplification

Questions?