Geodesic Patterns

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September 2018

UPC - MPDA'18

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Objective

Discretize a given freeform surface into panels with the following properties:

1. Panels must be ***developable*** (Shelden 2002)
2. Panels should be of approximate ***equal width***
3. Panels should be ***as straight as possible***
4. Panels should ***bend by their weak axis*** to approximate the surface.

Background

The use of *straight developable planks* is widely used in:

Figure 1: Traditional boat building

Also common practice in naval engineering industry:

Figure 2: Connected developable patches for boat hull design

Frank Ghery

This techniques have also been used in the architecture world, mainly by **Frank Ghery**.

His façades are usually a collection of connected developable surfaces.

Latest architectural work following this techniques was:

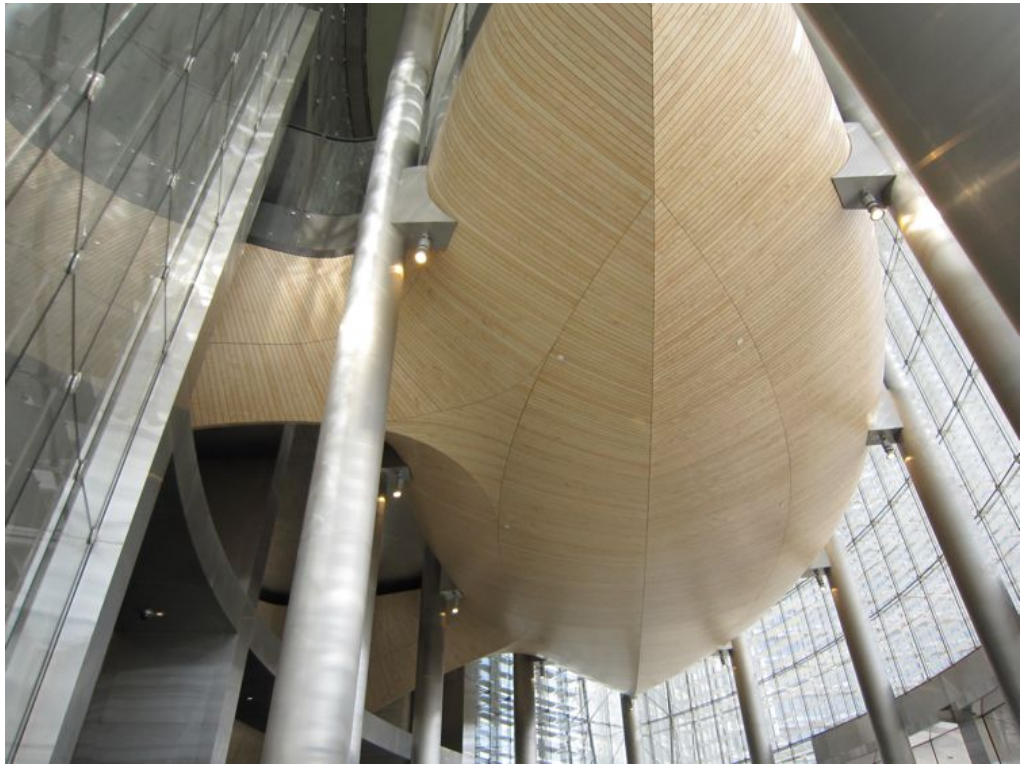


Figure 3: Burj Khalifa by Frank Ghery

It was designed as a collection of:

- **Developable surfaces**
  - *Which can be covered by equal width planks*
- **Surfaces of constant curvature**
  - *Which can be covered by repeating the same profile*

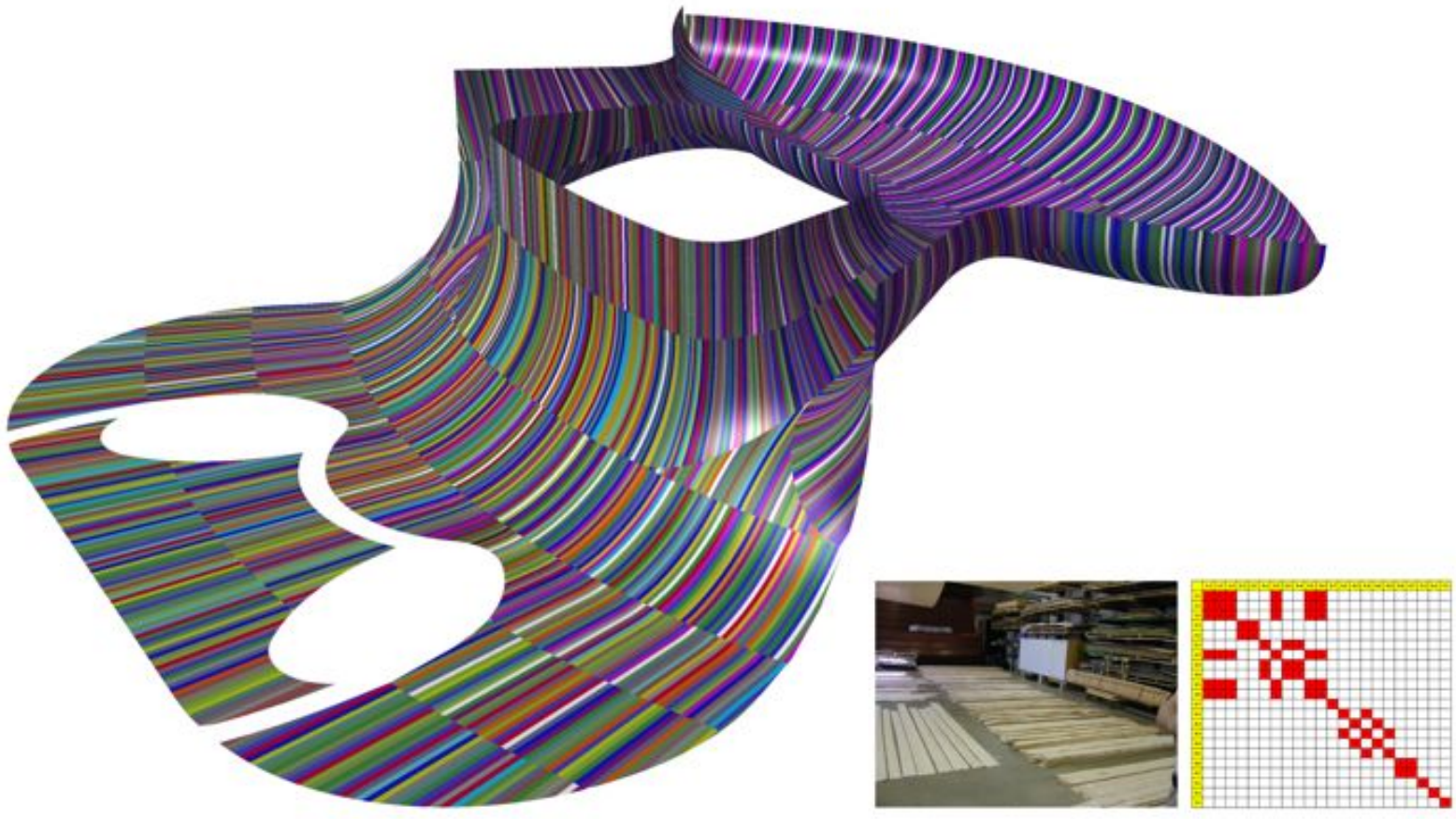


Figure 4: Burj Khalifa final panel solution

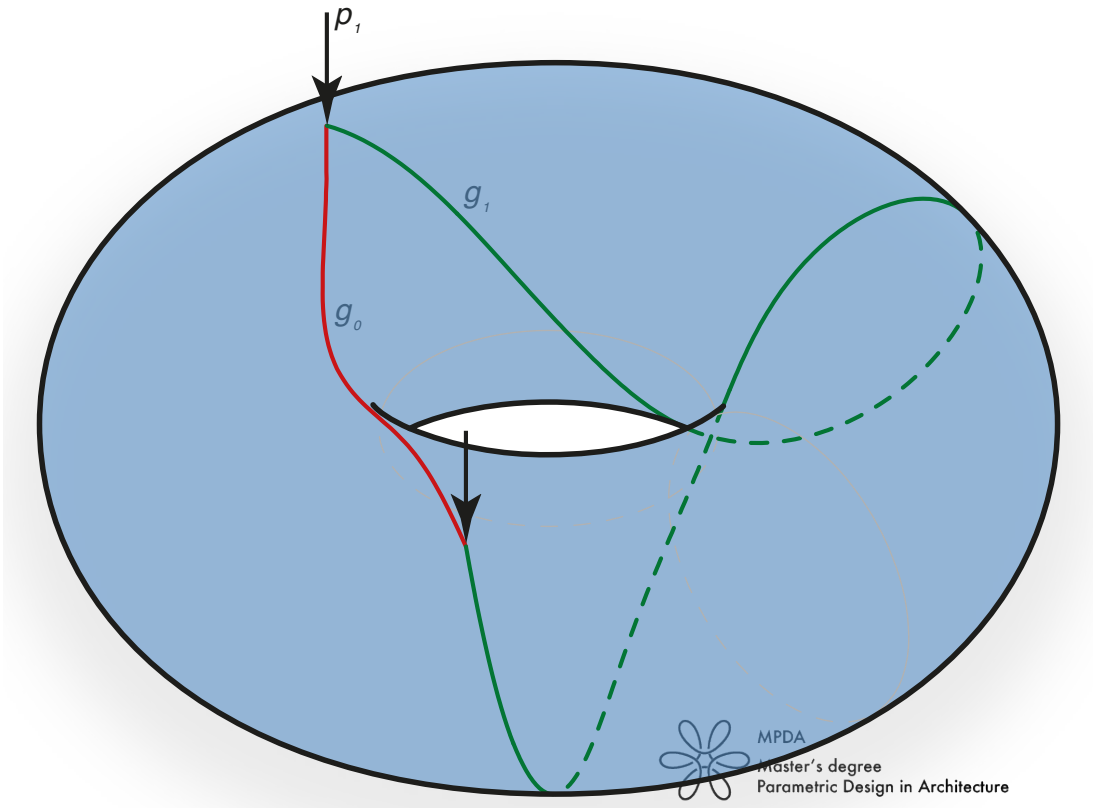
Construction technique

Geodesic curves

A geodesic curve is the generalization of a *straight line* into *curved spaces*.

Straightest geodesics

In this research, we concentrate on the concept of ***straightest geodesics***.



Developable surfaces

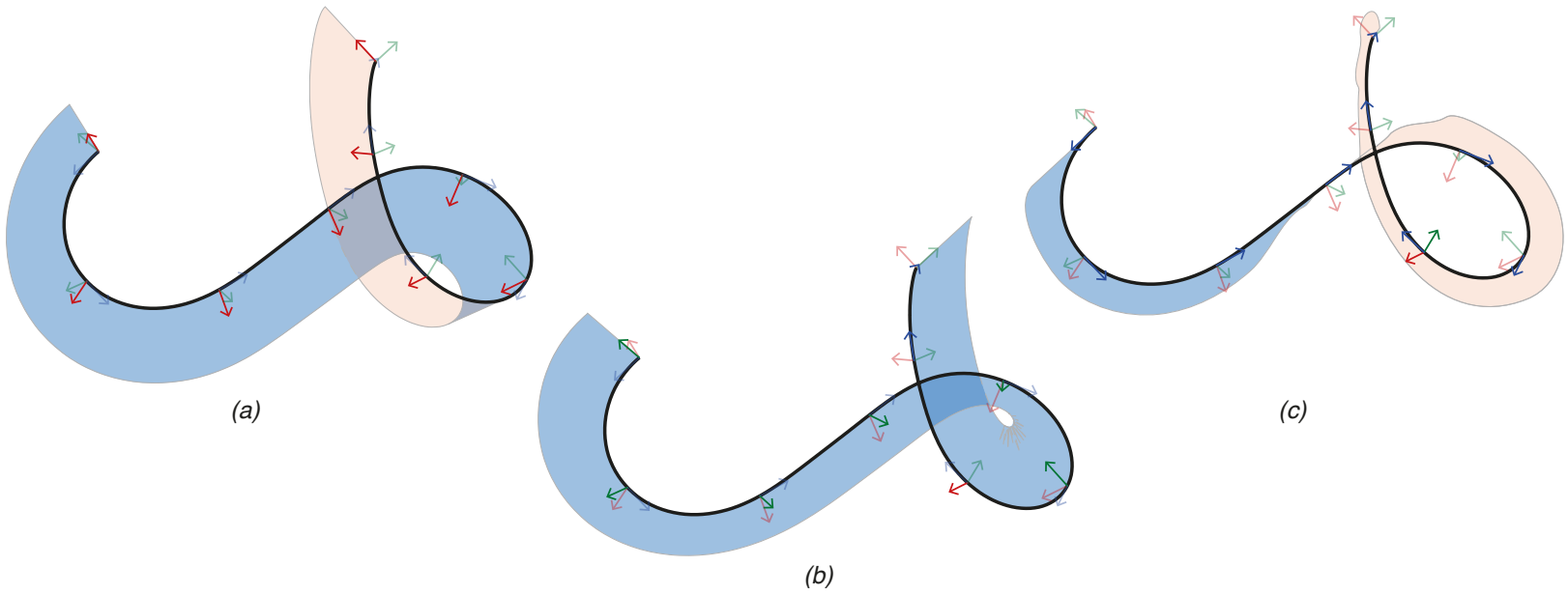


Figure 6: Surfaces with ***0 gaussian curvature***. Meaning, they can be flattened onto a plane ***without distortion***

Developable surfaces

- surfaces that can be flattened.
- can be generated by a single curve.

Geodesic curves

- are straight lines in a curved space.

If Panels are generated using geodesic curves on the surface

Then Resulting panels will be ***developable*** and mostly ***straight*** when flat.

In other words

We wish to cover a given freeform surface with a pattern of **geodesic curves** with equal spacing.

This can only be achieved if the provided surface is already *developable*.

A compromise exists between the *curve spacing* and the *curves geodesic property*

Algorithmic strategies

Obtaining Geodesic Patterns

These are the main methods for the obtaining successful geodesic patterns:

1. The ***parallel transport*** method
2. The ***evolution*** method
   2.1 The ***piecewise geodesic*** evolution method
3. The ***level-set*** method

The parallel transport method

Vector parallel transport

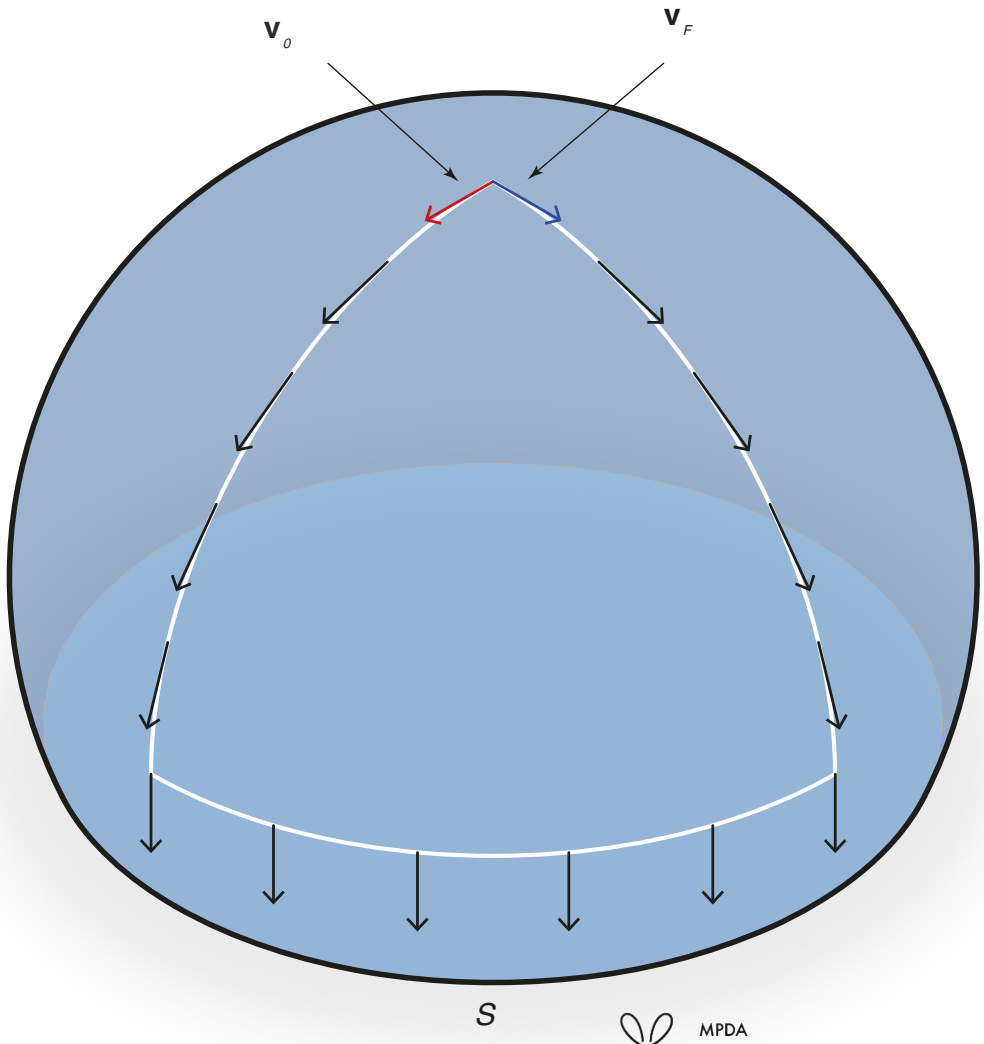


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Figure 7: Parallel transport of a vector over a path on a sphere

P.T. Example

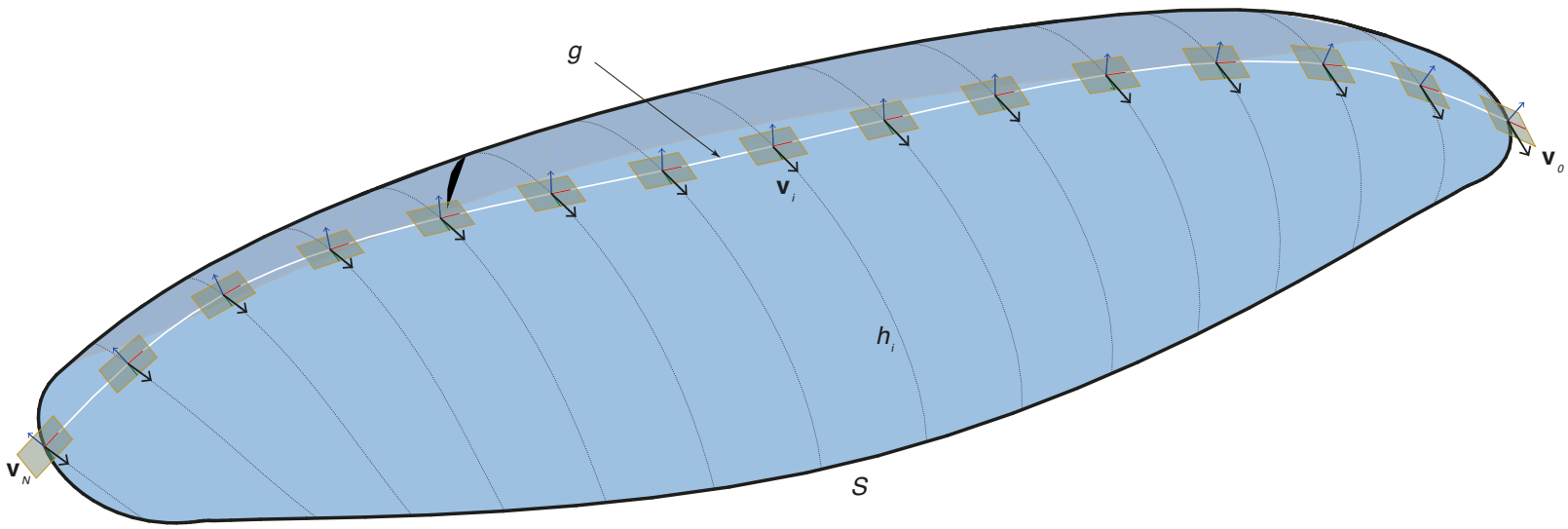


Figure 8: Parallel transport method over a positive curvature surface

P.T. Implementation

PLACE P.T. ALGORITHM HERE!!!

P.T. Results

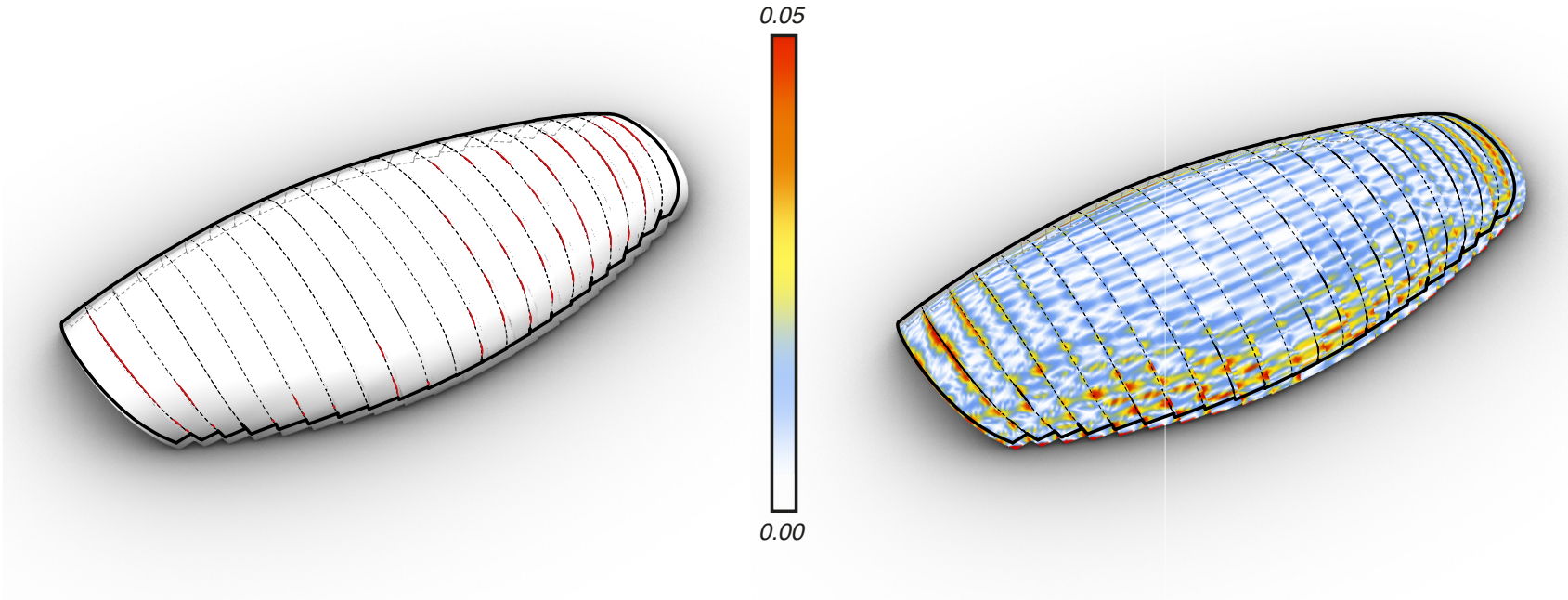


Figure 9: TNB generated panels & distance to original mesh

The Evolution Method

Evolution Implementation

PLACE ALGORITHM HERE!!

Evolution Method Results

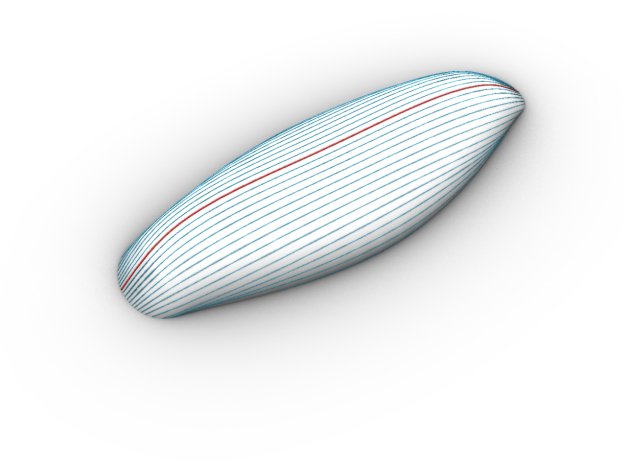


Figure 10: Evolution method example

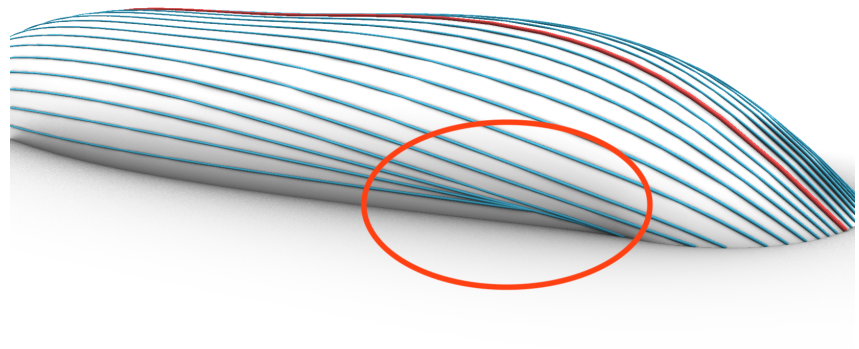


Figure 11: Evolution method problems

The Piecewise Evolution Method

Piecewise Ev. Implementation

Piecewise Ev. Results

The level set method

Level-set Implementation

Results

Modeling planks

Tangent developable method

Bi-Normal method

Comparison

Optimization

Piecewise geodesic vector-fields

Developability of triangle meshes

Analysis

Gaps in panelization

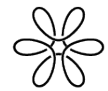
???

Stress in panels

???

Conclusion

Thanks



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Appendix

Resources

PUT LINKS TO GH COMPONENTS HERE + OTHER NICE SOFTWARE!

References i

Shelden, Dennis Robert. 2002. “Digital Surface Representation and the Constructibility of Gehry’s Architecture.” PhD thesis, Massachusetts Institute of Technology.
http://hdl.handle.net/1721.1/16899.