DESIGN AND PANELIZATION OF ARCHITECTURAL FREEFORM-SURFACES BY PLANAR QUADRILATERAL MESHES

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WHY QUADS ?

While **triangulation** is the easiest way of segmenting a freeform surface such that it can be built by using planar panels, **Planar Quadrilateral Meshes ('PQ-meshes')** offer much more:

- **offset properties**, which are useful for realizing multilayer constructions (not adressed here)

- **torsion - free nodes**, which are easier to produce

- **lightweight connections** of joining members: as opposed to six joining beams per node for common triangular meshes, regular PQ meshes only exhibit four.

- **reduced need for material,** resulting in **cost reduction**

- good overall **aesthetics** - the mesh appears less dense

vs.

Zlote Tarasy, Waagner-Biro.
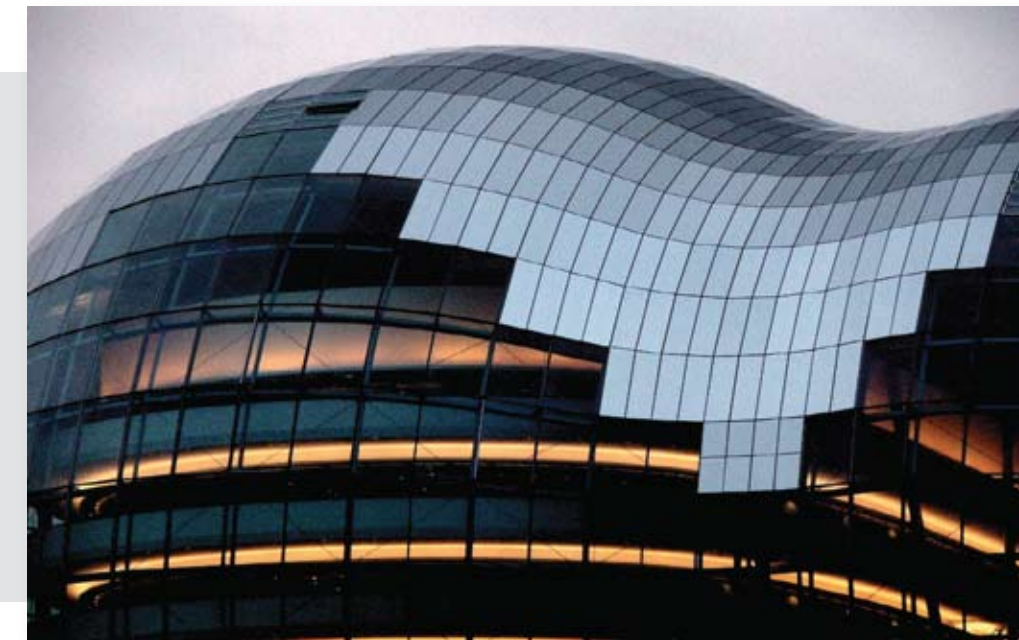Freeform-structure segmented
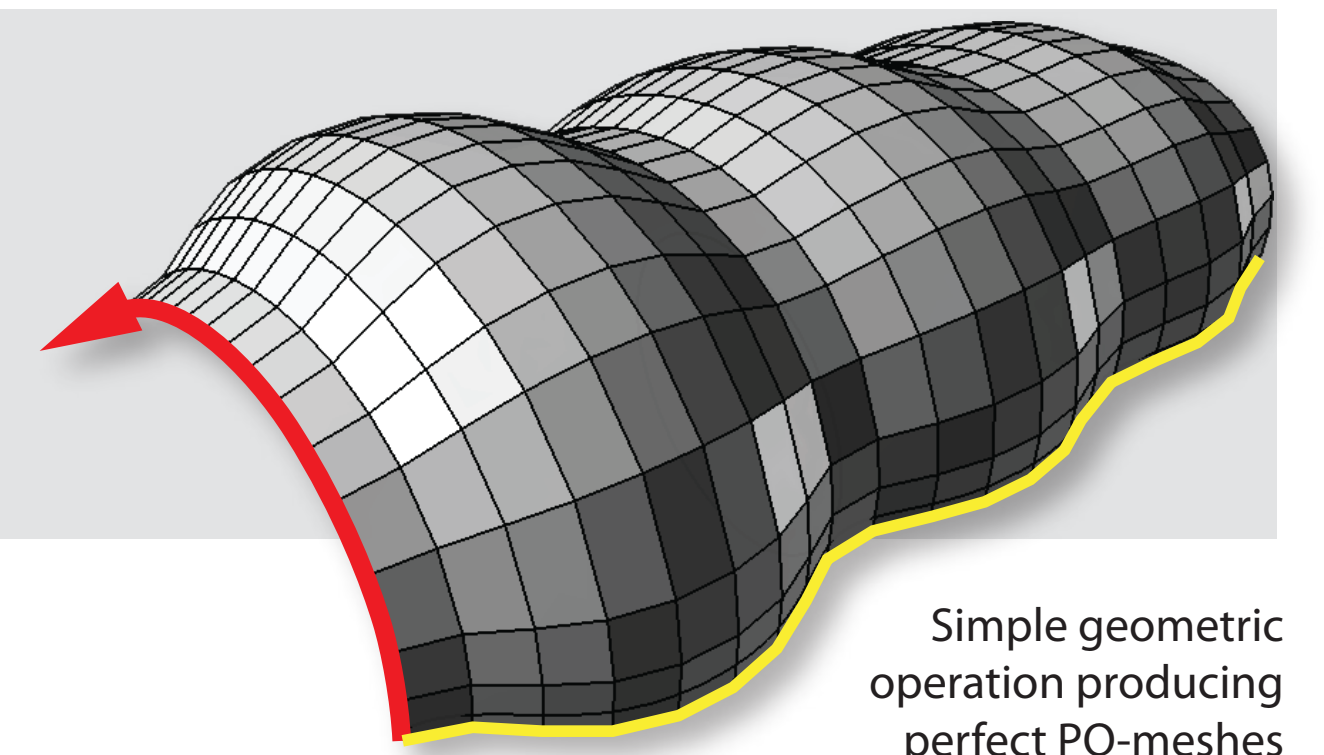by triangular panels
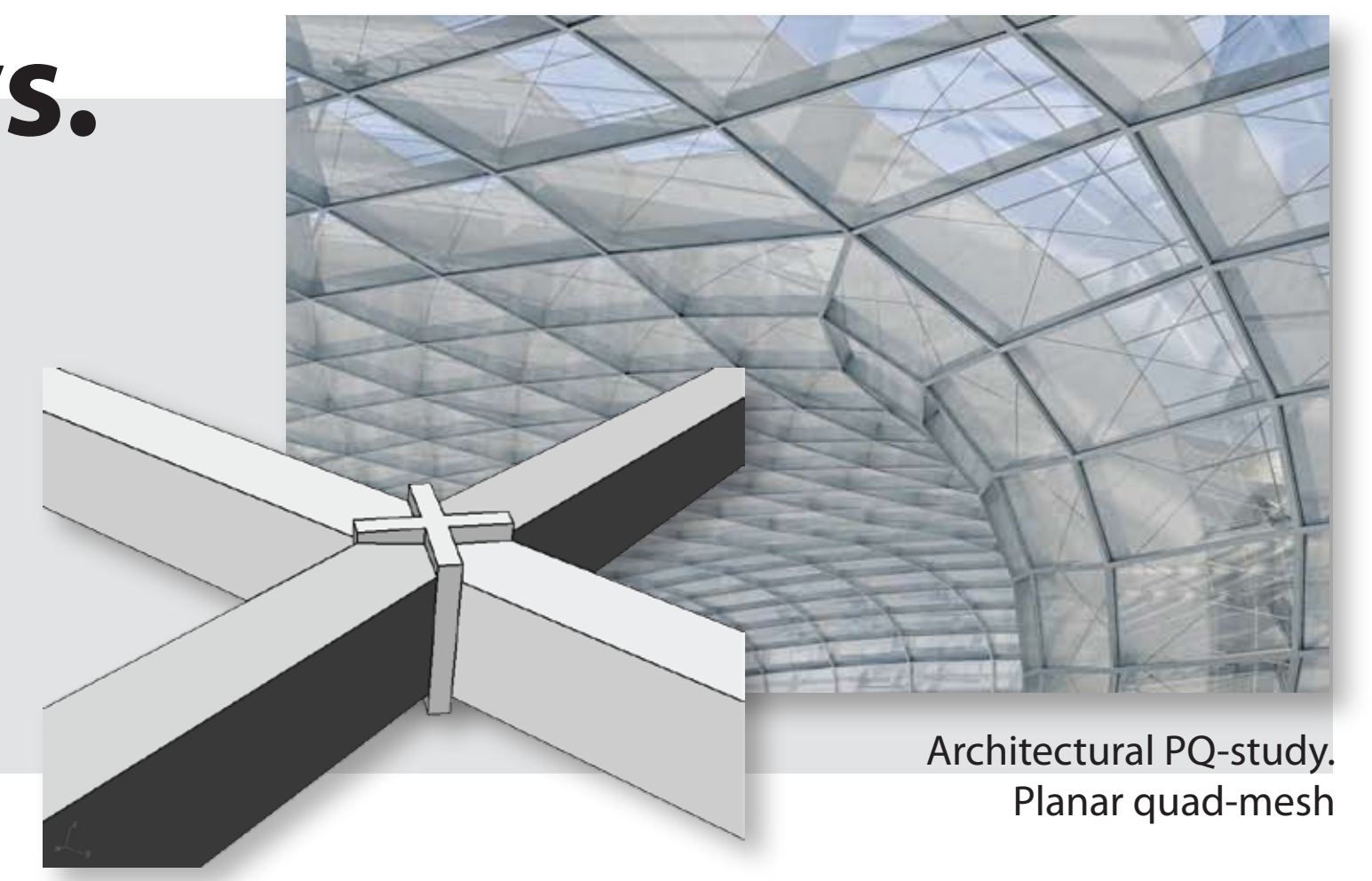
Architectural PQ-study.
Planar quad-mesh

BASIC PQ DESIGN

The Sage by Norman Foster, segmented by flat, trapezoidal panels of glass. Obtained by a simple geometric operation, approaches like this are insufficient for the design of arbitrary free-form shapes.
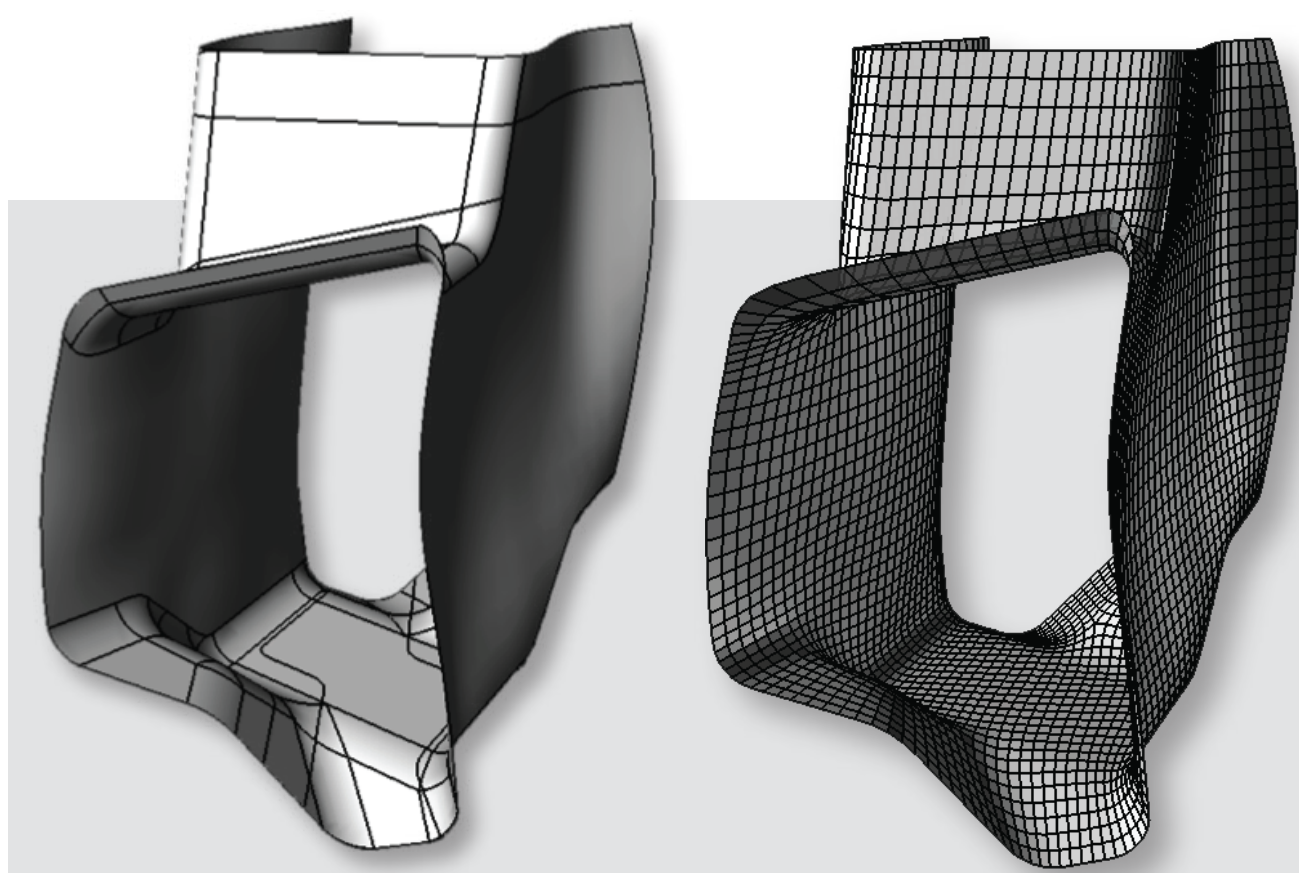

The Sage, Foster and Partners

Simple geometric
operation producing
perfect PQ-meshes

CONSTRAINTS Architectural conditions adressed by our design-approaches

VERTEX POSITIONS

Façade construction limitations as well as design intent may necessitate to constrain vertices to certain planes, e.g. floor slabs or symmetry planes. We have incorporated this into our optimization framework.

TORSION-FREE NODES

Symmetry planes of adjoining beams intersecting in one single line, the so-called 'vertex normal', will greatly enhance the buildability of nodes. While this cannot be guaranteed for triangular meshes, PQ meshes automatically offer this property.
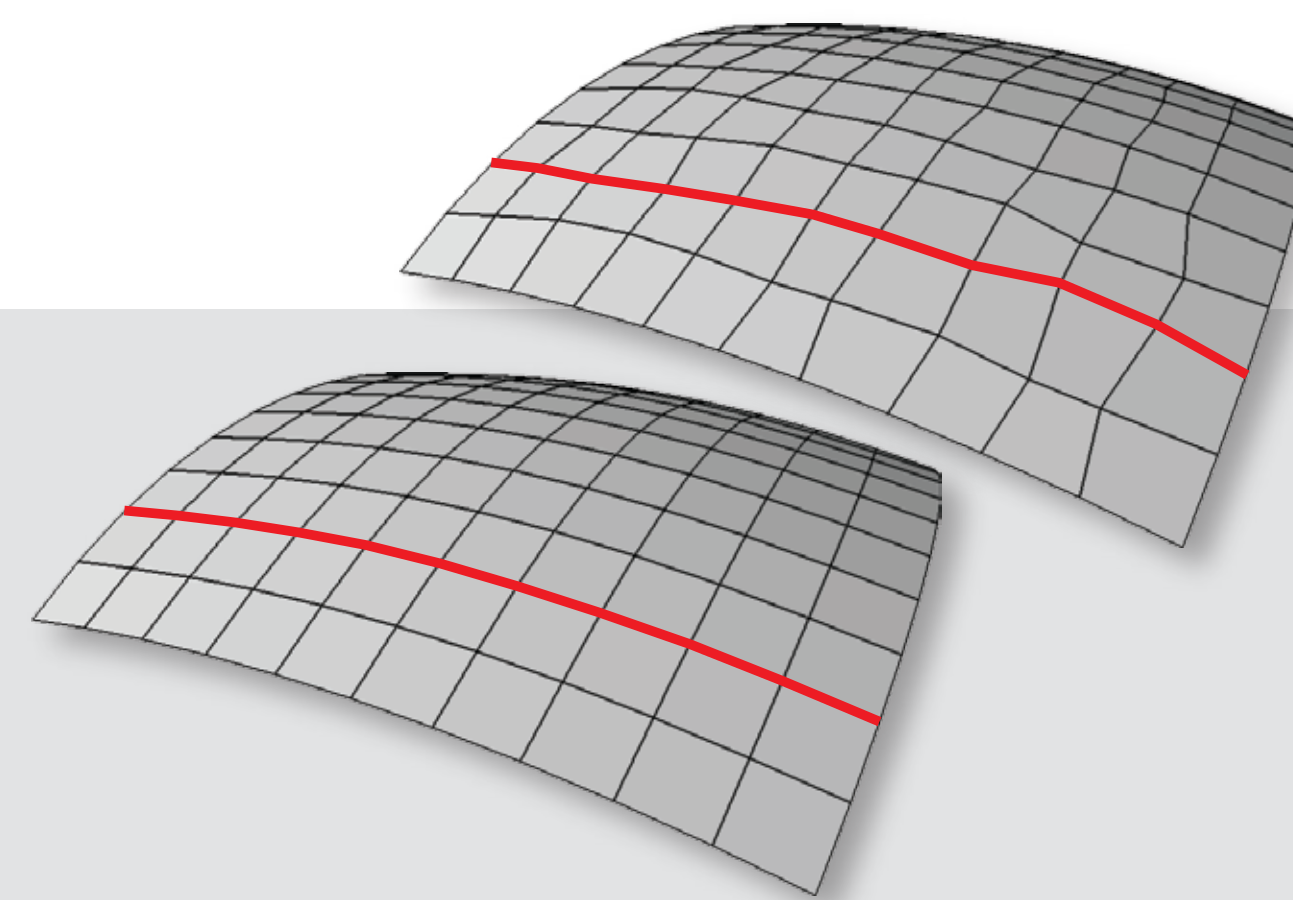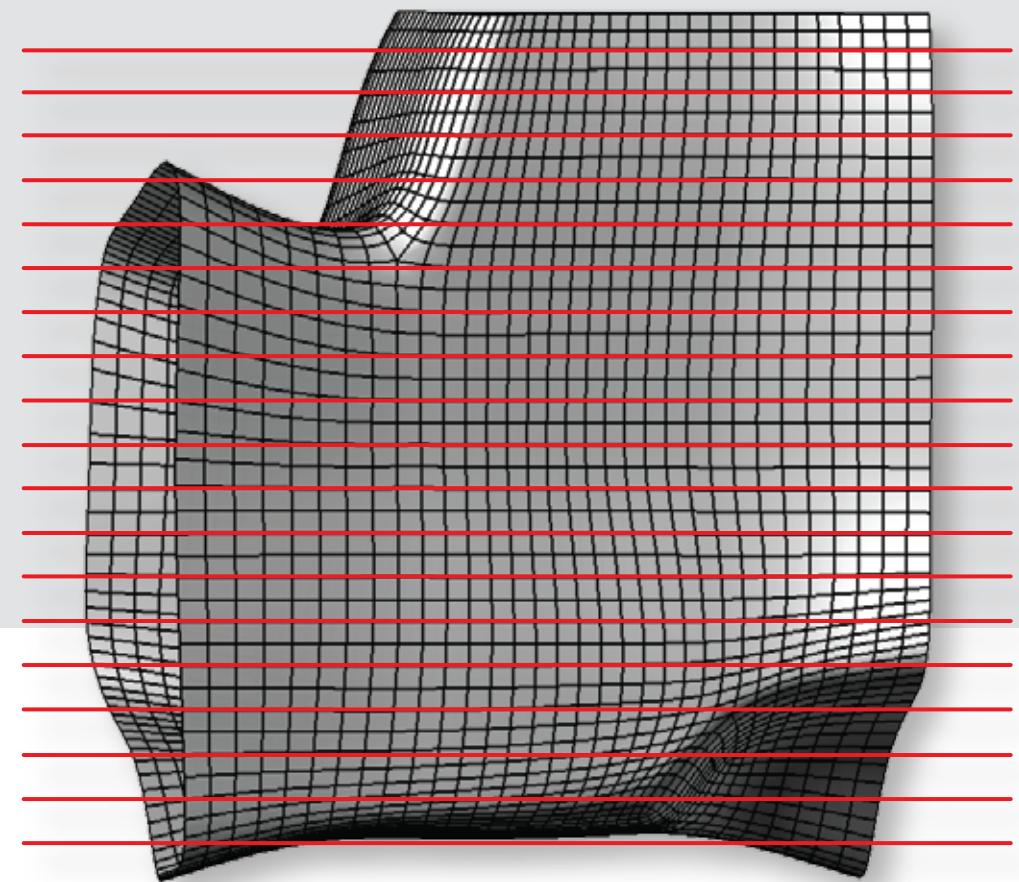
CLOSENESS TO DESIGN

In order to have a planar segmentation resemble the original freeform-design as good as possible, the closeness to a reference surface can be set as a side-condition of our optimization.
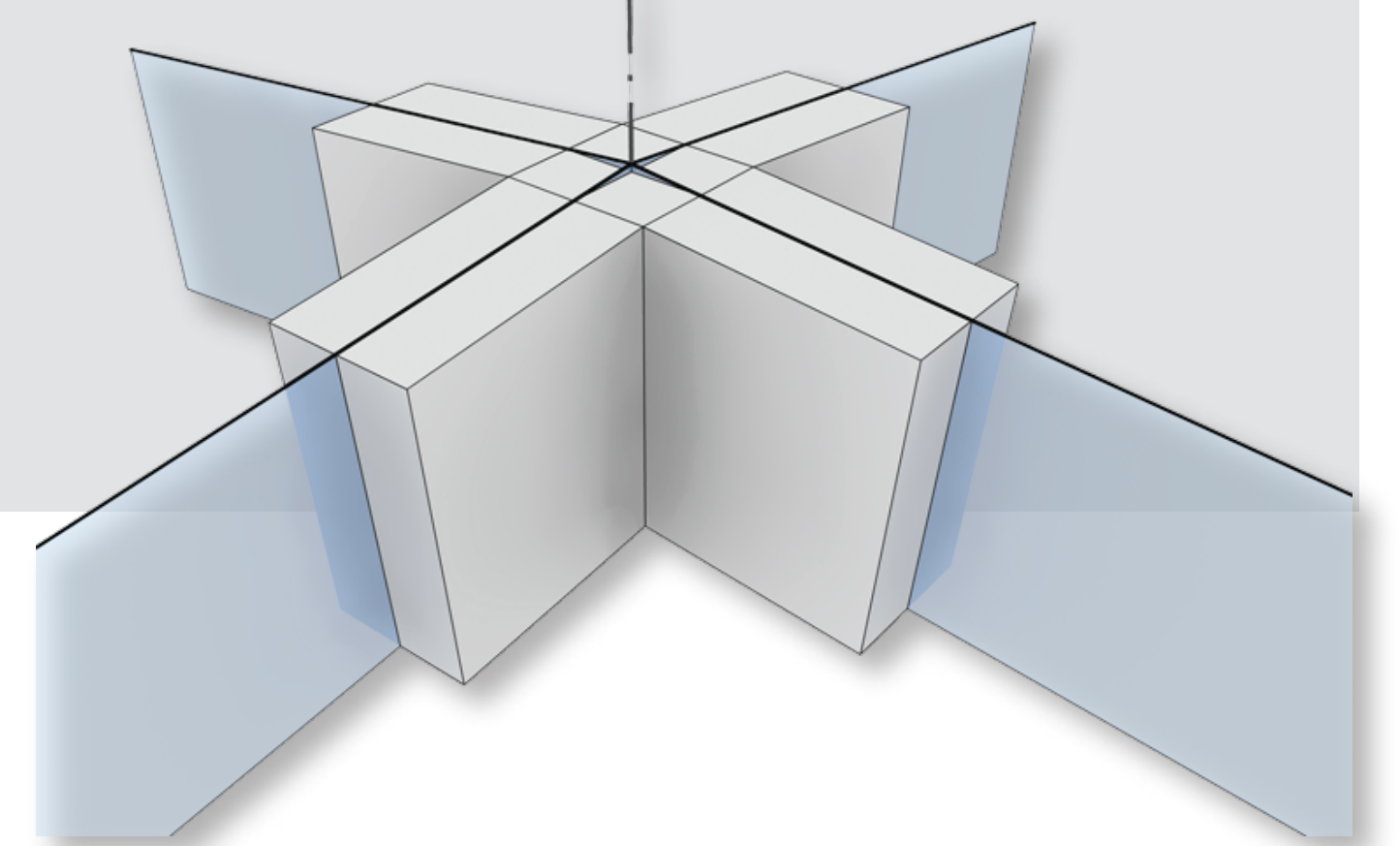
SYSTEM-LINE FAIRNESS

The look of polygons defined by successive edges ('system lines') of a quad mesh adds a lot to the perception of aesthetics of a façade structure. We account for that by accordingly weighting the fairness of these polygons in the optimization.

ADVANCED DESIGN STRATEGIES FOR PQ-MESHES

Panelization of ANY shape by a mesh of Planar Quads with respect to architectural and manufactural constraints
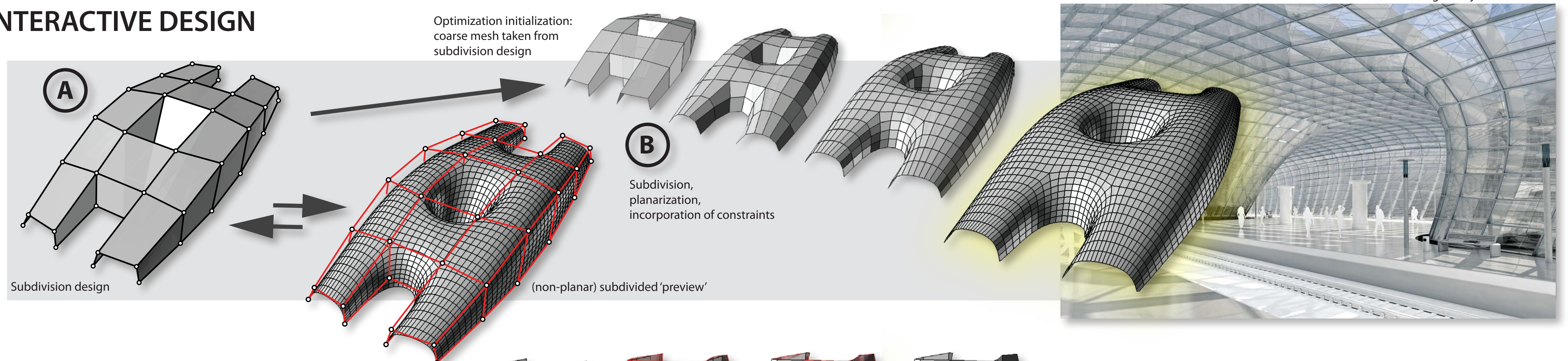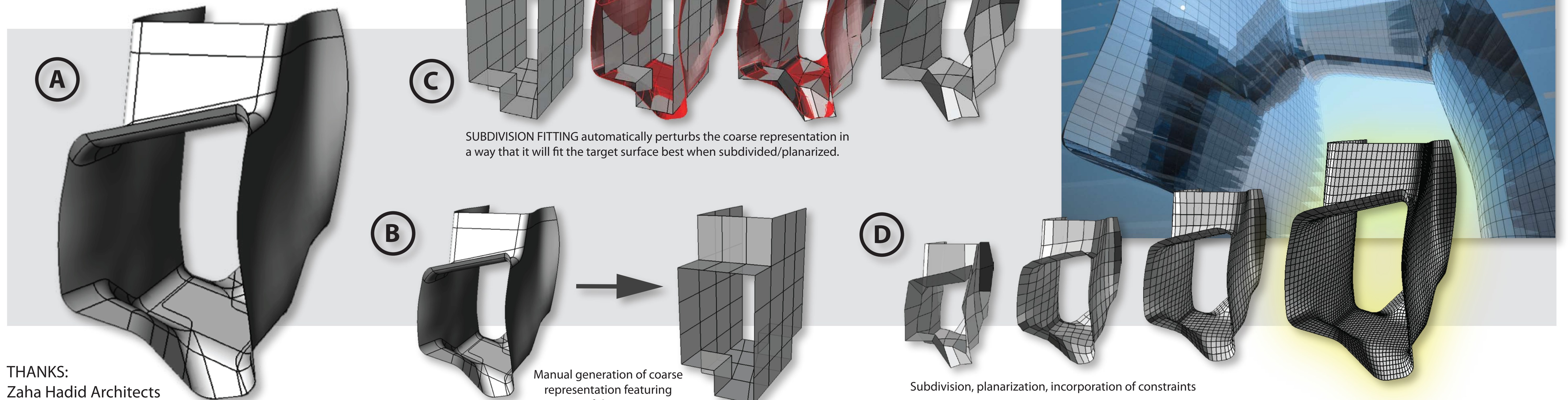
INTERACTIVE DESIGN

Image: Benjamin Schneider

A

Optimization initialization:
coarse mesh taken from
subdivision design

B

Subdivision,
planarization,
incorporation of constraints

Subdivision design

(non-planar) subdivided 'preview'

SURFACE REFITTING

General freeform-design
('The Opus', Zaha Hadid Architects)

Resulting planarized version of 'The Opus', inner view

A

C

SUBDIVISION FITTING automatically perturbs the coarse representation in a way that it will fit the target surface best when subdivided/planarized.

B

Manual generation of coarse
representation featuring
meaningful connectivity

D

Subdivision, planarization, incorporation of constraints

REFERENCES:
BRELL-COKCAN, S. AND POTTMANN, H. Tragstruktur für Freiformflächen in Bauwerken. Patent Nr. AT 503.021, PCT/AT2007/000302.
LIU, Y., POTTMANN, H., WALLNER, J., YANG, Y. AND WANG, W. 2006. Geometric Modeling with Conical Meshes and Developable Surfaces. ACM Trans. Graphics 25, 3, 681-689.
POTTMANN, H., BRELL-COKCAN, S. AND WALLNER, J. 2006. Discrete Surfaces for Architectural Design. Curves and Surface Design: Avignon 2006.

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