Efficient computer models for use in textile architecture

technet gmbh

Juergen Holl

Dieter Stroebel

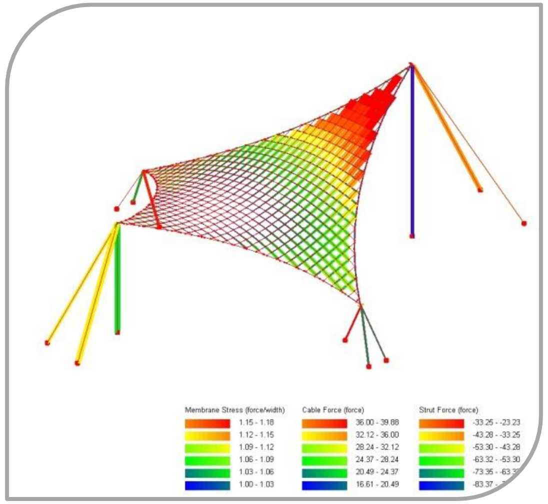
Peter Singer

Bernhard Simmler

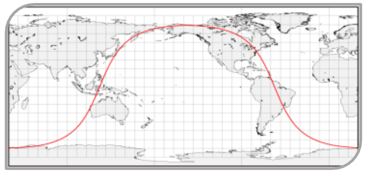
Ulrike Gruendig-Tsoukalas

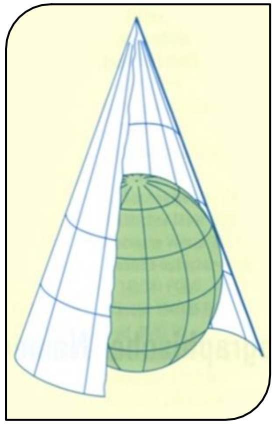
Company profile

technet gmbh



Who we are





Company profile

technet GmbH
gründig + partner

Founded: 1989

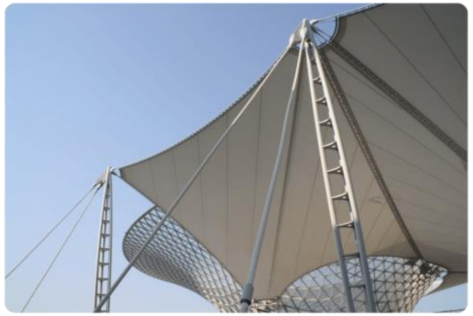
Germany: Berlin - Stuttgart
China: Shanghai

www.technet-gmbh.com

Easy program system:

Easy.Form:	Formfinding
Easy.Static:	Statics
Easy.Cut:	Cutting Patterns

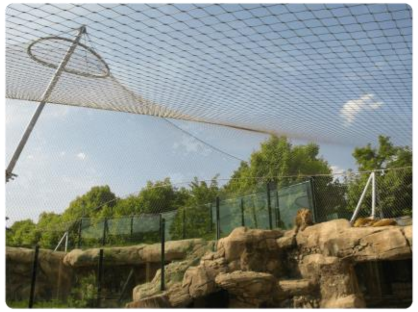
Company profile - Customer projects









Customers' requirements

technet gmbh

What we as software developers have observed in recent years:

- Projects are becoming increasingly complex

Customers expect models that achieve certain goals or tasks with minimal effort or resource consumption

→ Efficient models

- Most accurate and complete formulation
- Highly accurate results

Efficient models – Examples in different areas

technet gmbh

Efficient geometric models

- Accurate representation of the relevant aspects of the system
- Minimum number of variables and parameters

$$p_x = \frac{F_a}{l_a} \cdot (x_m - x_i) + \frac{F_b}{l_b} \cdot (x_j - x_i) + \frac{F_c}{l_c} \cdot (x_k - x_i) + \frac{F_d}{l_d} \cdot (x_l - x_i)$$

$$p_y = \frac{F_a}{l_a} \cdot (y_m - y_i) + \frac{F_b}{l_b} \cdot (y_j - y_i) + \frac{F_c}{l_c} \cdot (y_k - y_i) + \frac{F_d}{l_d} \cdot (y_l - y_i)$$

$$p_z = \frac{F_a}{l_a} \cdot (z_m - z_i) + \frac{F_b}{l_b} \cdot (z_j - z_i) + \frac{F_c}{l_c} \cdot (z_k - z_i) + \frac{F_d}{l_d} \cdot (z_l - z_i)$$

Efficient mechanical models

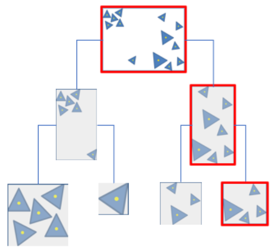
- Relevant physical laws and principles
- Simple enough to be practically applicable.

$$\begin{bmatrix} \sigma_u \\ \sigma_v \\ \tau \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & 0 \\ m_{21} & m_{22} & 0 \\ 0 & 0 & m_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_u \\ \varepsilon_v \\ \Delta\alpha \end{bmatrix}$$

$$m_{12} = m_{21}$$

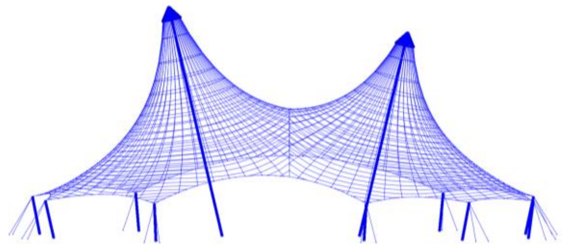
Efficient computer models

- Fast algorithms
- Little memory requirement
- Accurate results



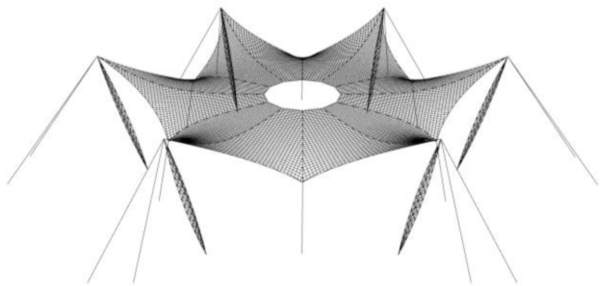
Model Generation – Geometric description

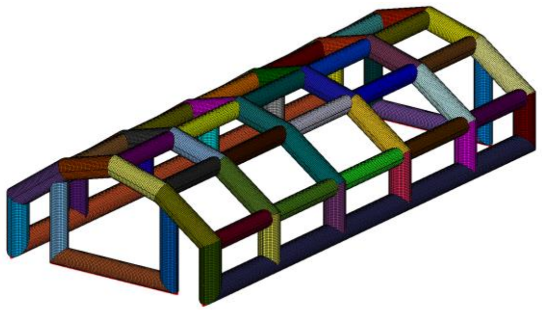
What kind of models are we talking about here?

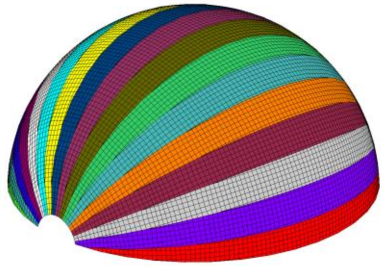


Discretised surface and boundary representation using points, edges and triangles.

→ The discrete description can also be derived from a continuous surface description.







Model Generation – Mechanical description

In general, we define for textile membranes

- Warp- and weft stiffness
- Crimp stiffness
- Shear stiffness

$$\begin{bmatrix} \sigma_u \\ \sigma_v \\ \tau \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & 0 \\ m_{21} & m_{22} & 0 \\ 0 & 0 & m_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_u \\ \varepsilon_v \\ \Delta\alpha \end{bmatrix}$$

$$m_{12} = m_{21}$$

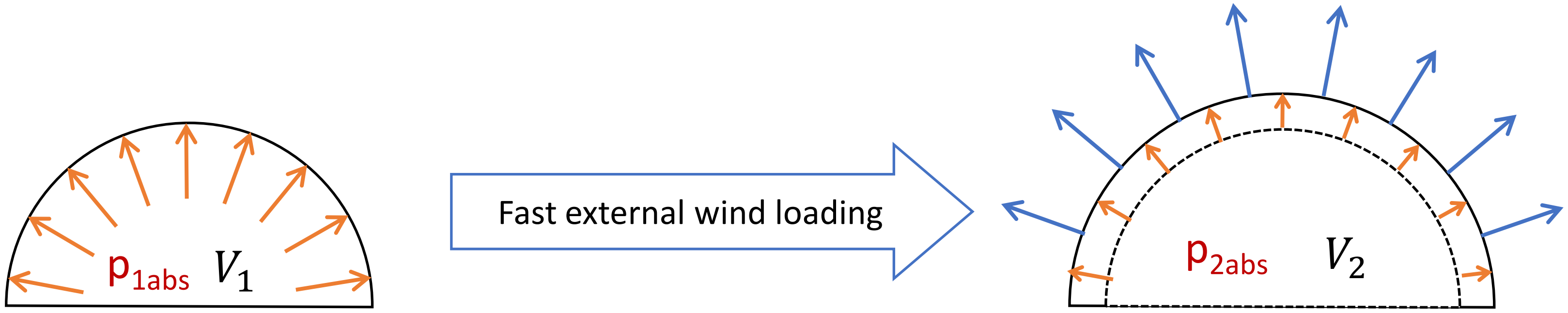
σ_u:	Stress in direction 1
σ_v:	Stress in direction 2
τ:	Shear stress
m_{12}:	Membrane crimp stiffness
m_{11}:	Membrane stiffness in direction 1
m_{22}:	Membrane stiffness in direction 2
m_{33}:	Membrane shear stiffness
ε_u:	Strain in direction 1
ε_v:	Strain in direction 2
$\Delta\alpha$:	Shear deformation

Model Generation – Mechanical description

technet gmbh

Additional boundary conditions must be fulfilled for pneumatic structures:

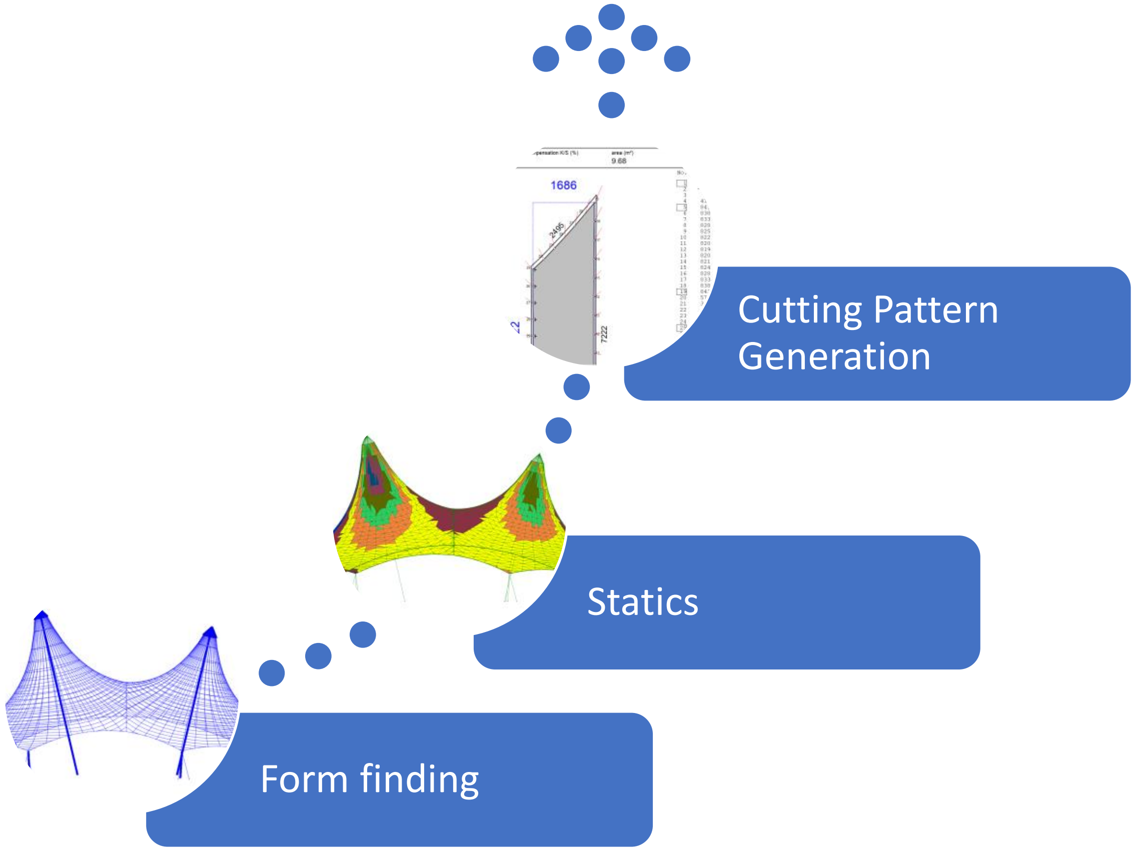
- A given internal pressure or volume must be maintained
- Consideration that internal pressure loads are non-conservative
- For certain load cases, the Gas Law must be applied



$$p_{1abs} \cdot V_1 = p_{2abs} \cdot V_2$$

Effective Models – Examples

technet gmbh



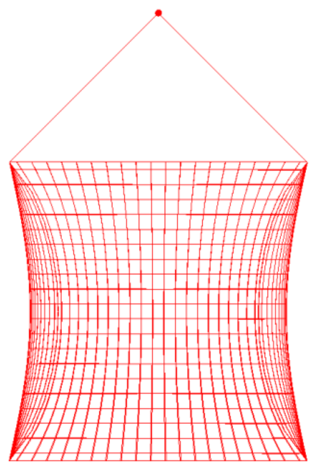
1. Buoyancy loads
2. Sliding supports/Sliding cables
3. Digital wind tunnel
4. Equidistant cable nets
5. Data structures
6. Kink points

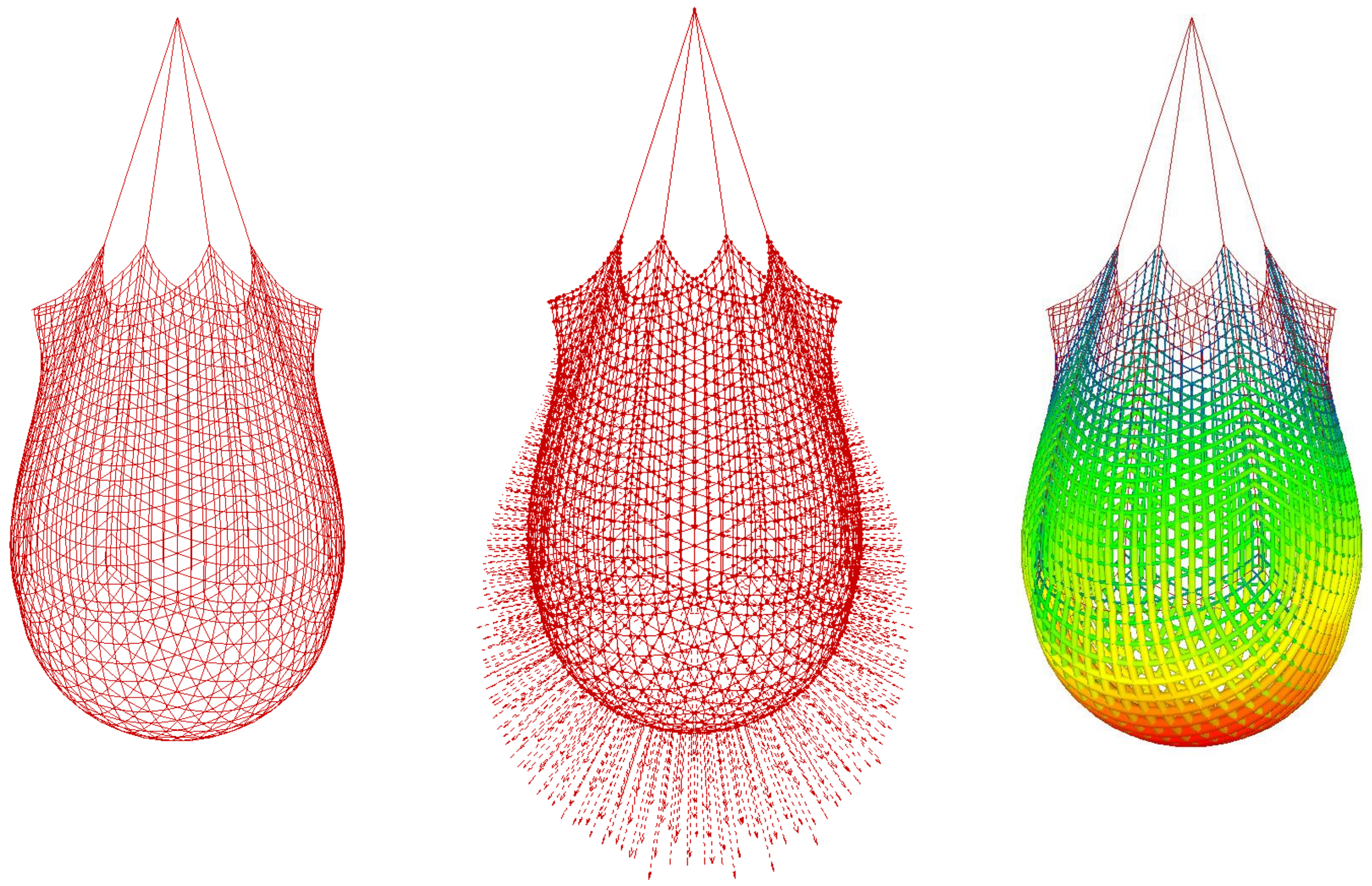
Buoyancy loads I

Example waterbag:

- Water bag completely filled
- Non conservative area loads
- No contact

Start situation:

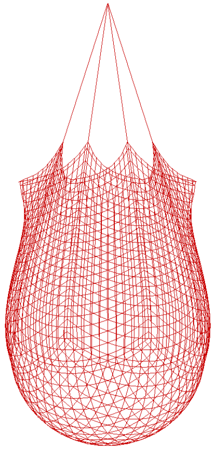
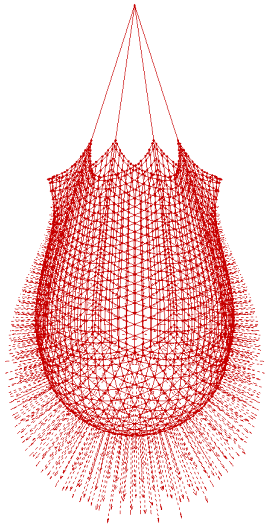
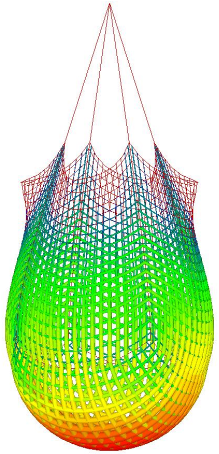




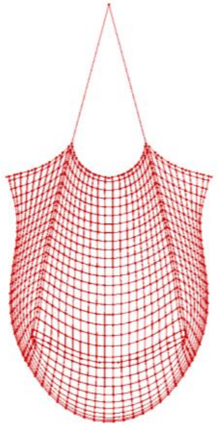
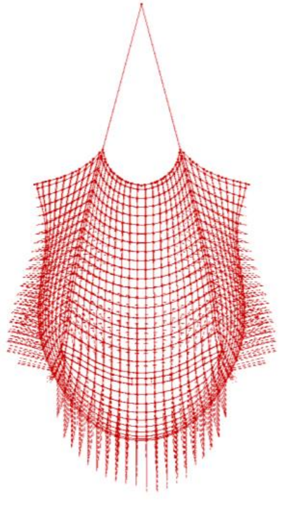
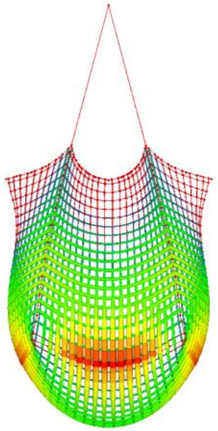
Buoyancy loads I

Example waterbag

→ Non conservative area loads

→ Conservative area loads

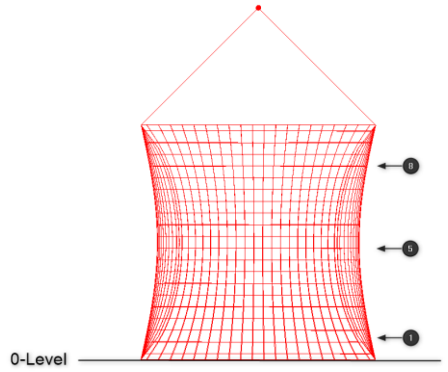




Buoyancy loads II

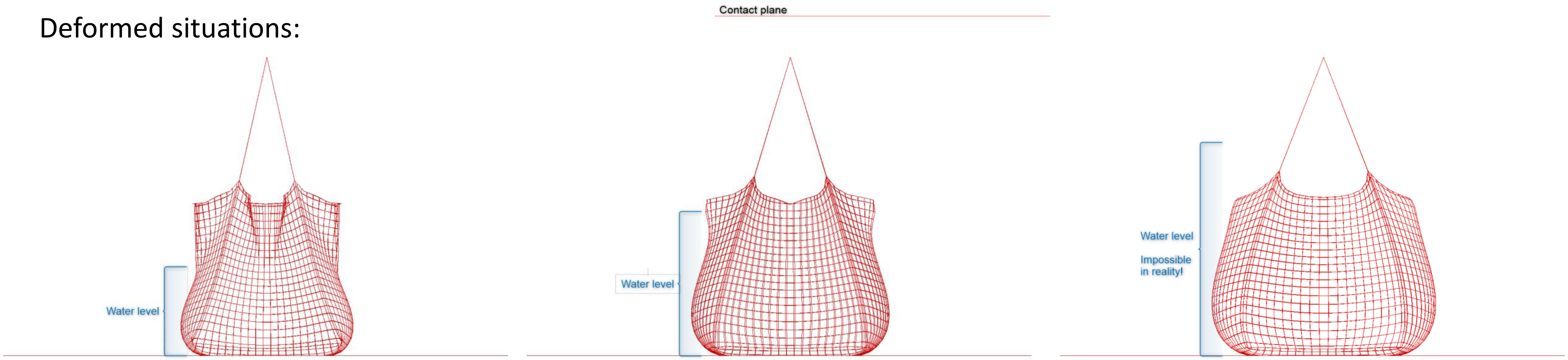
Example waterbag:

- Fixed water levels
- Non conservative area loads
- Contact

Start situation:



Deformed situations:

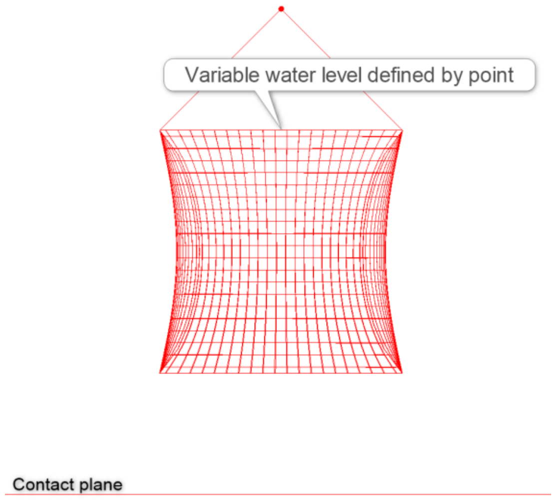


Buoyancy loads II

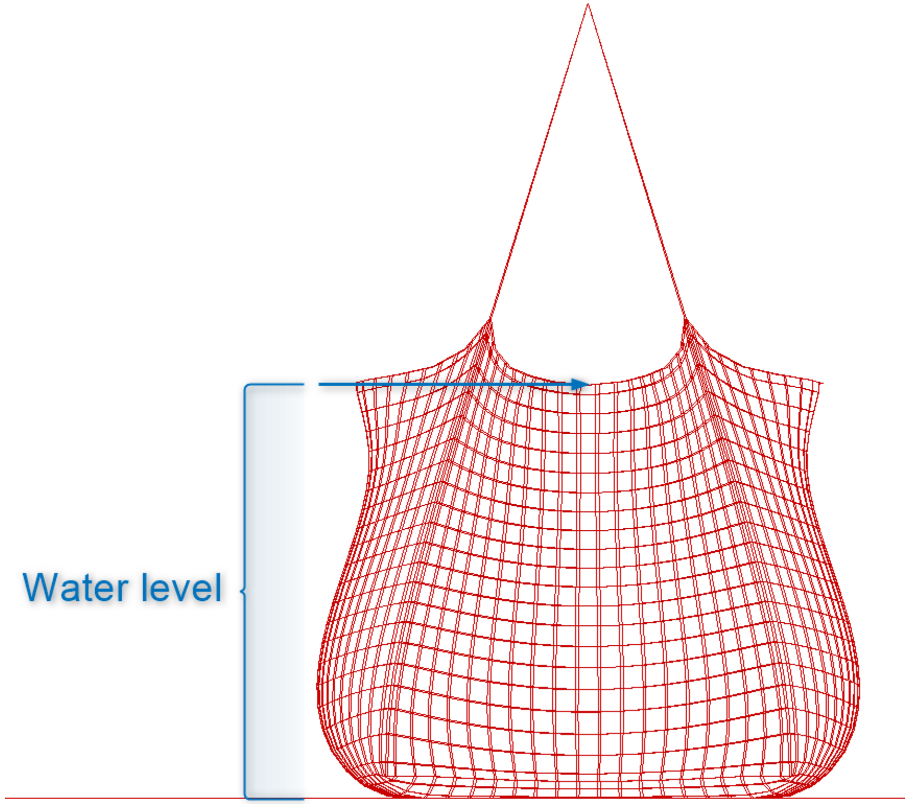
Example waterbag:

- Variable water level defined by point
- Non conservative area loads
- Contact

Start situation:



Deformed situation:

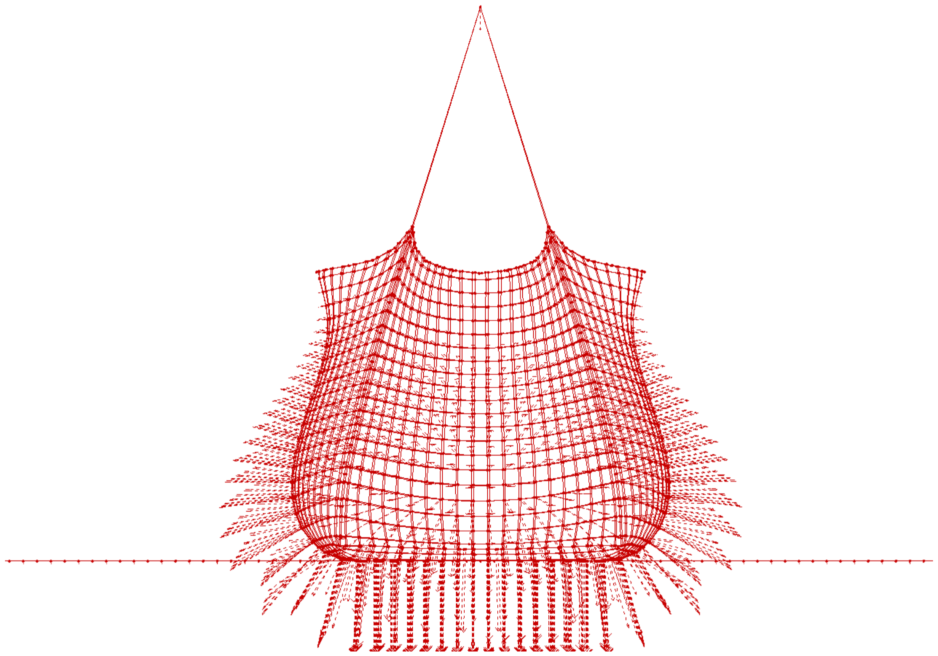


Buoyancy loads II

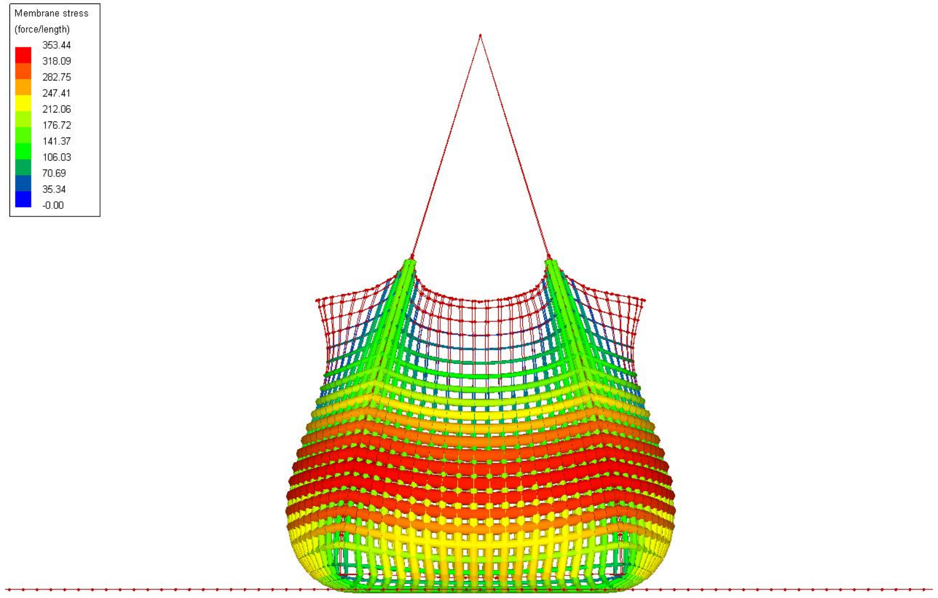
technet gmbh

Example waterbag:

Calculation method → Non conservative area loads



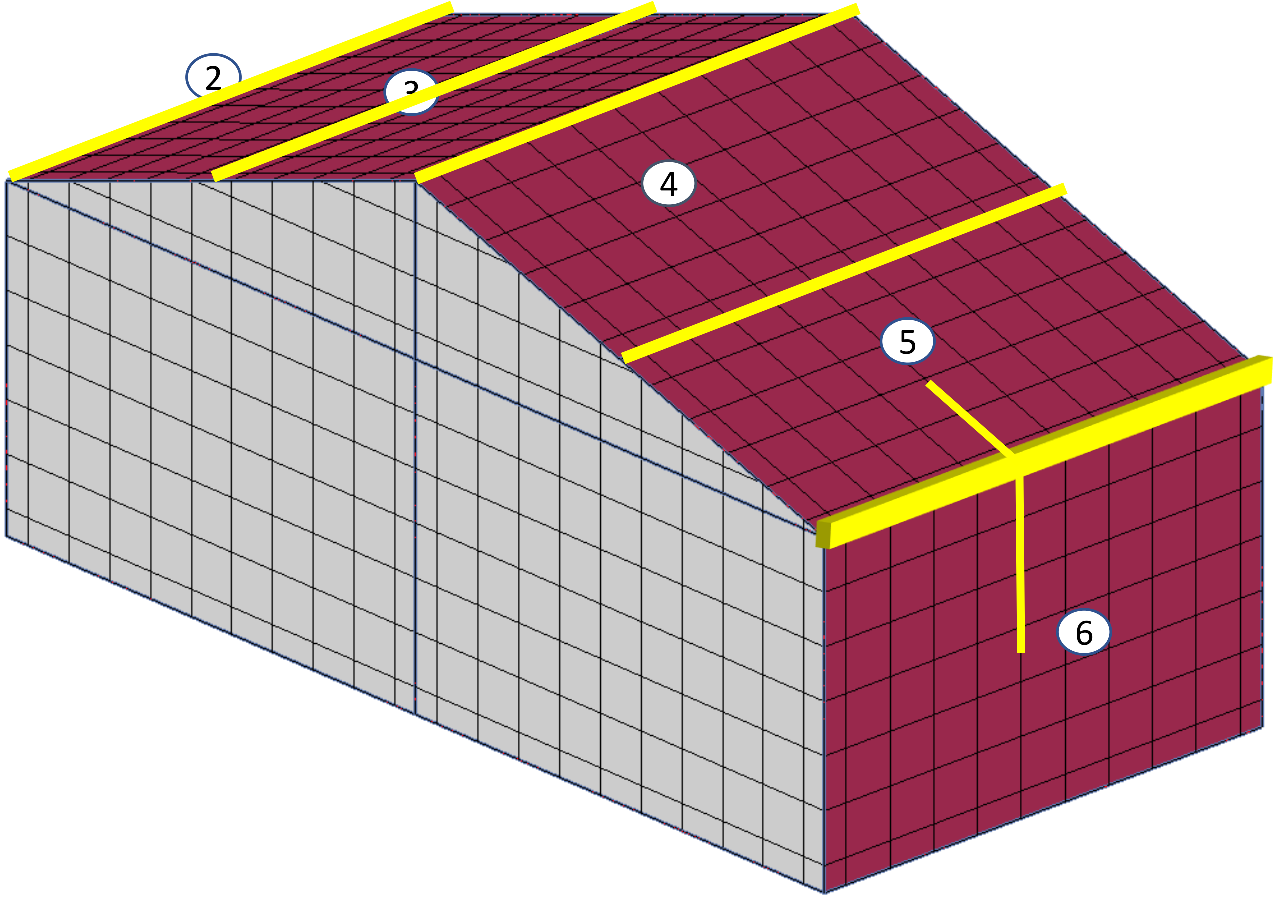
External loads: Self weight + Buoyancy



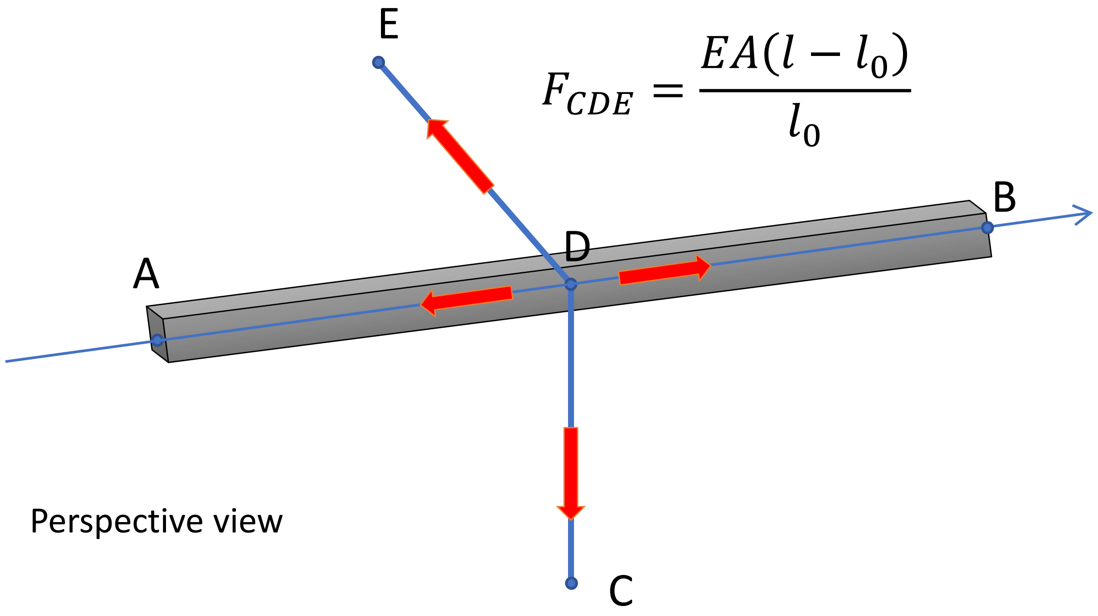
Membrane stress

Sliding supports

Individual membrane fields are acting as one piece of membrane



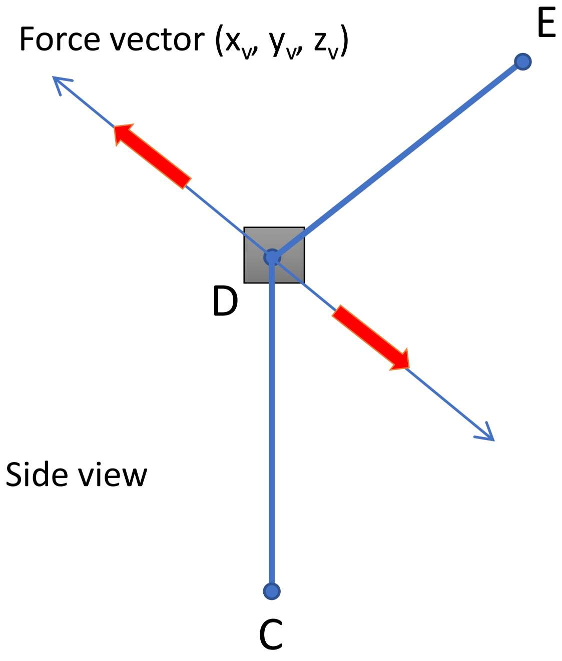
Sliding supports



Perspective view

- 1 element: C-D-E: l_0, EA, q, x_v, y_v, z_v
- Force in DE and CD is the same.
- Length DE and length CD can be different and can change.
- Total length C-D-E is always the same.
- Element slides over the free point D in „horizontal“ and „vertical“ direction.
- Sliding in „horizontal“ direction can be disabled by user.

Sliding supports



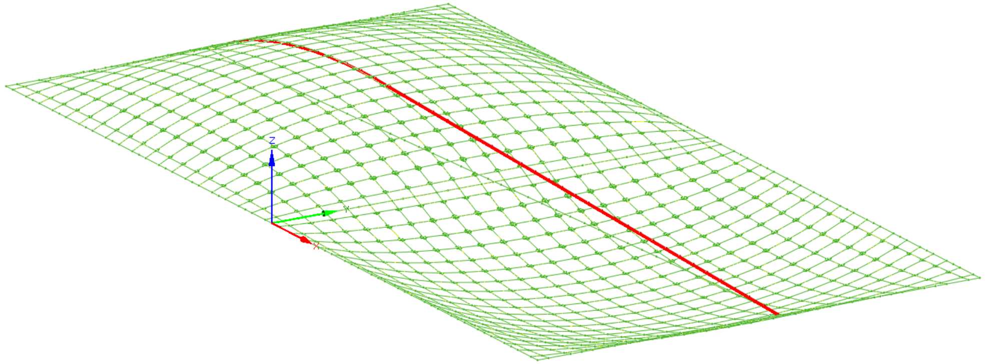
„Intelligent" supports:

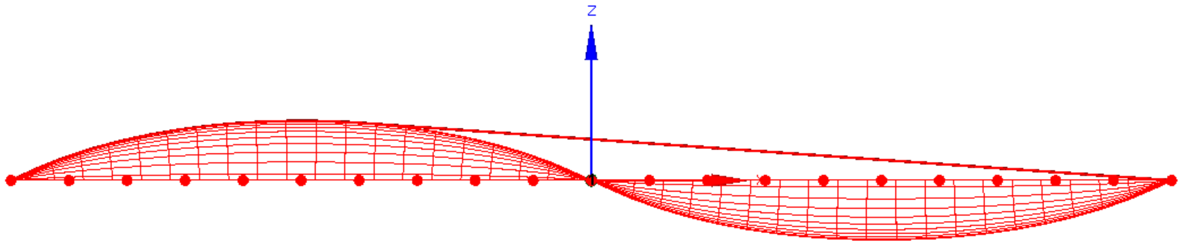
Force vector decides: Lift off or pressure

Sliding cables

Sliding Cables are used as reinforcements for the membrane structures.

- Free
- Fixed in a pocket



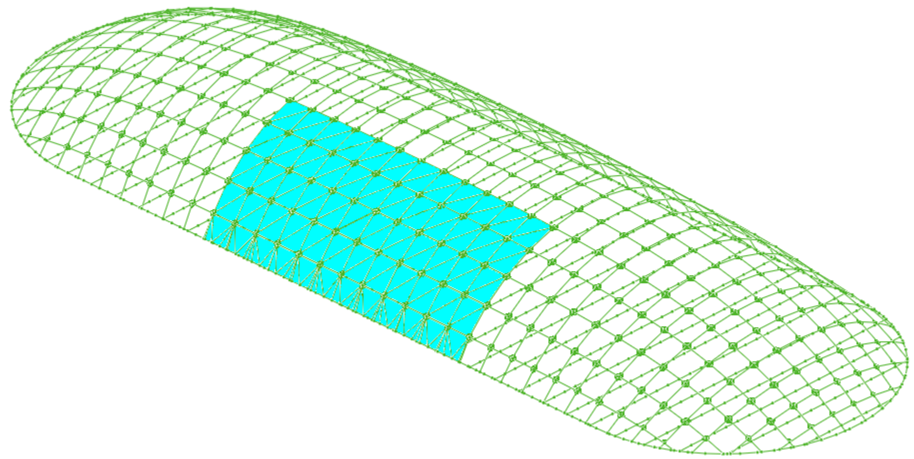


Free sliding cables

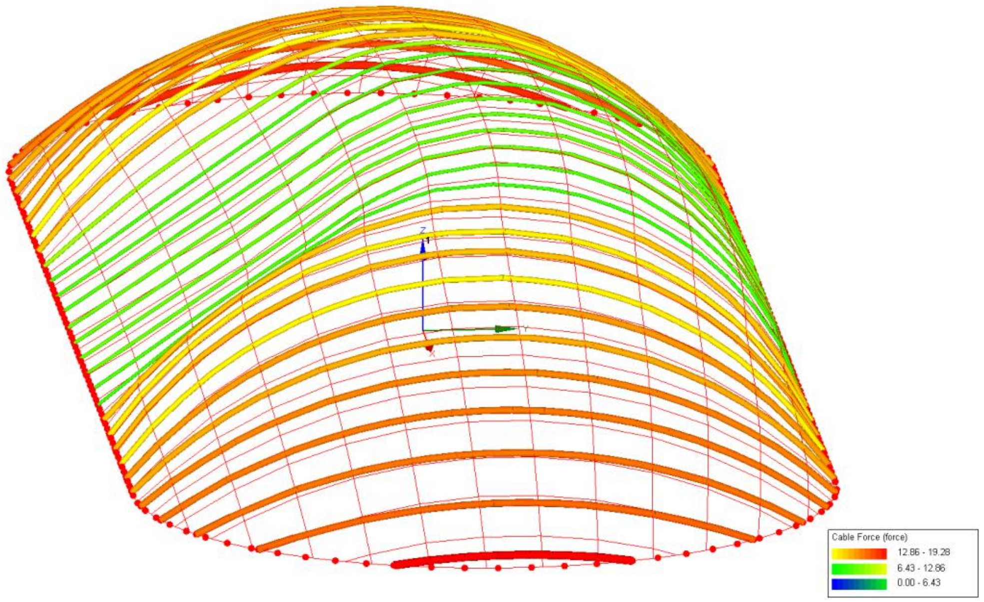
technet gmbh

Sliding Cables lift up from the membrane under wind loads.

Airhall under operating pressure.

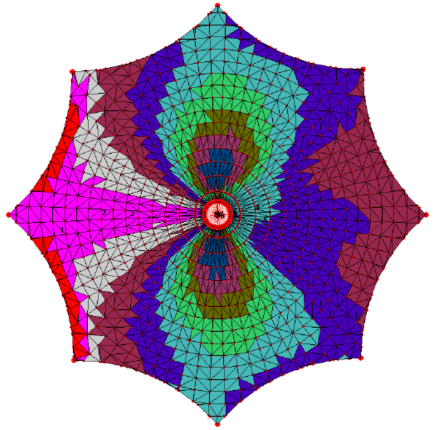


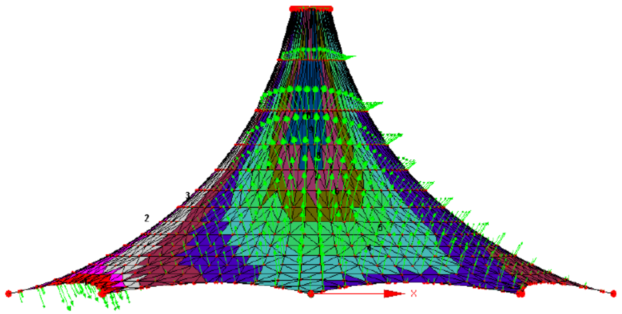
Airhall under maximum windloads.



Digital Wind Tunnel

- Import of geometries using the file formats EIN and DRE
- One analyze geometry and any number of additional geometries for additional building parts and surroundings
- Rotation of geometry to analyze different wind directions
- Automatic sizing of the tunnel
- Turbulence models: k-epsilon, k-omega, k-omega SST
- Height dependent wind profiles
- Output of c_p values and load zones or load vectors
- Graphical analysis of the results with the tool ParaView





Equidistant cable nets

technet gmbh

Which meshes are we talking about here:

→ Equidistant quadrilateral nets

This type of net has optimal properties in terms of spatial shapes:

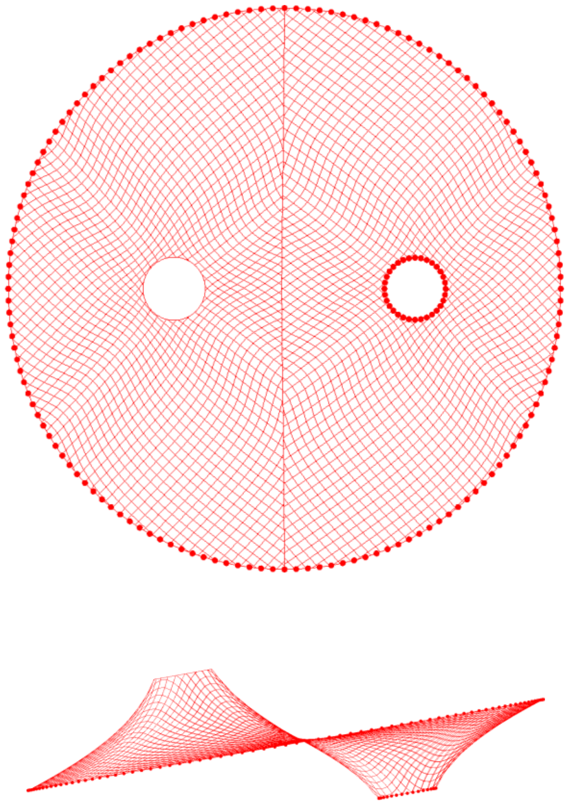
- It can adapt to a curved surface without tension by changing the mesh angle.
- It ideally fulfils the economical construction of complicated cable net constructions.

  Prefabrication → Cheaper production → Easier assembly

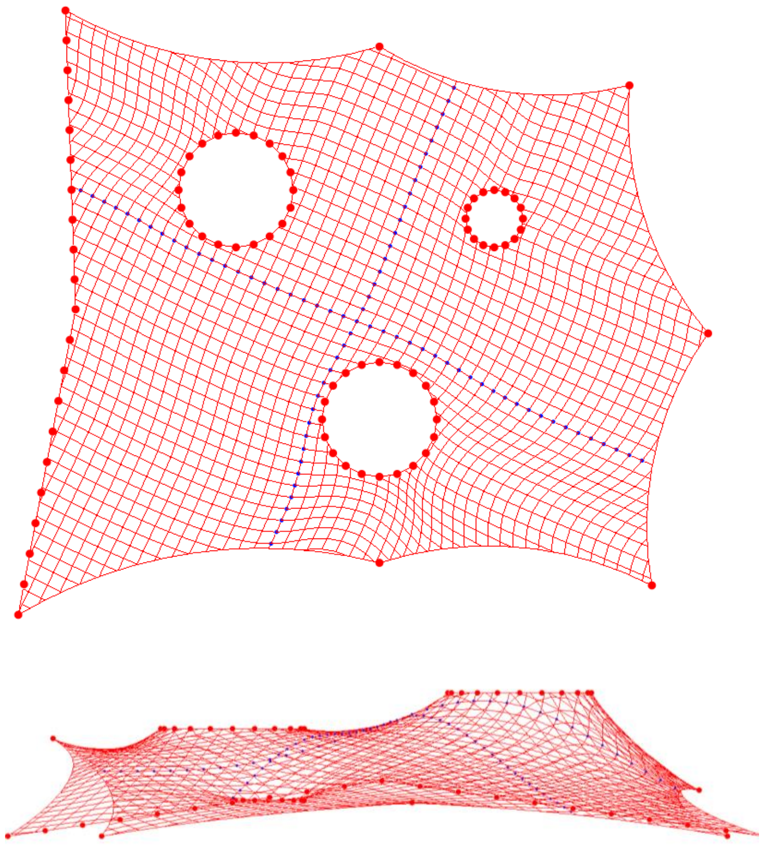
Images: Hans Schober, Form, Topologie, Tragwerk

Generating equidistant meshes – Examples

technet gmbh



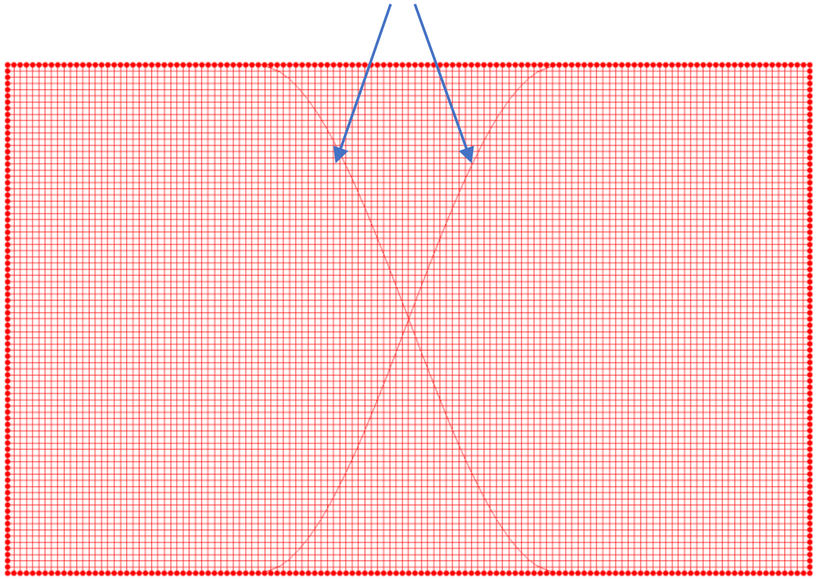
Playground structures

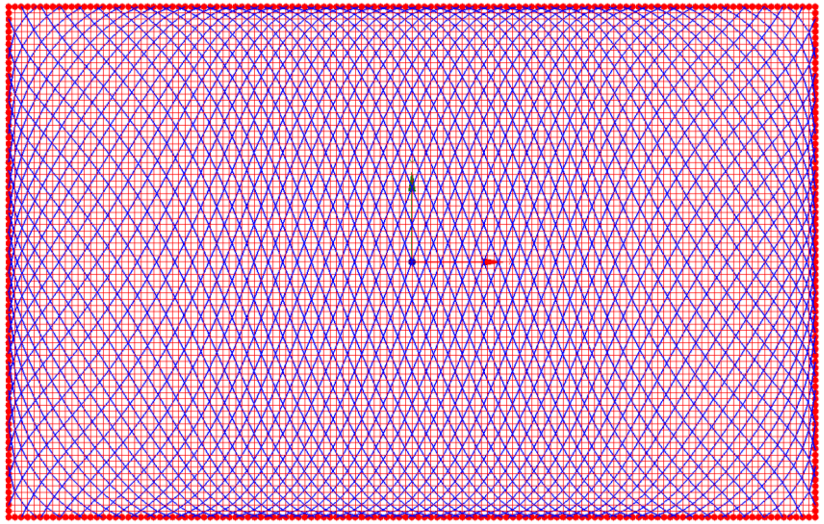


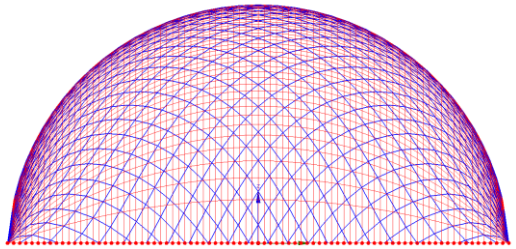
Large-area nets

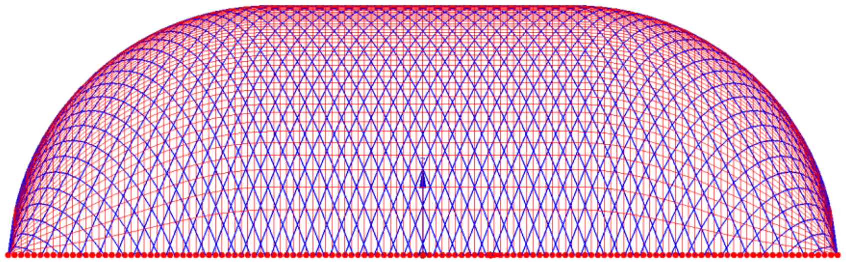
Generating equidistant meshes – Example gasholder

Big gas holder with equidistant cable mesh
The guidelines were 2 geodesic lines



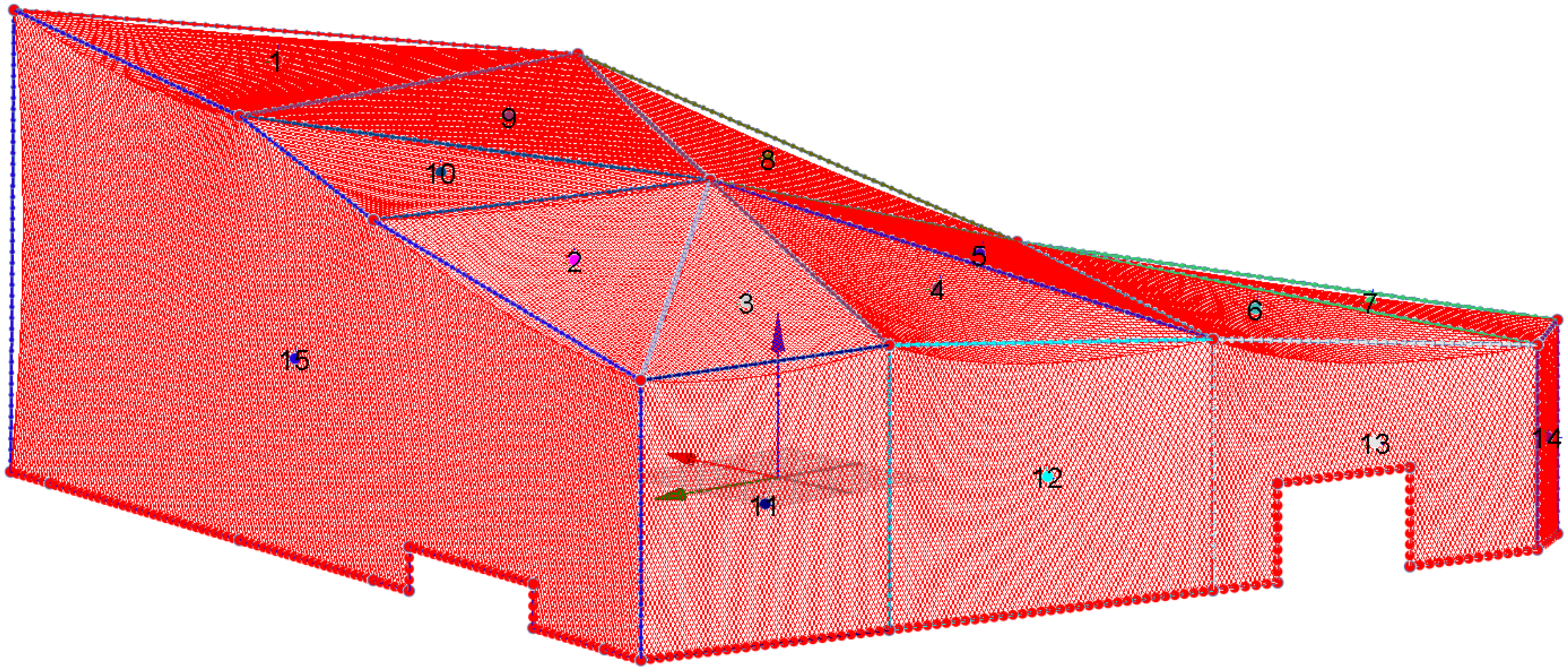






Generating equidistant meshes – Example cage

technet gmbh

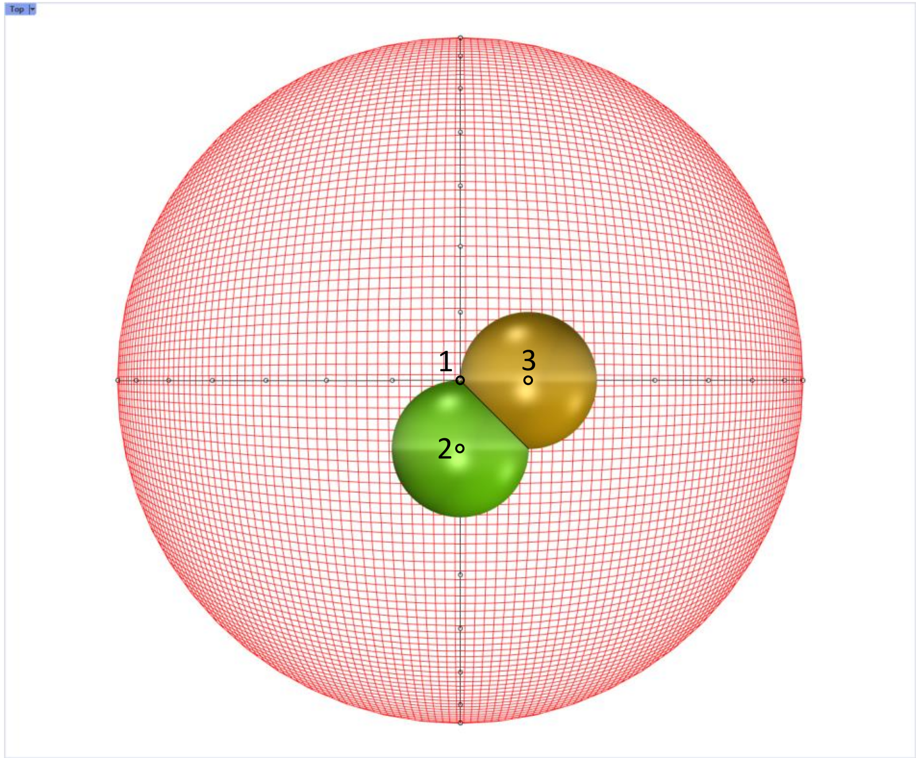


Large cages:

- Very large data volume
- Specialized algorithms are needed

Generating equidistant meshes - Algorithms

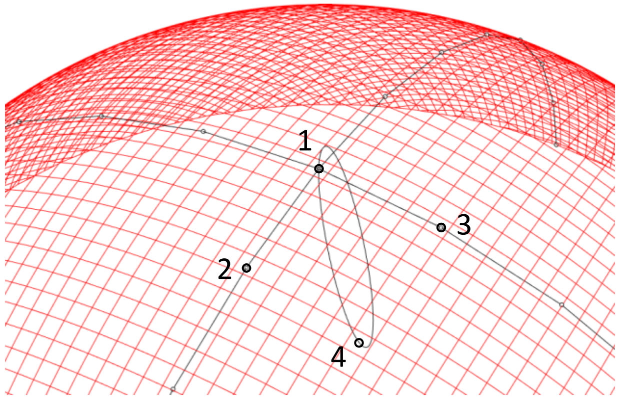
Spheres are included at positions 2 and 3. The radius of the spheres is as large as the desired mesh size.

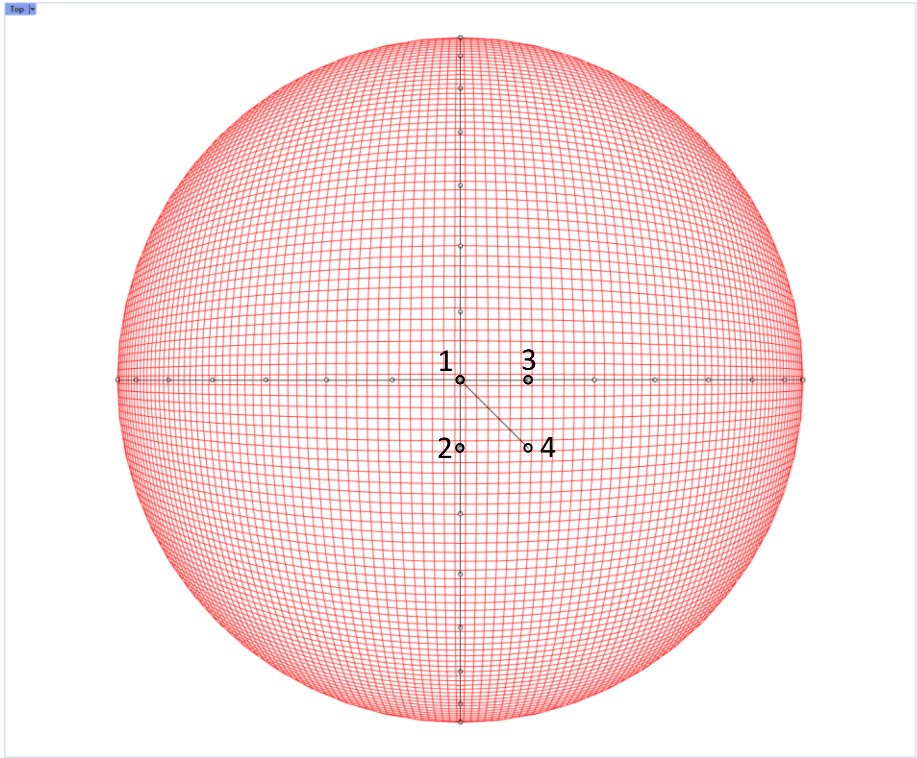


Generating equidistant meshes - Algorithms

The intersection between 2 spheres is a circle.

The intersection of the circle with the triangular surface of the base surface is the new mesh point (4)



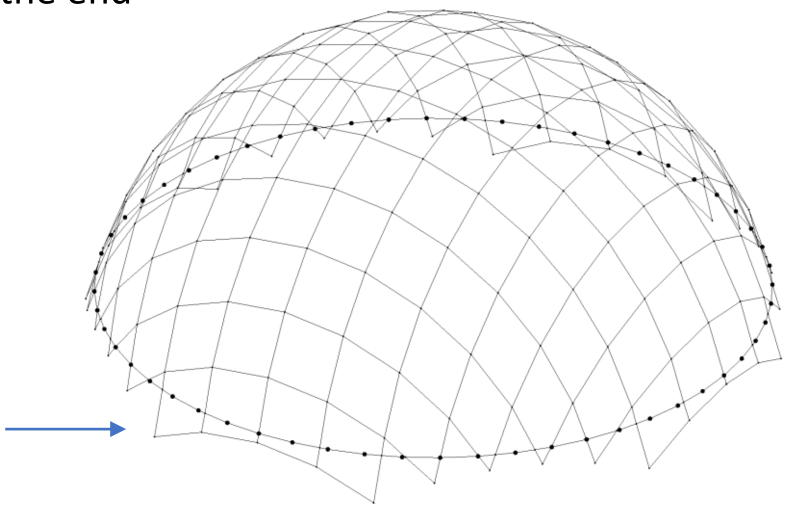


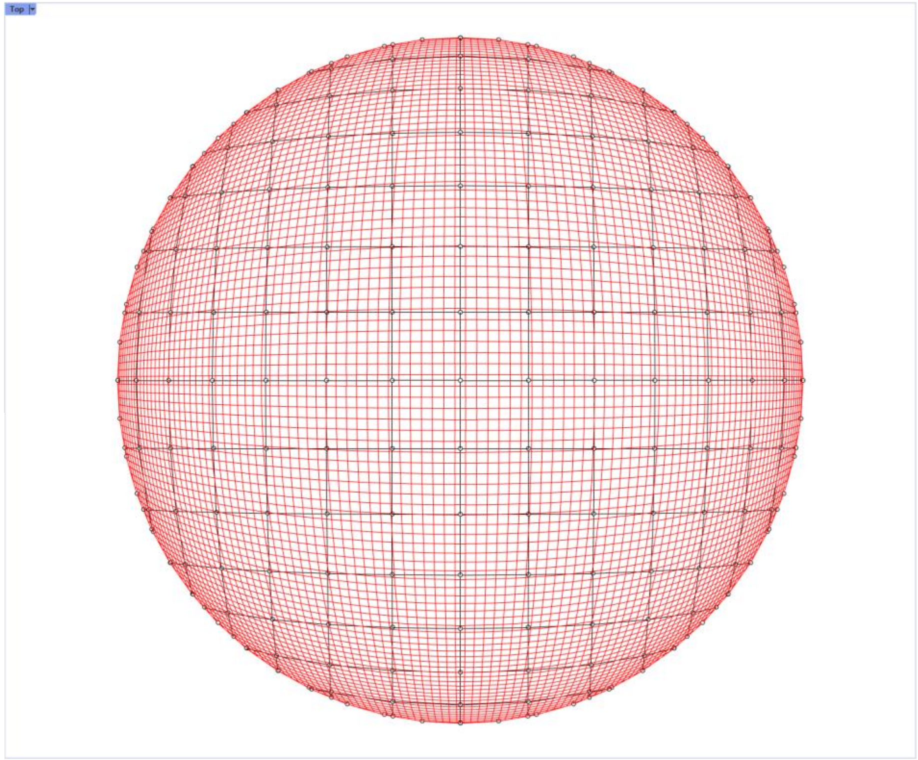
Generating equidistant meshes - Algorithms

The procedure is now applied to all points of the guidelines and the newly created mesh points.

This is how the equal-meshed discrete mesh is created.

The new equidistant mesh must be cut with the edge at the end



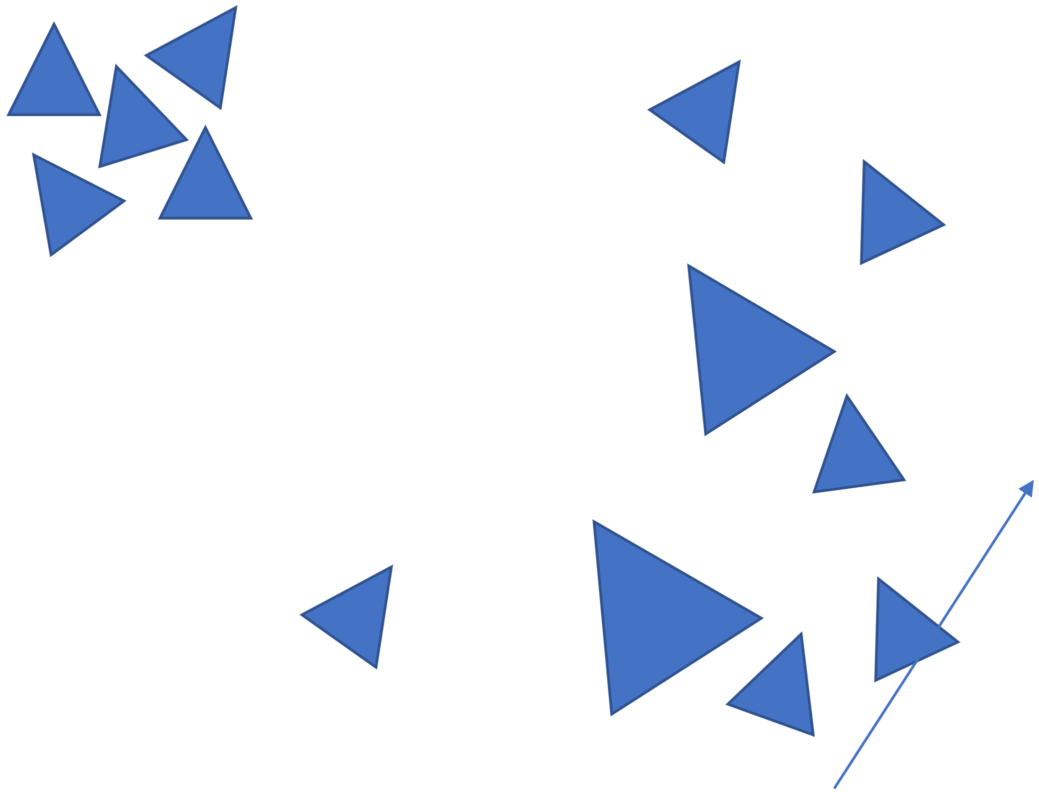


Fast generating equidistant meshes with acceleration structures

Used acceleration structure: **B**oundary **V**olume **Hierarchy** (BVH)

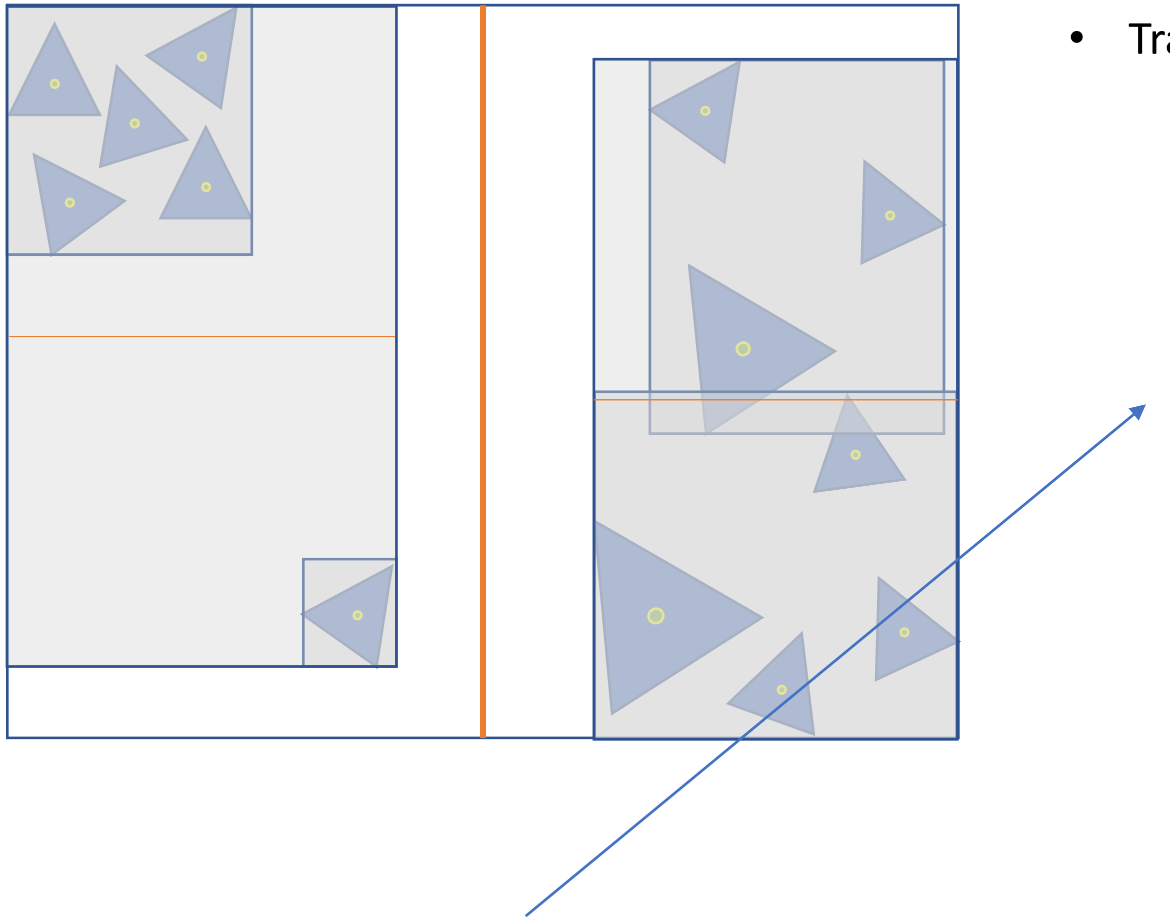
A BVH structure helps to decide very quickly which triangular elements of the surface are intersected by a given ray (circle) and which are not.

Principle:

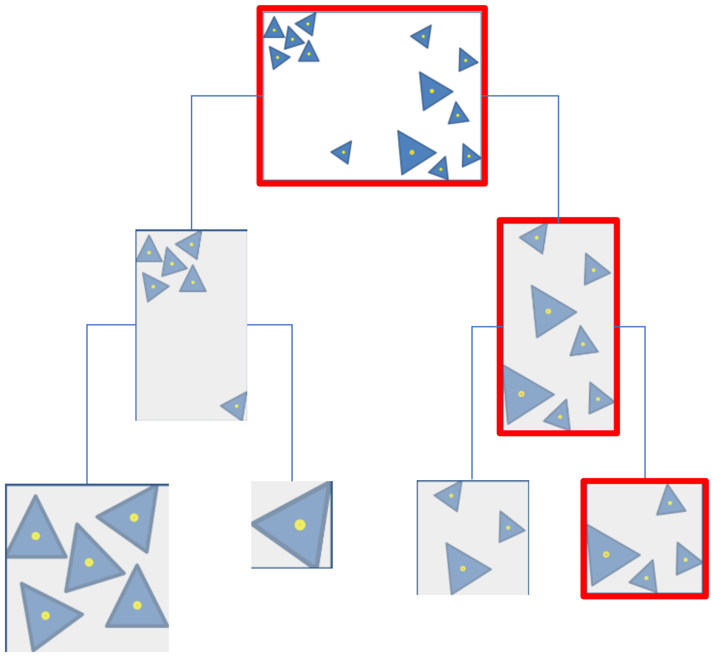


Fast generating equidistant meshes with acceleration structures

technet gmbh



- Traversing the bvh



4 Triangles are to be checked for intersection.

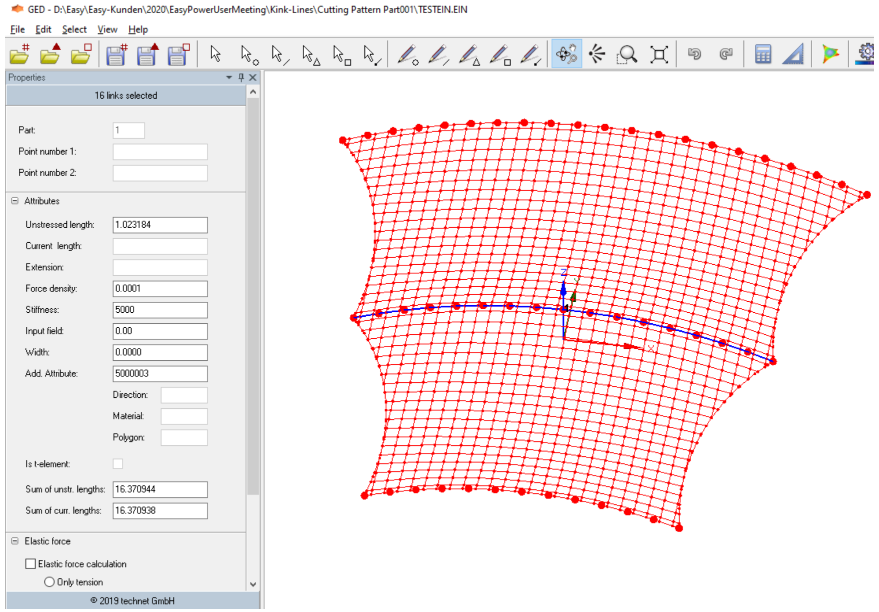
Automation and problem-based solutions

technet gmbh

Highly efficient solutions adapted to the problem

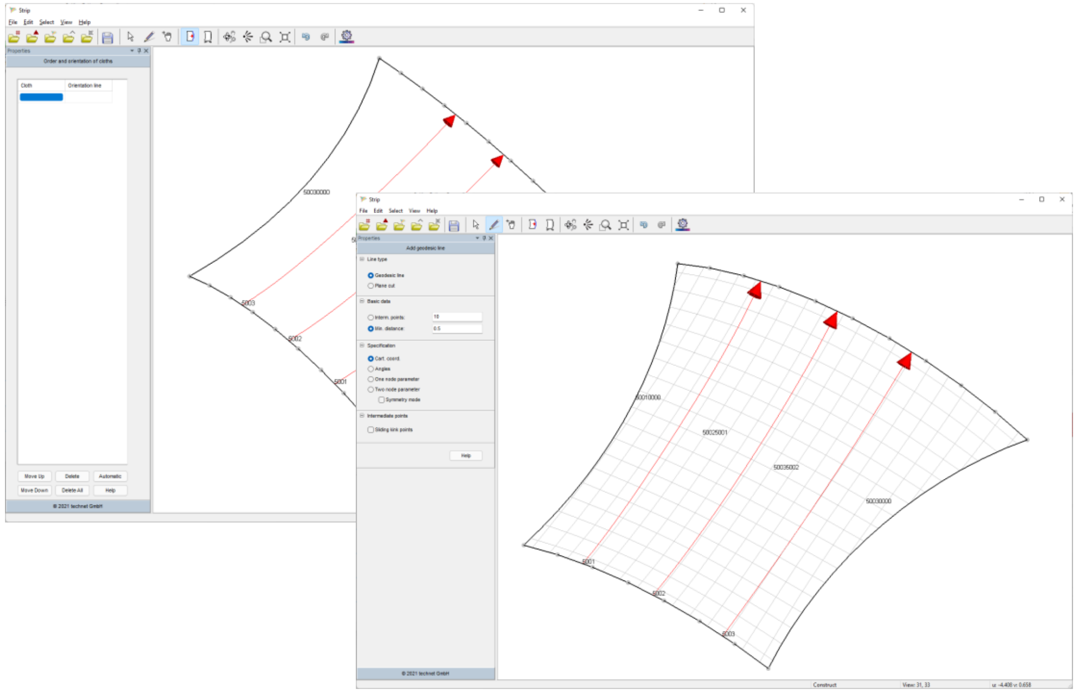
→ e.g. Pattern generation with kink-points

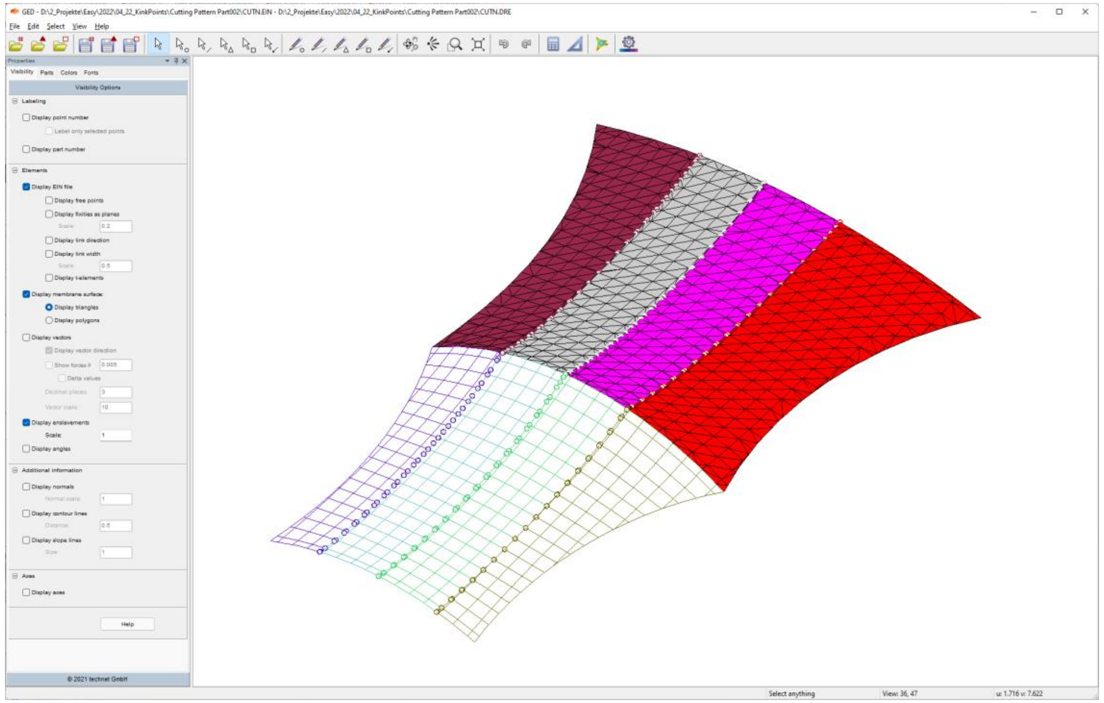
In ridge and valley structures it can be useful to run the seam lines through.



Length blue line = 16.371 m

Automation and problem-based solutions



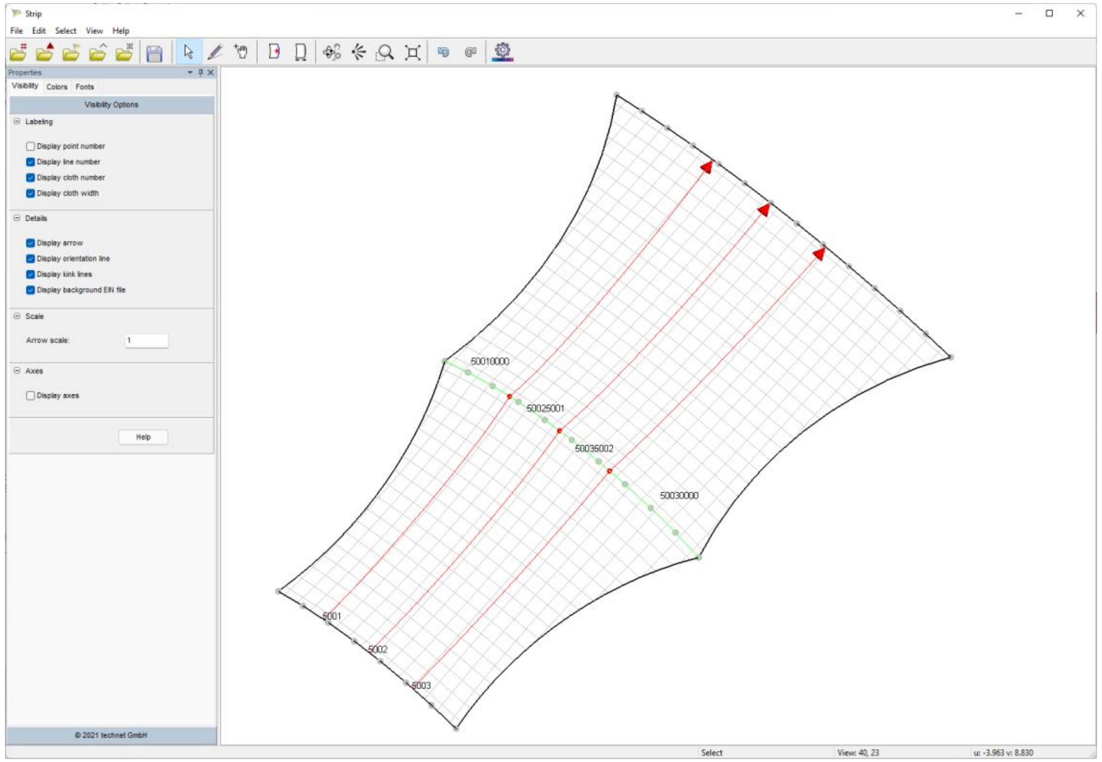


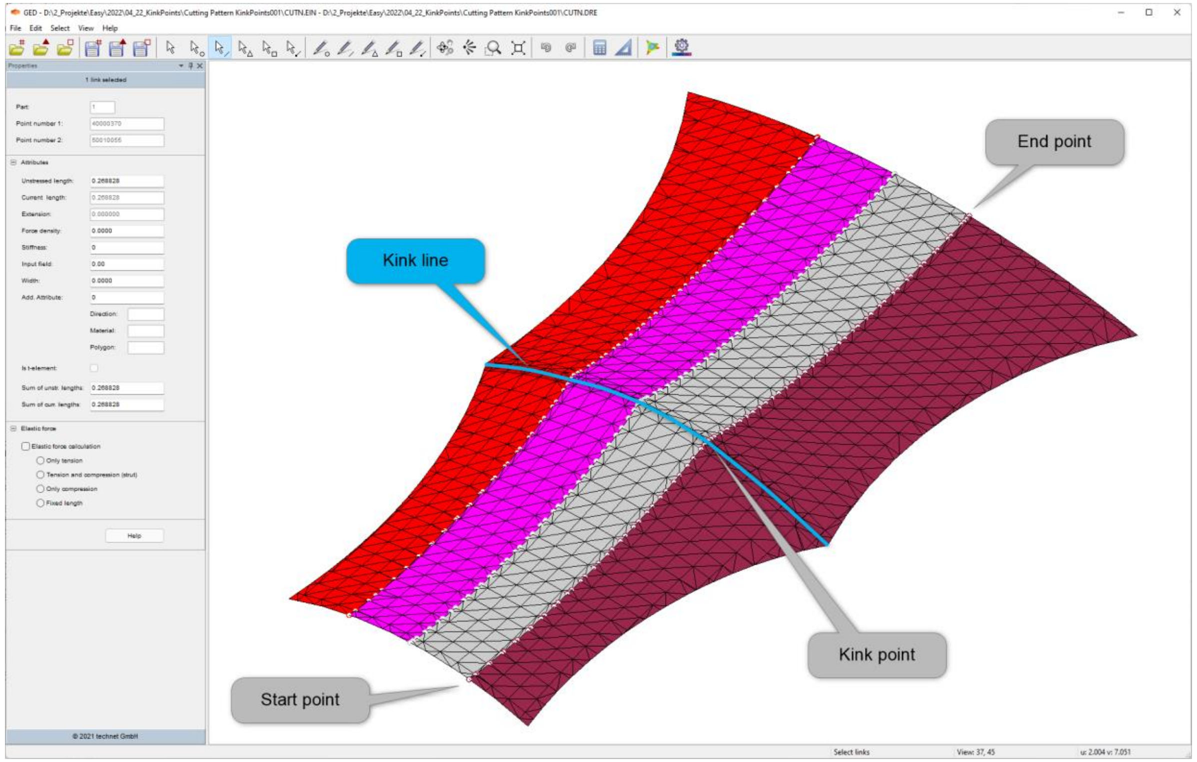
Standard procedure:

Cuts separately for the two parts.

Automation and problem-based solutions

technet gmbh





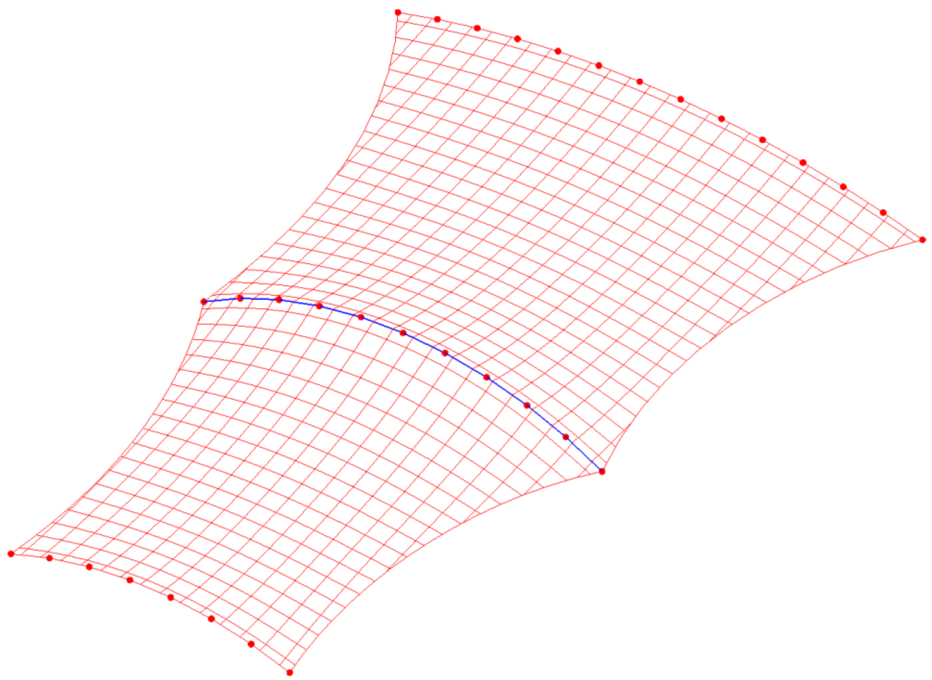
Procedure with kink points:

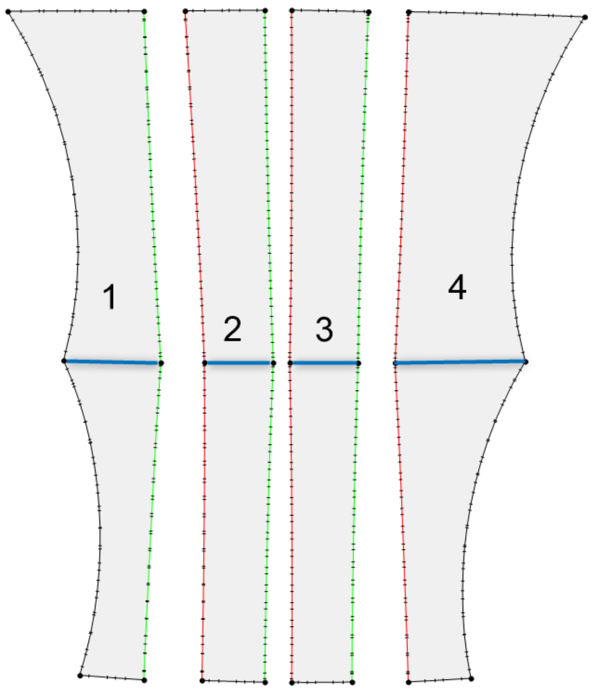
Cuts from start point over kink-point on kink-line to end point.

If desired: The kink points can slide along the kink line.

Automation and problem-based solutions

technet gmbh





Advantages:

- Less cutting patterns
- Correct lengths

Program note

technet gmbh

Sunday, Monday + Tuesday afternoon:

→ Computational Modeling with technet’s Easy team

Thank You!

technet gmbh

Over 30 years of membrane structure experience

Professional assistance in all work steps

technet GmbH
gründig + partner
Berlin - Stuttgart

Best performance provided by sophisticated high precision algorithms

User-friendly programs

www.technet-gmbh.com
mail@technet-gmbh.com

Specialised, individual solutions for customers based on the standard software package

Branch- specific and interdisciplinary know how technet gmbh

ENGINEERING SOFTWARE