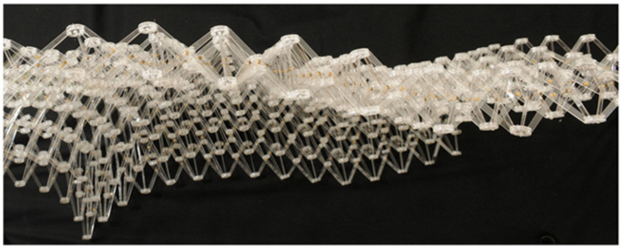

An Anti-Clastic, Double-Curved Scissor-Like Elements Structure

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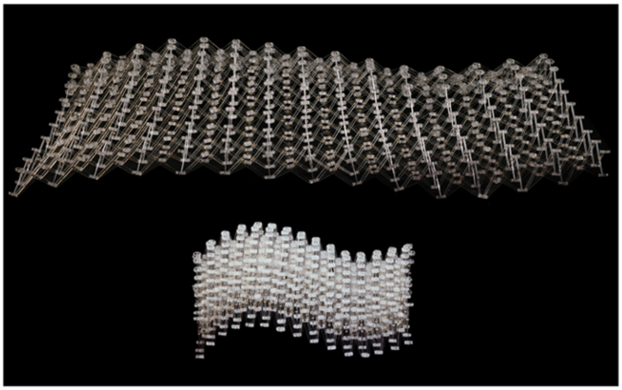
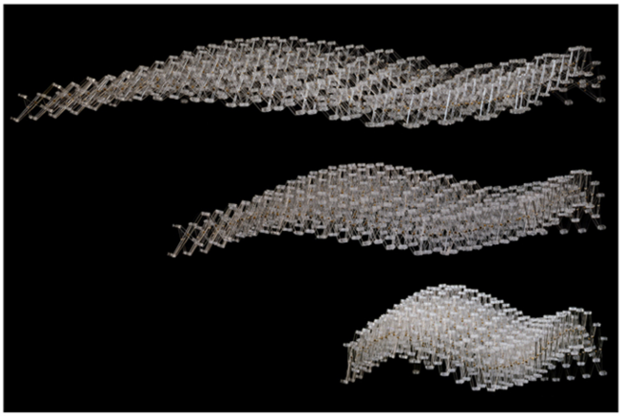
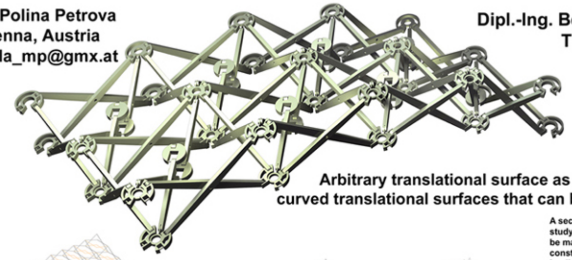






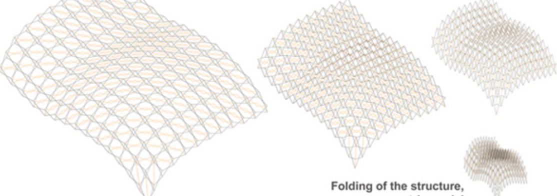
Arbitrary translational surface as a case study of manifold double-curved translational surfaces that can be made by scissor-like elements

A second-order translational surface is investigated as a case study of manifold double-curved translational surfaces that can be made by scissor-like elements (SLEs). It presents a prototype construction regarding its geometrical as well as its structural implications. Design methodology for these shapes is developed.

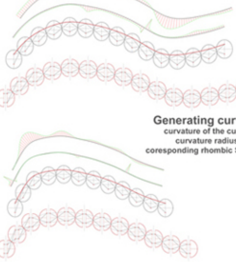
First a parametric model of arbitrary double-curved translational frame has been developed. This first model did not consider physical properties, such as bar or rod thicknesses or the size of joints, but showed that the structure folds and deploys smoothly, prooving the geometrical methodology to be correct. Further an acrylic model of scale 1:20 with joint diameter of 150mm and bars of thickness 1,5mm was built. In this model the excentricity in the connecting joints was ignored. Yet, it worked properly, due to material deformation.

To test the mechanical properties of the construction and to avoid mistakes due to the small scale model, a kinematic simulation was established. The eccentricity of scissor pairs was considered and the elements are of approximately realistic dimensions. The reliability of the frames as load bearing structures in the deployed configuration was then proven using FEM models.

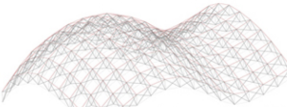
The resulting construction is a mechanism with a single degree of freedom: a single rotation and can work as a structure by means of proper mechanical devices to fix it at desired position.



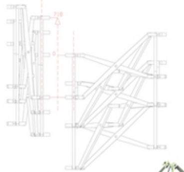
Folding of the structure, parametric model



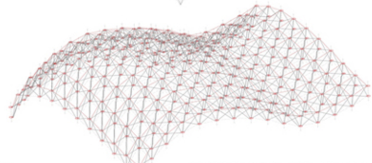
Generating curves
curvature of the curves, curvature radius and coresponding rhombic SLEs



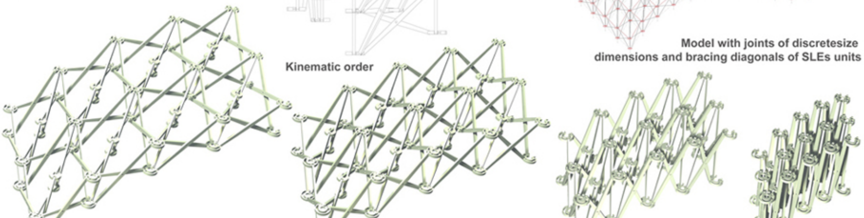
Smoth surface



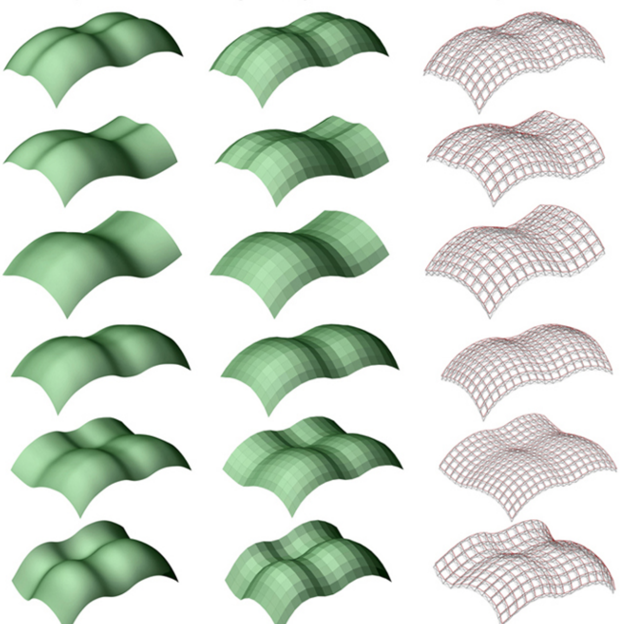
Surface created by plain rhombic units of SLEs



Kinematic order

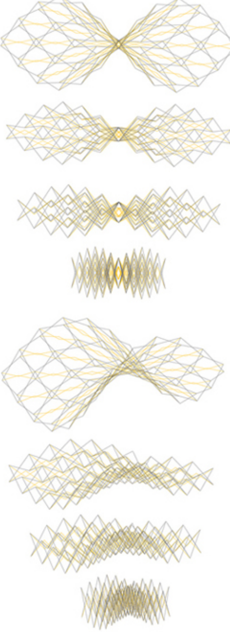


Model with joints of discretesize dimensions and bracing diagonals of SLEs units



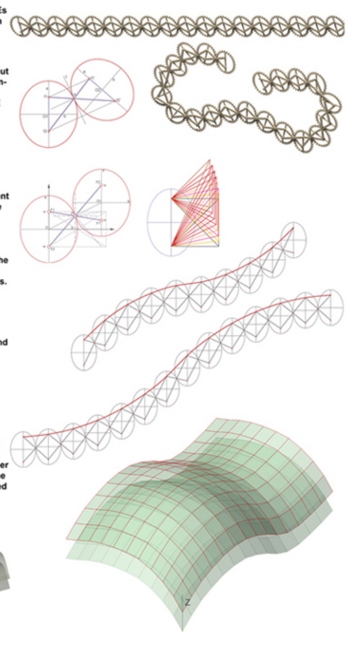
4 stages of deployment process
Kinematic simulation (Catia V5.12)

Different shapes of translational surfaces generated by the same basic unit but different plane curved sections



smoth surfaces — discrete surfaces with planar rhombic faces — surface created by plain rhombic units of SLEs

Folding hyperbolic paraboloid as translational surface, parametric model



Geometrical Concepts for a SLEs Structure Approximating Second Order Surfaces

Using the properties of an ellipse we can construct a pair of SLEs in a pre-determined configuration with intermediate pivots on an ellipse. The resulting structure will ever fold properly.

Antiparallelogramms

In every instant each ellipse is symmetrical to its neighbors about a tangent through a corresponding mutual Point P. The lines connecting the foci of these ellipses are building an antiparallelogramm. The long sides crossing in point P are the bars of a SLE unit. The other two f1f1´ and f2f2´are the normals of two plane parallel curves, one going through the upper foci of the ellipses and one through the corresponding lower foci. The curves describe the shape of an arbitrary two-dimensional pantographic structure.

Congruent ellipses with parallel major axes

Assuming that the ellipses underlying the structure are congruent with the same linear eccentricities and the major axes should be parallel. The polygon with vertices the focal points of two such ellipses can be only a rhomb or a rectangle as a special case. Point P is any point of the ellipse and the distances between P and the foci are half of a pantograph. If we rotate the segments PF1 and PF2 about P with rotational angle of 180° the image is the second part of the pantograph. The points F1, F2, F1´and F2´are the vertices of a rhomb with two sides parallel to the vertical axis.

Discretized planar curves

When we repeat the transformation with an arbitrary point P on the second ellipse and so on, the result is a two-dimensional frame of rhombs with every two sides having the same length and parallel to a global vertical axis. Rearranging the rhombic units yields a different polygon curve.

Translational Surfaces

To keep the connection of upper to corresponding lower nodes parallel to a global vertical axis, is also the concept for the the double-curved SLEs structre. Thus, the surface describing the shape of the structure, its inner and outer skin, will be simply translated along this axis. The structure has two identical layers and their projections on a horizontal plane overlap.The faces of the discrete surfaces are also planar rhombic polygons and upper and lower sides of prisms with every two sides being parallel.The prismatic SLE unit can be regarded as part of a pair of discretized planar curves, generating a translational surface.