

Rigid-foldable Quad Meshes with Control Polylines: Interactive Design and Motion Simulation

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Generic discrete surfaces composed of quadrilateral plates connected by rotational joints in the combinatorics of a square grid are rigid, but there also exist special ones with 1-parametric flexibility. This dissertation focuses on two particular classes of so-called T-hedra (trapezoidal quad surfaces) and V-hedra (discrete Voss surfaces). T-hedra can be thought of as a generalization of discrete surfaces of revolution in such a way that the axis of rotation is not fixed at one point but rather sweeping a polyline path on the base plane. Moreover, the action does not need to be a pure rotation but can be combined with an axial dilatation. After applying these transformations to the breakpoints of a certain discrete profile curve, a flexible quad-surface with planar trapezoidal faces is obtained. Therefore, the design space of T-hedra also includes as subclasses discretized translational surfaces and moulding surfaces beside the already mentioned rotation surfaces. V-hedra are the discrete counterpart of Voss surfaces which carry conjugate nets of geodesics. In discrete case the opposite interior angles of a vertex star are equal. From a V-hedral vertex one can always generate an anti-V-hedral vertex with the same kinematics, in which the sum of corresponding opposite angles equal to π and therefore is a known case of valence four flat-foldable and developable origami vertex. The author developed Rhino/Grasshopper plugins, implemented with C-sharp, which make the design space of T-hedra, V-hedra and anti-V-hedra accessible for designers and engineers. The main components enable the user to design these quad surfaces interactively and visualize their deformation in real time based on a recursive parametrization of the quad-mesh vertices under the associated isometric deformation. Furthermore, this research investigates semi-discrete T-hedral surfaces and other topologies, such as tubular structures composed of T-hedra.

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