About Freeform Origami (0.2.x Alpha)

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1 Overview

Freeform Origami is a Win32 software written by Tomohiro Tachi for enabling interactive design of three-dimensional origami based on continuously modifying origami shapes under several geometric constraints.

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1.2 URLs

- The software is downloadable from `http://www.tsg.ne.jp/TT/software/#ffo`.
- Any questions and bug reports are planned to be responded at freeform origami group at curvedfolding.com (`http://www.curvedfolding.com/group/freeformorigami/`).

1.3 Papers

For technical details of the software, the following references can help.

- Tomohiro Tachi, "Generalization of Rigid-Foldable Quadrilateral-Mesh Origami," Journal of the International Association for Shell and Spatial Structures (IASS), 50(3), pp. 173–179, December 2009.
- Tomohiro Tachi, "Freeform Variations of Origami", in Proceedings of The 14th International Conference on Geometry and Graphics (ICGG 2010), Kyoto, Japan, pp. 273–274, August 5-9, 2010.
- Tomohiro Tachi, "Freeform Rigid-Foldable Structure using Bidirectionally Flat-Foldable Planar Quadrilateral Mesh", Advances in Architectural Geometry 2010, pp. 87–102, September 2010.

2 Basic User Interface

2.1 Screens

FreeformOrigami.exe shows the screen like Figure 1.

Left pane 3D View. Shows 3D view of the model when the model is loaded. Most of manipulation is done on this screen.

Right pane optional graphics: this is shown when related constraints are activated. From top to bottom:

1. Crease pattern shows the developed pattern of the form when "developable" constraint is activated (check System→developable).
2. Flat-folded pattern shows the X-ray view of the form in the completely flat-folded state if "flat-foldable" constraint is activated (check System→flat-foldable).
3. Reciprocal Figure shows the reciprocal figure related to the first order folding mode when "shaky" constraint is activated (check System→shaky).

2.2 Coloring Scheme

The edges are colored according to the crease property. These assignment can be changed using Tool→assign.

Red	Mountain
Blue	Valley
Dark Gray	General Crease

2.3 Changing View

In order to change view, use mouse:

Rotate View : Use **Right Button Drag** for 3D rotation (for 3D view) and 2D rotation (for crease pattern and flat-folded pattern views).

Pan View : use **Middle Button Drag** or **Shift + Right Button Drag** for panning.

Zoom View : use **Wheel** to zoom up and down.

Most of other operations are done by left click/drag, selecting menu, or pressing key, and their combination depending which tool you are using.

Figure 1: Screen shot of the software.

2.4 Simulation Mode vs. Edit Mode

The software runs in two different mode "Simulation Mode" and "Design Mode." The modes can be switched by "System → Simulation Mode" check list. Advanced: By pressing **Tab** key, the software temporarily runs in the opposite mode.

Simulation Mode When the background color of Crease Pattern and Flat-Folded Pattern windows is **gray**, CP and FF are fixed, and the system runs in simulation mode. In this mode, the software does a rigid origami simulation using truss elements.

Edit Mode When the background color of Crease Pattern and Flat-Folded Pattern windows is **white** (CP and FF are fixed), the system runs in simulation mode. In this mode, manipulation to the 3D object affects the crease pattern and flat-folded pattern. The deformation of the object follows the constraints checklist in System menu.

3 File Menu

3.1 Open

This operation opens files of ***.dxf (2d drawing, i.e., crease pattern) or ***.obj (3d mesh folded form). You can drag and drop the files to the window to open. The files must be treated carefully so that it works. You can drag and drop multiple files or open multiple files to manipulate more than one meshes at the same time.

DXF Two dimensional crease pattern must be prepared in dxf format.

- Only LINES and POLYLINES in 2D are used.
- Color scheme: Red=Mountain, Blue=Valley, Black=Crease.
- The software cannot recognize Group, Block Instance.
- All the line data should be ungrouped.
- The lines can intersect but cannot overlap (bad double line).

OBJ Three-dimensional surface must be imported as a polyhedral mesh in obj file format.

- Surface must be singly covered and must be an orientable manifold, i.e., the edges must be shared by one or two facets (if one, the edge is on the boundary).
- The constraints are now only supporting disk topology, so you should import a mesh homeomorphic to a disk.
- The shared vertices must be shared in the obj files also. For example, in **Rhinoceros**, every edge should be welded.

- OBJ file is without crease information. If you want to assign Mountain and Valley according to the current state, use Model→Re-Assign MV.

3.2 Save

Save 3D mesh in OBJ or crease pattern in DXF.

3.3 Add Reference

This operation appends point data from ***.dxf (2d drawing, i.e., crease pattern) or ***.obj (3d mesh folded form). File preparation is the same as the open command. This is intended to be used for reading reference geometry such as boundary condition and existing shapes, using *stitch command*.

3.4 Load Texture

You can load an image used for the texture of paper.

4 System Menu

System menu controls the constraints and the background calculation of the software.

Simulation Mode This check item set either the simulation mode or edit mode. See Section 2.4 for the difference between modes.

Constraints

Developable Forces the pattern developable, i.e., foldable from a piece of flat paper.

DevBoundaryNonOverlap Forces the boundary not to overlap

DevBoundaryAngle Forces the angles of the boundary unchanged.

DevBoundaryRigid Forces the model to be folded from the same size of piece of paper by preserving the length of edges of the paper boundary.

Globally Developable Forces the mesh to be developed to a piece of paper even if it is with holes.

Flat-Foldable Forces the pattern to be flat-foldable. Activate this constraints only after you assign proper Mountain and Valleys.

FlatBoundaryAngle Forces the angles of the boundary unchanged in the flat-folded state.

Globally Flat-foldable Forces the mesh to be flattened to a planar state even if it is with holes.

Avoid Collision (Edge) This forces mountain to be folded in mountain-wise, and valley in valley-wise.]

Avoid Collision (Vert) This avoids local collision between facets sharing a vertex]

Planar This forces each mesh to be planar (triangulation lines have the folding angle of 0).

Rigid Segment Rigidize the edges marked as rigid bars displayed as green segments. This constraint can work in the editing mode. Rigid bars are specified using Tool→Rigidize Edge.

Stitch This enables the stitch constraint (stitch constraints are created using Tool→Stitch)

Shaky This finds the form so that the first order folding mode exists. Can be used for generating shaky closed polyhedron.

Inequality Sector Angle Solves angle inequality condition for flat-foldability.

Triang Weight Defines the flexibility of the triangulating hinge.

Flat Limit This can limit the folding angle so that dihedral angle cannot be to small. This is used with the Avoid Collision option checked.

Set Iteration This defines the number of iteration of CG method in each projection step. If this is set to 1, the software works in steepest descent method, which is slow but sometimes stable.

Constraint On/Off Background calculation is enabled or disabled. Default: ON.

Adaptive Mesh Enables or disables adaptive mesh by merging close vertices.

5 Model

Model menu is for performing action to the entire model. Undo/Redo is supported.

Set Length This command sets the length of the selected edges to the specified value, and make these edges rigid bars.

Add Ref Pt Create a point in 3D to which you can stitch vertices of mesh.

Stitch Verts This command operates Tool→Stitch for close vertices and reference points so that they won't separate. Stitch constraint is activated by System→Stitch.

Auto MV This command assigns Mountains and Valleys to the edges according to the current folding angles.

Pin Boundary Select all boundary points and set them fixed in space.

Pin Selected Pin fix selected vertices in space.

6 Tool

Select Used for selecting elements. Rectangle region selection is possible. (Left to Right and Right to Left has different selection, following conventional 3D CAD interface.)

Move This tool is for translating selected vertices by dragging. Following keyboard shortcut can be combined.

Shift Adding points to the selection.

x, y, z The transformation is constrained in x, y, and z directions.

Finger / Move Magnet This tool is similar to Move tool, but also affects neighbor vertices (in geodesic sense). Finger uses the dragging speed and Magnet uses the size of the window for the unit distance for defining the decay of effect. In the Finger mode, left dragging of the background rotates the whole object.

Assign This is for assigning mountain and valley to the edges. Chose the assignment from the palette and then click or region select edges that you want to "color."

Complementary foldlines try to unfold when foldlines fold, and fold when foldlines unfold. It is completely folded in the developed state, and is completely unfolded in flat-folded state. Using

complementary foldlines along with normal foldlines with Planarity, Developability, Flat-foldability constraints is useful for making Bi-directionally Flat-foldable one-DOF rigid foldable surface such as egg-box surface or discrete Voss surface. See Tomohiro Tachi "Freeform Rigid-Foldable Structure using Bidirectionally Flat-Foldable Planar Quadrilateral Mesh" in Advances in Architectural Geometry 2010.

Flip Mesh Performs edge flipping.

Rigidize Edge This tool is for specifying which edges are rigid.

Stitch to Ground Set the selected vertices on the ground ($z = 0$ plane).

Non Dev Select singular points in which developability condition is not applied.

Non Flat Select singular points in which flat-foldability condition is not applied.

Stitch Vertices This tool is for "stitching" two vertices or reference points, so that their coordinates are the same. Select the first point and then select the second point. The segment between vertices represent the stitch constraint, clicking of which results in eliminating the constraint. Stitch constraint is activated by System→Stitch.

EqAngle Set selected edges to have the same folding angle.

EqLength Set selected edges to have the same length.

Unweld Unweld mesh to decompose.

7 View

This menu changes the visibility of elements.

8 Keyboard Shortcuts

This section lists the implicit keyboard commands.

Tab Key Temporarily switches Simulation mode and Edit Mode.

Space Key Fold the model

'B' Unfold the model

'N' Add random white noise to the vertices.

'F' Fullscreen (Shift + F → Fullscreen with menu)

9 Acknowledgement

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