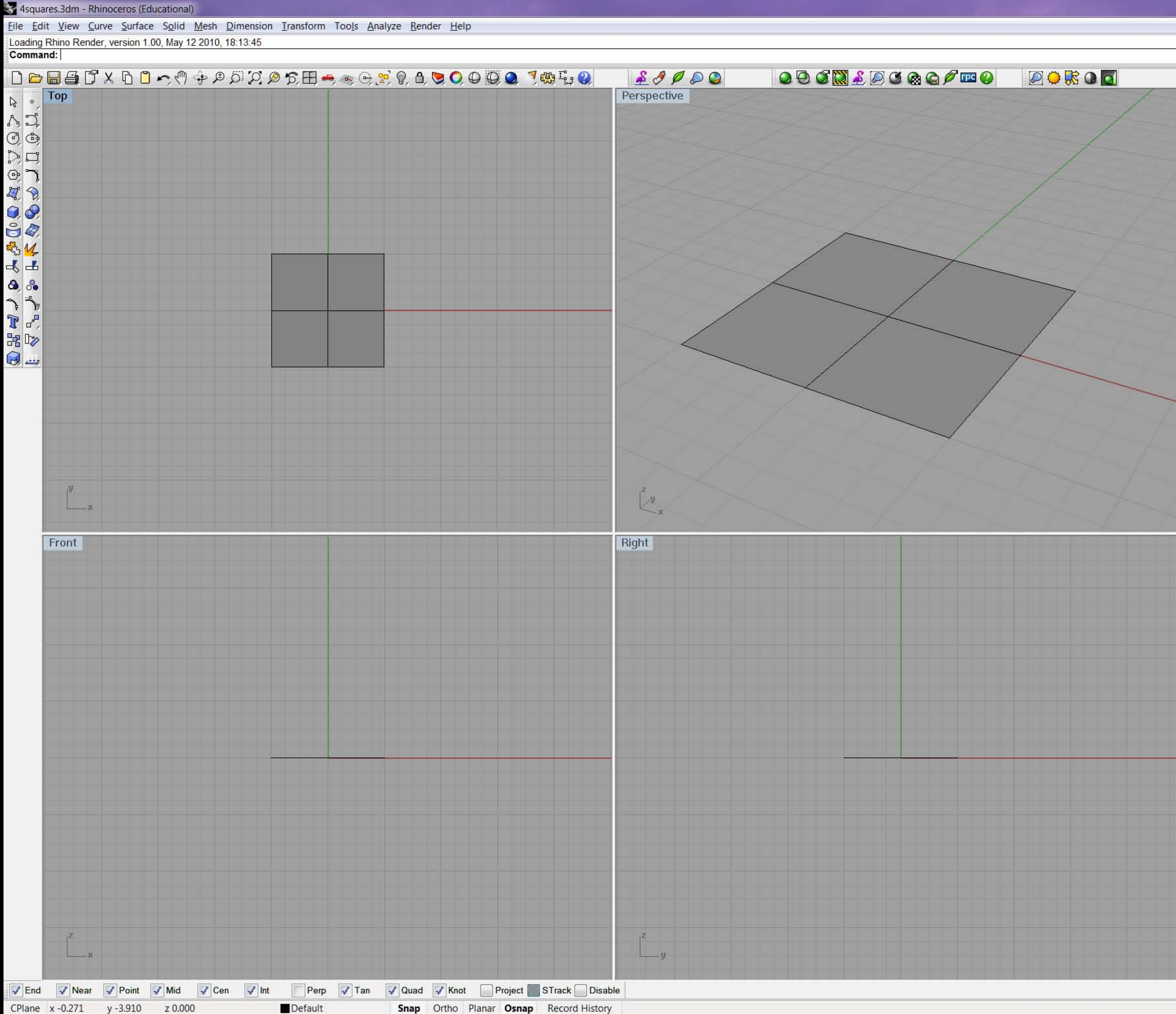
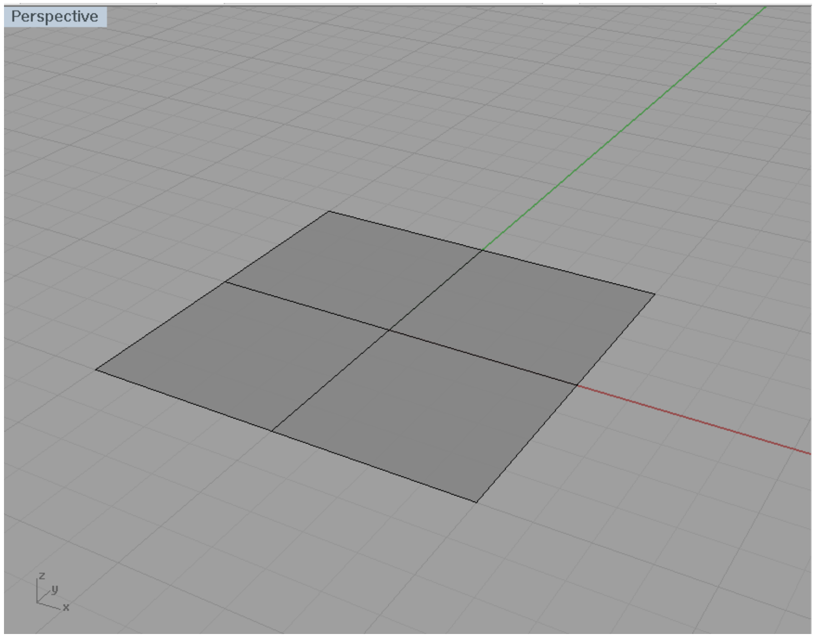
I would like to fold an example of the edge tuck and vertex tuck molecules from Origamizer.

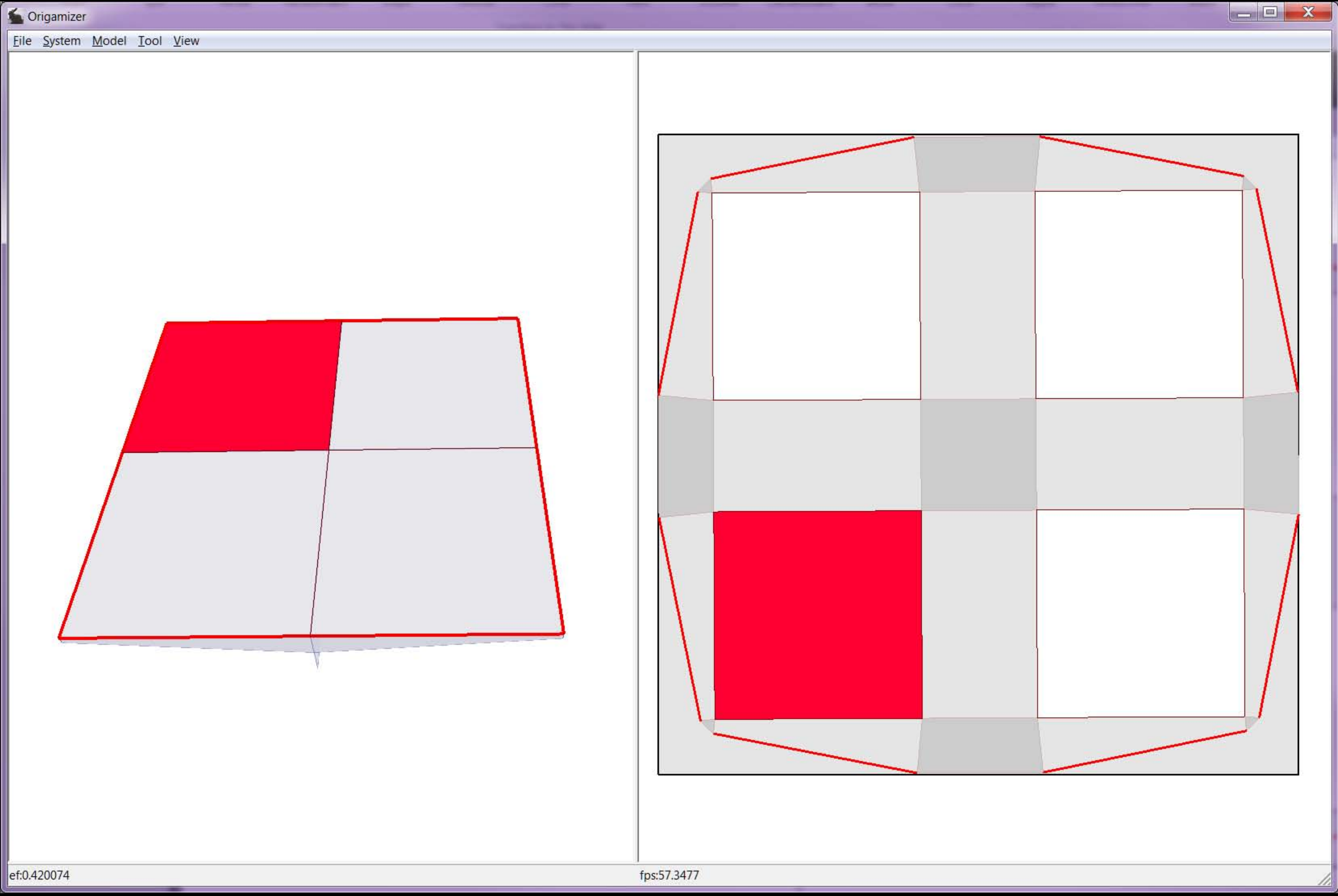
Is there a simple Origamizer crease pattern you can have us fold? I don't have 10 free hours to spend folding a bunny, but it would be neat to see how the folds work in person.

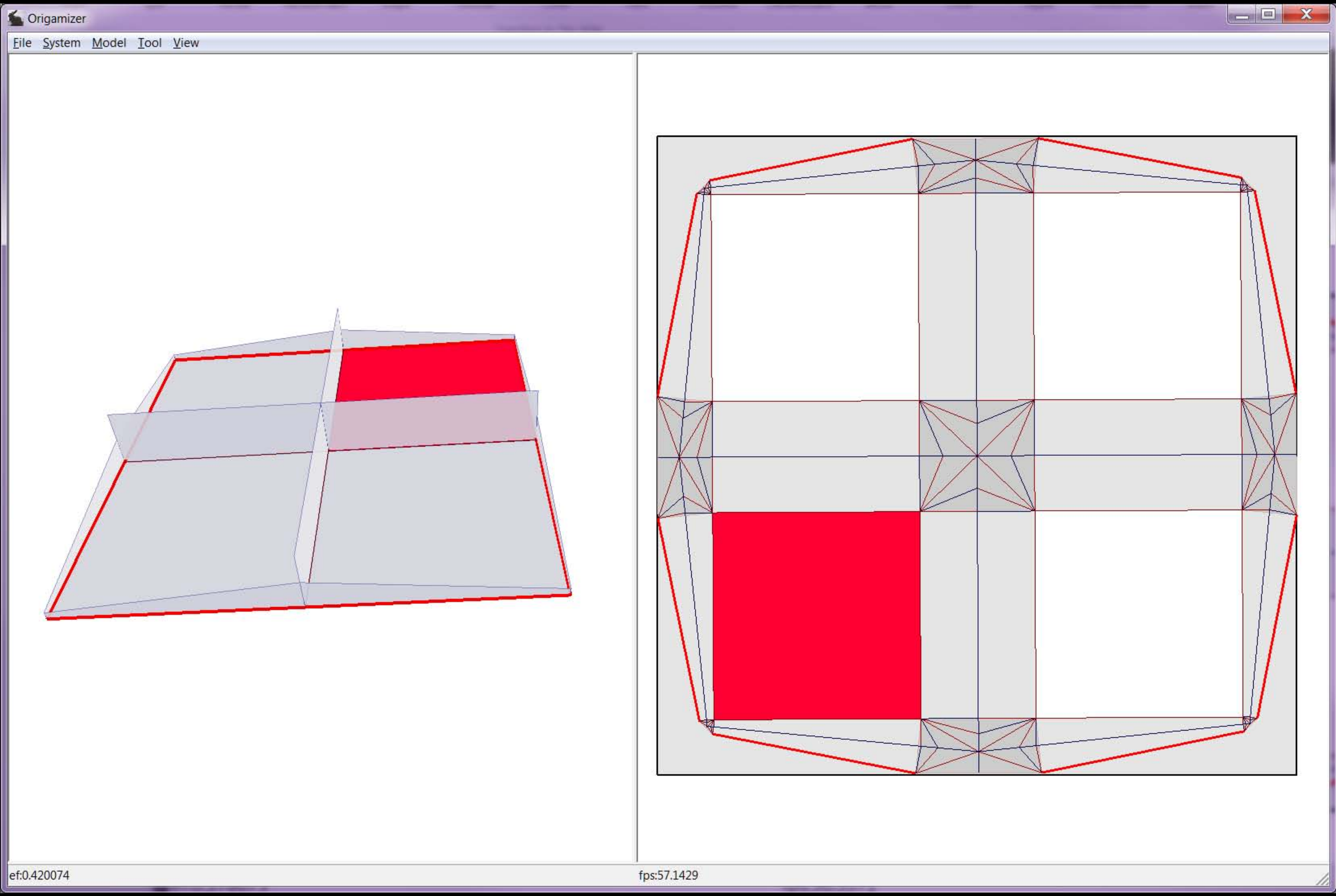

4squares.3dm - Rhinoceros (Educational)
File Edit View Curve Surface Solid Mesh Dimension Transform Tools Analyze Render Help
Loading Rhino Render, version 1.00, May 12 2010, 18:13:45
Command:
Top
Perspective
Front
Right
End Near Point Mid Cen Int Perp Tan Quad Knot Project STrack Disable
CPlane x -0.271 y -3.910 z 0.000 Default Snap Ortho Planar Osnap Record History

OBJ:

v	−1	1	0	
v	0	1	0	
v	1	0	0	
v	1	1	0	
v	−1	−1	0	
v	−1	0	0	
v	0	−1	0	
v	0	0	0	
v	1	−1	0	
f	2	1	6	8
f	4	2	8	3
f	8	6	5	7
f	3	8	7	9




Origamizer
File System Model Tool View
ef:0.420074
fps:57.3477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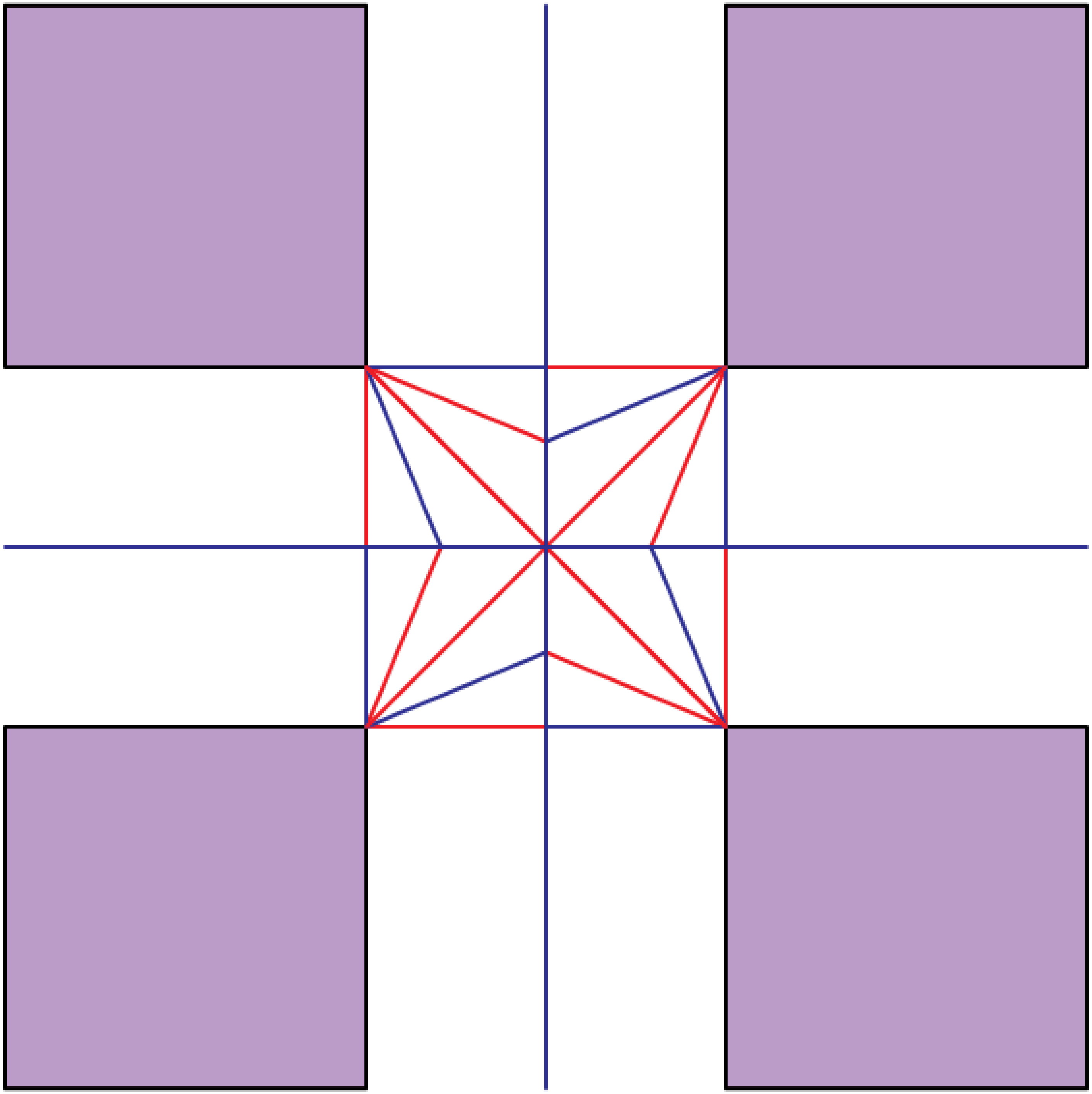
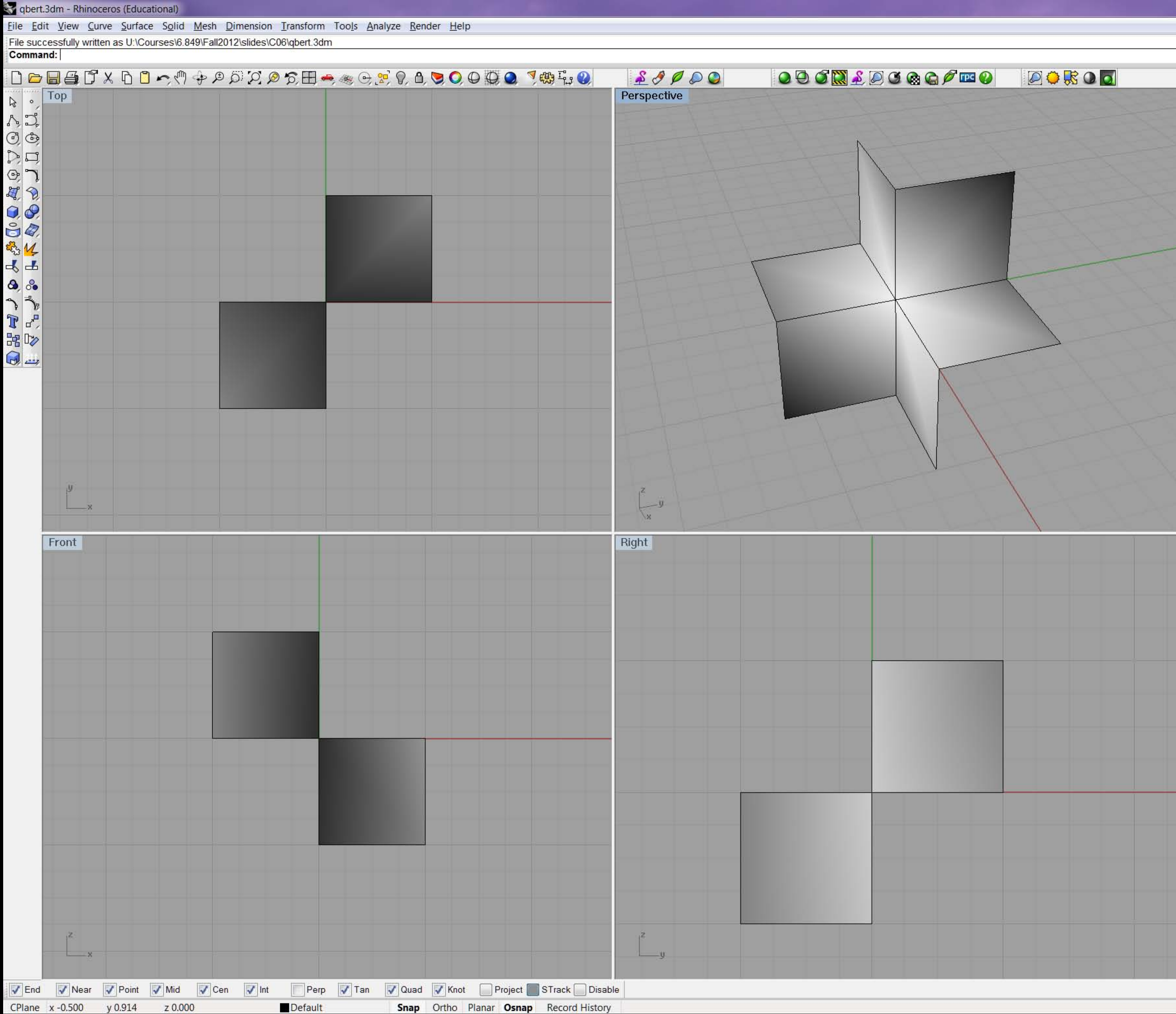
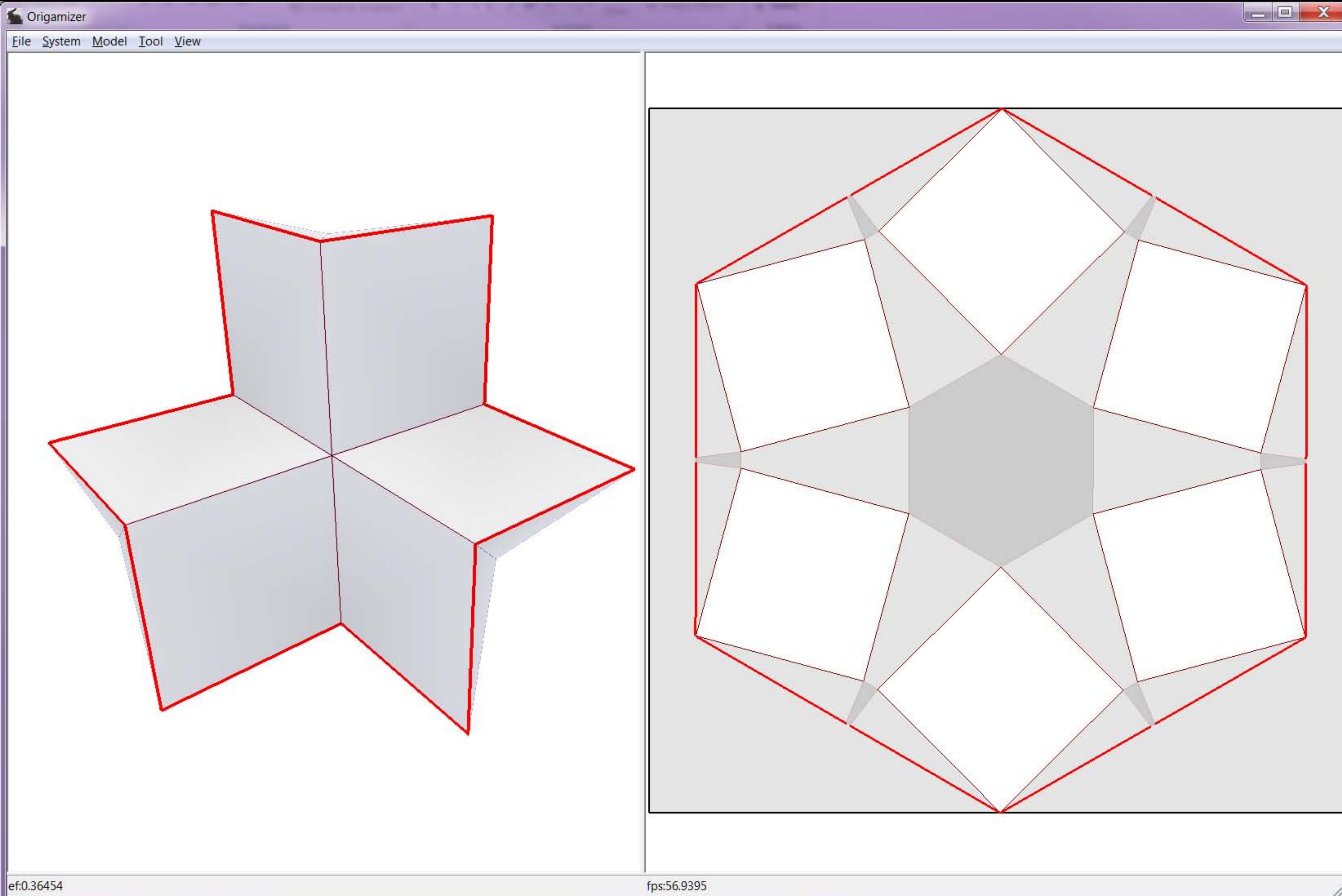


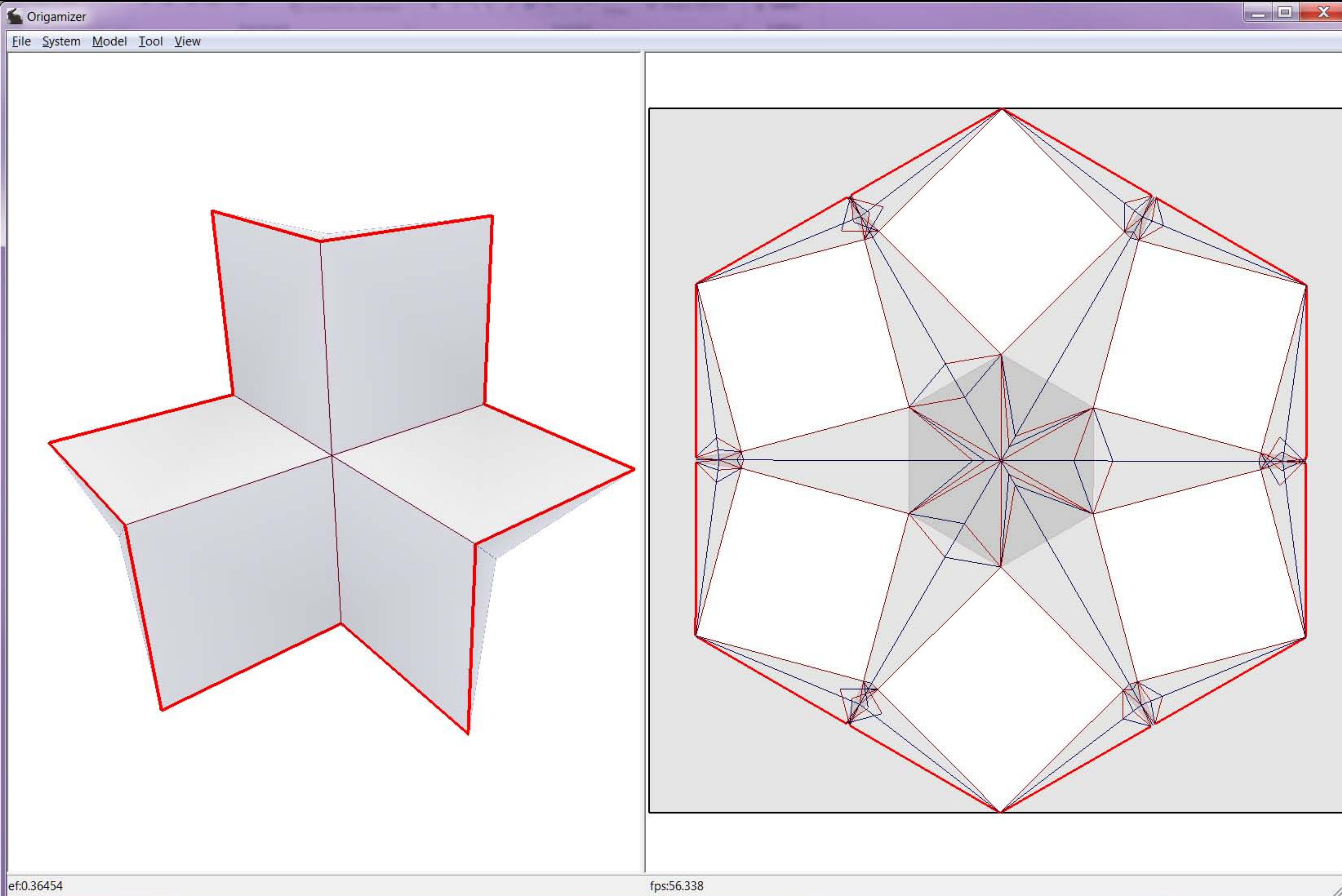
Why is it harder to make a concave vertex than a convex one? Couldn't you just push a convex vertex in, or redefine the inside and outside?


qbert.3dm - Rhinoceros (Educational)
File Edit View Curve Surface Solid Mesh Dimension Transform Tools Analyze Render Help
File successfully written as U:\Courses\6.849\Fall2012\slides\C06\qbert.3dm
Command:
Top
Perspective
Front
Right
End Near Point Mid Cen Int Perp Tan Quad Knot Project STrack Disable
CPlane x -0.500 y 0.914 z 0.000 Default Snap Ortho Planar Osnap Record History

Q*bert

[Gottlieb 1982]


Origamizer
File System Model Tool View
ef:0.36454
fps:56.9395


Origamizer
File System Model Tool View
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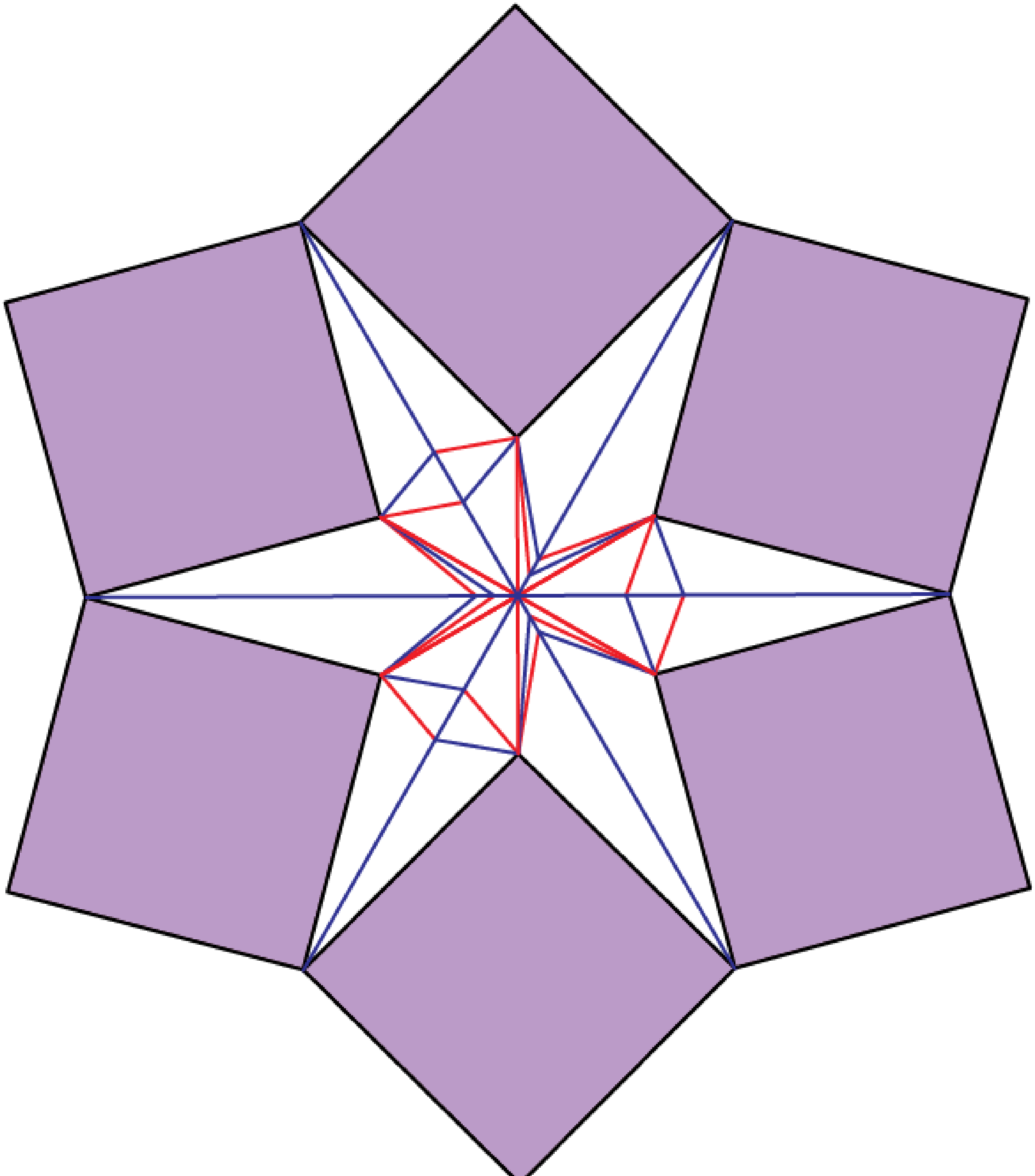
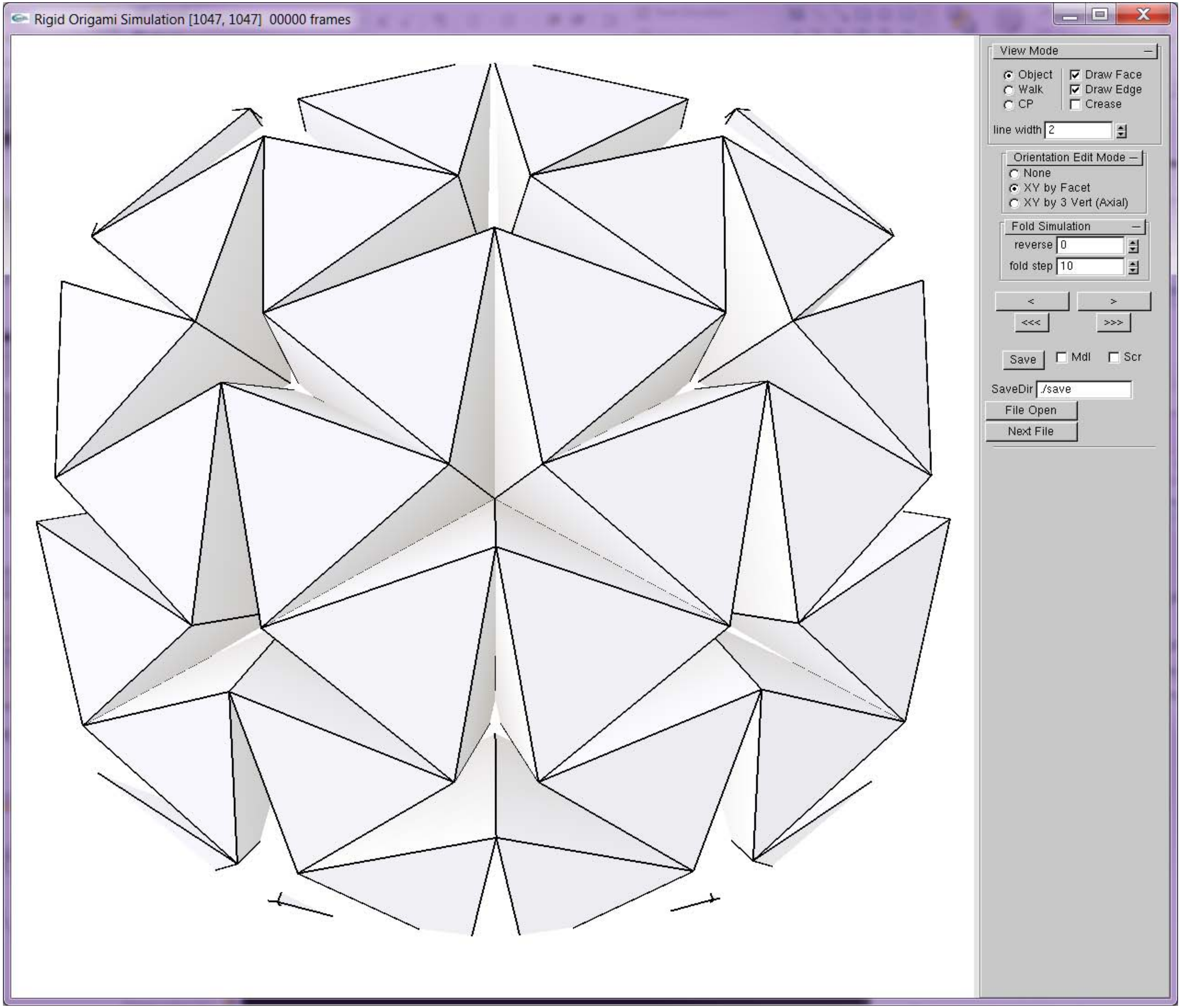


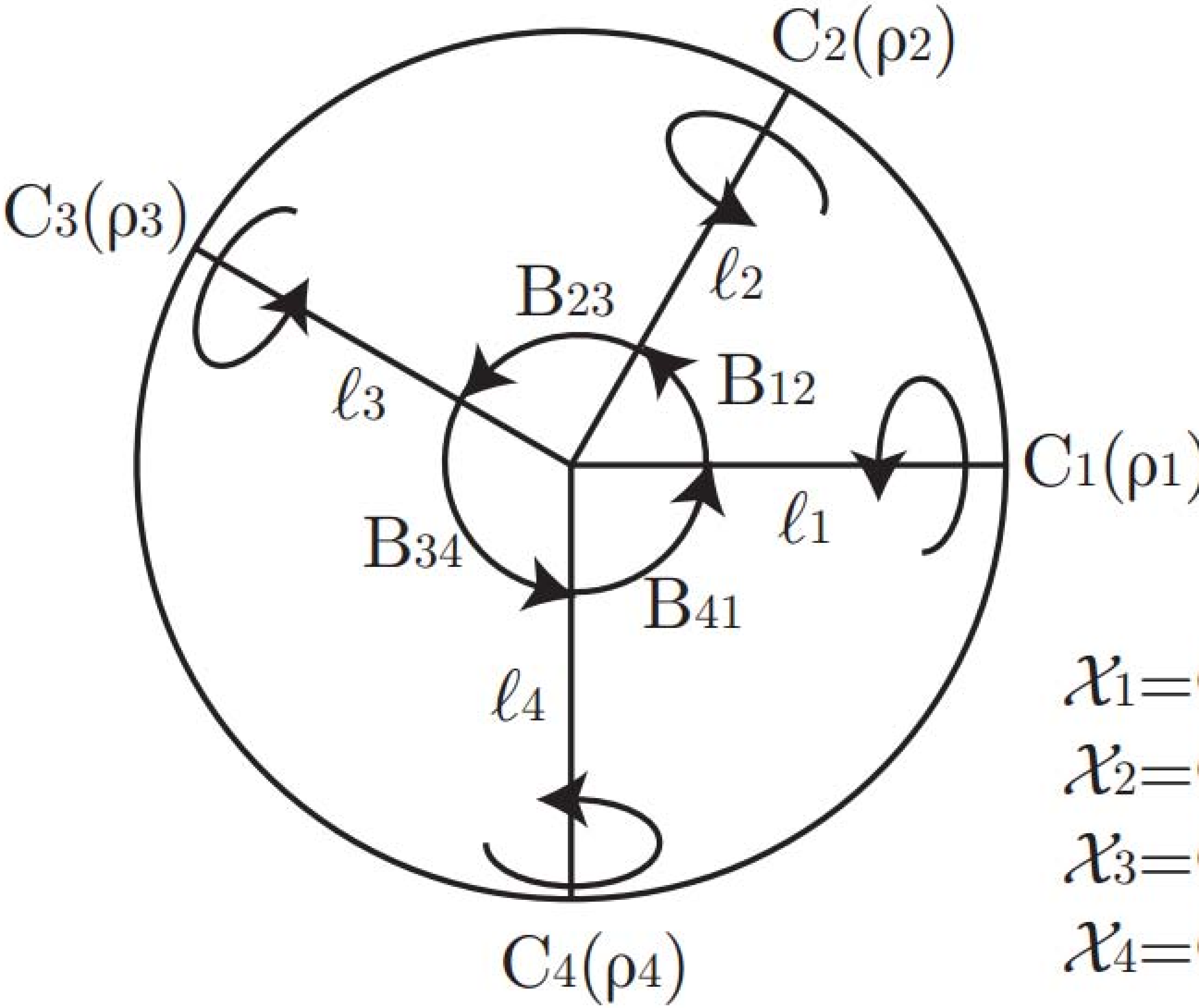
Can you elaborate more on the part of Freeform Origami, especially how the crease patterns change when you drag a point on the structure? It seems to me that … dragging one point would cause the structure to look different without changing the original origami design.

2. it would be helpful to go through the geometric constraints used in Origamizer.
3. ditto for rigid origami.

1 DOF rigid foldability is awesome! Can you go over what conditions this imposes on the crease pattern?



Courtesy of Tomohiro Tachi. Used with permission.



$\mathcal{X}_1 = C_1 B_{12}$

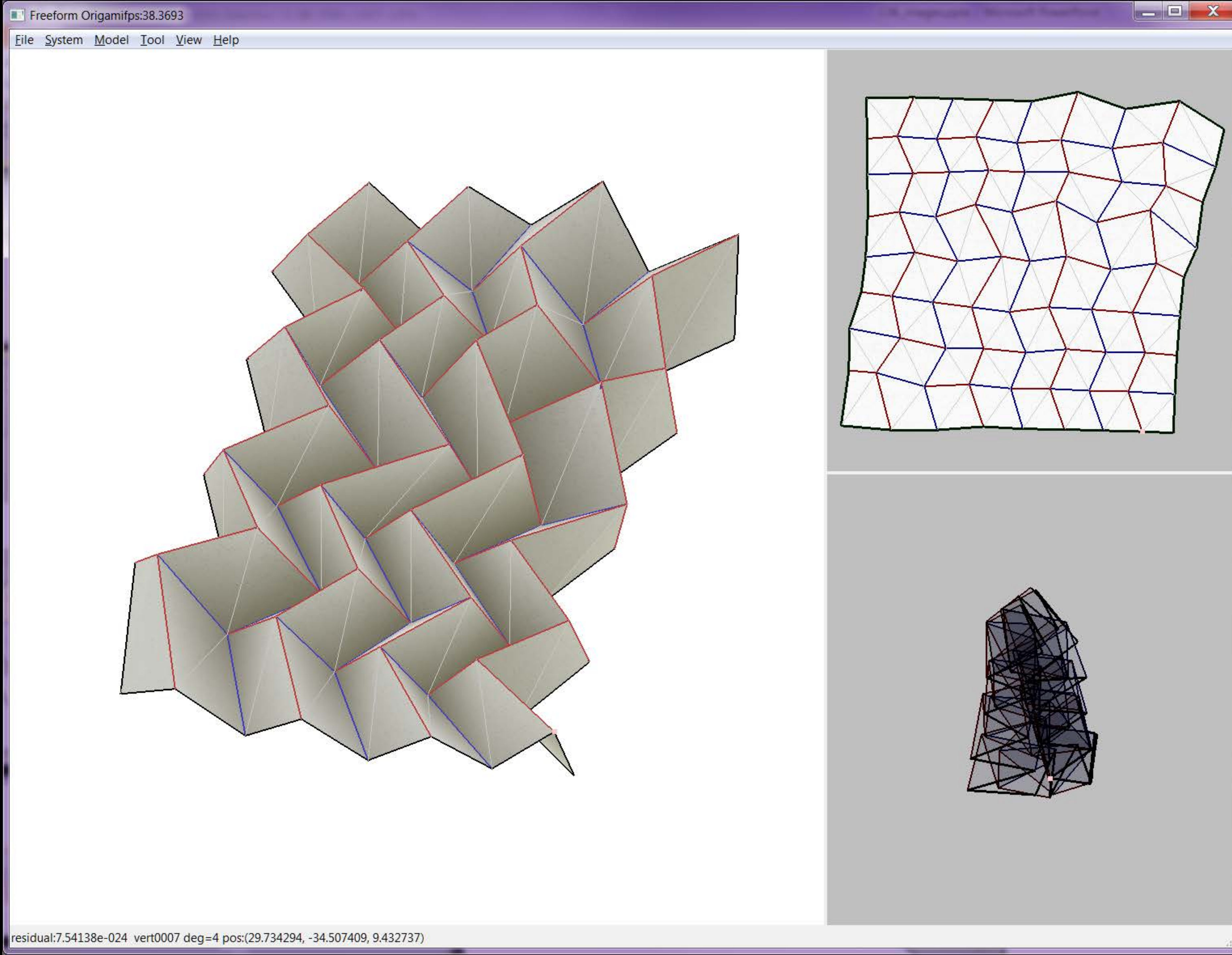
$\mathcal{X}_2 = C_2 B_{23}$

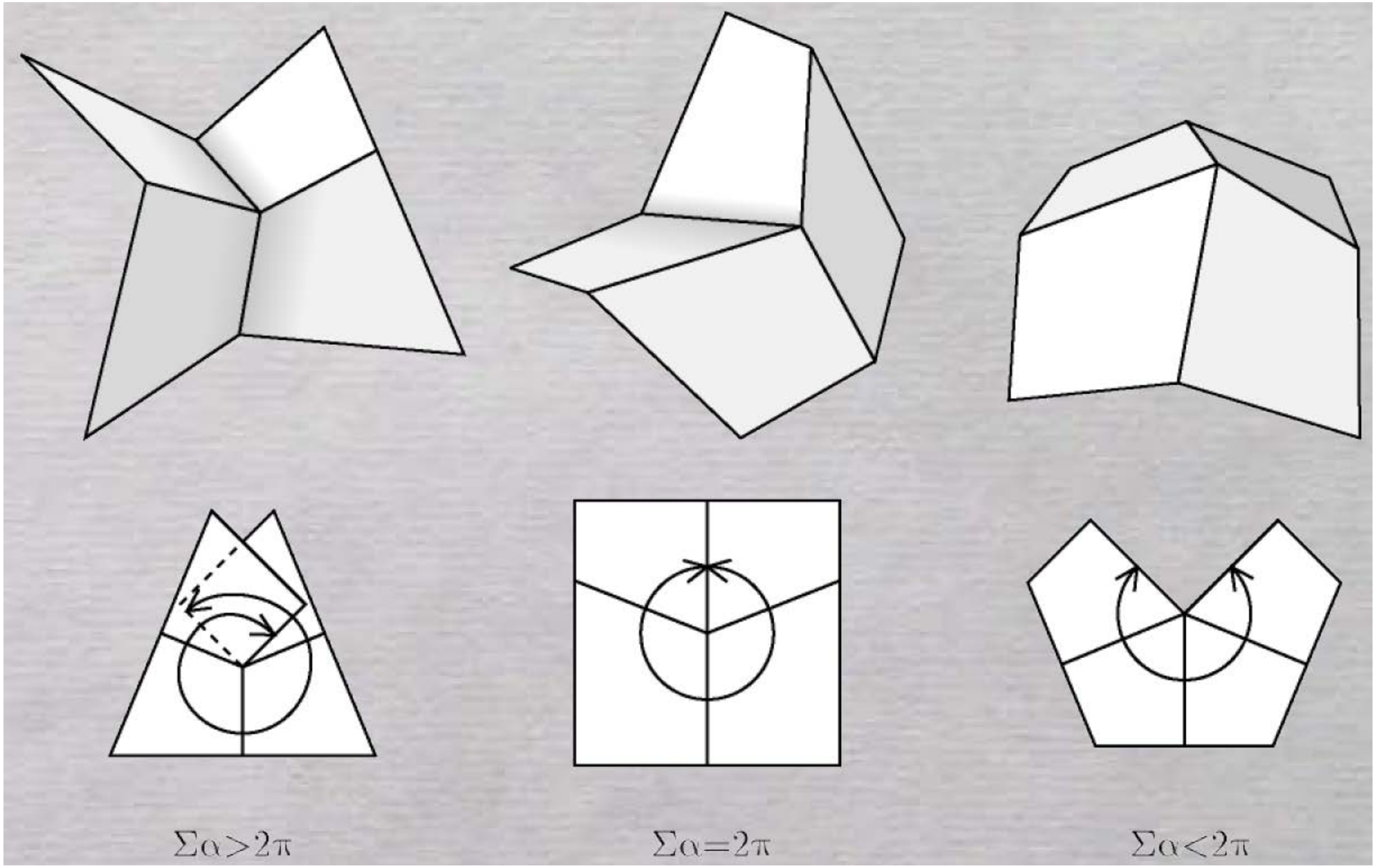
$\mathcal{X}_3 = C_3 B_{34}$

$\mathcal{X}_4 = C_4 B_{41}$

$$\chi_1 \cdots \chi_{n-1} \chi_n = \mathbf{I}$$

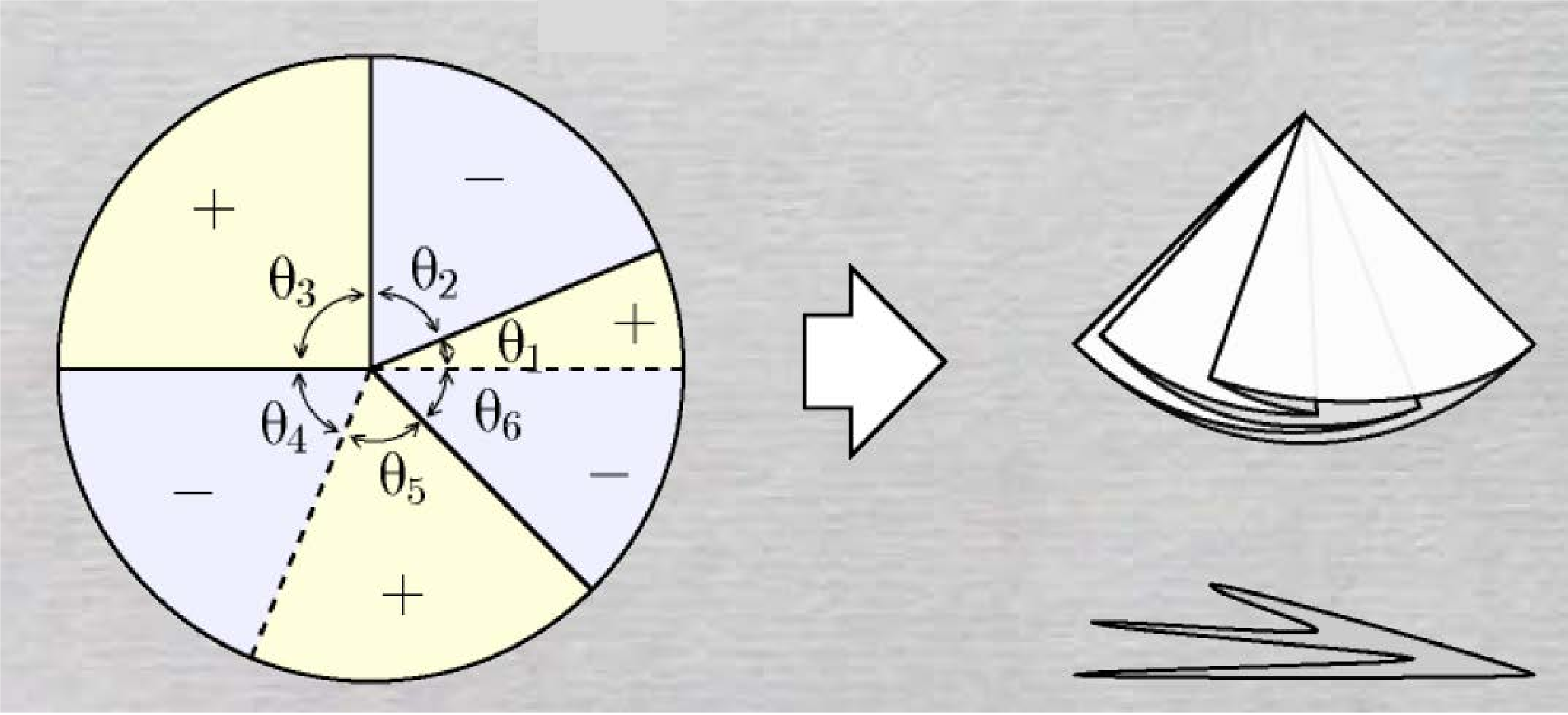
[belcastro & Hull 2001]


Freeform Origamifps:38.3693
File System Model Tool View Help
residual:7.54138e-024 vert0007 deg=4 pos:(29.734294, -34.507409, 9.432737)



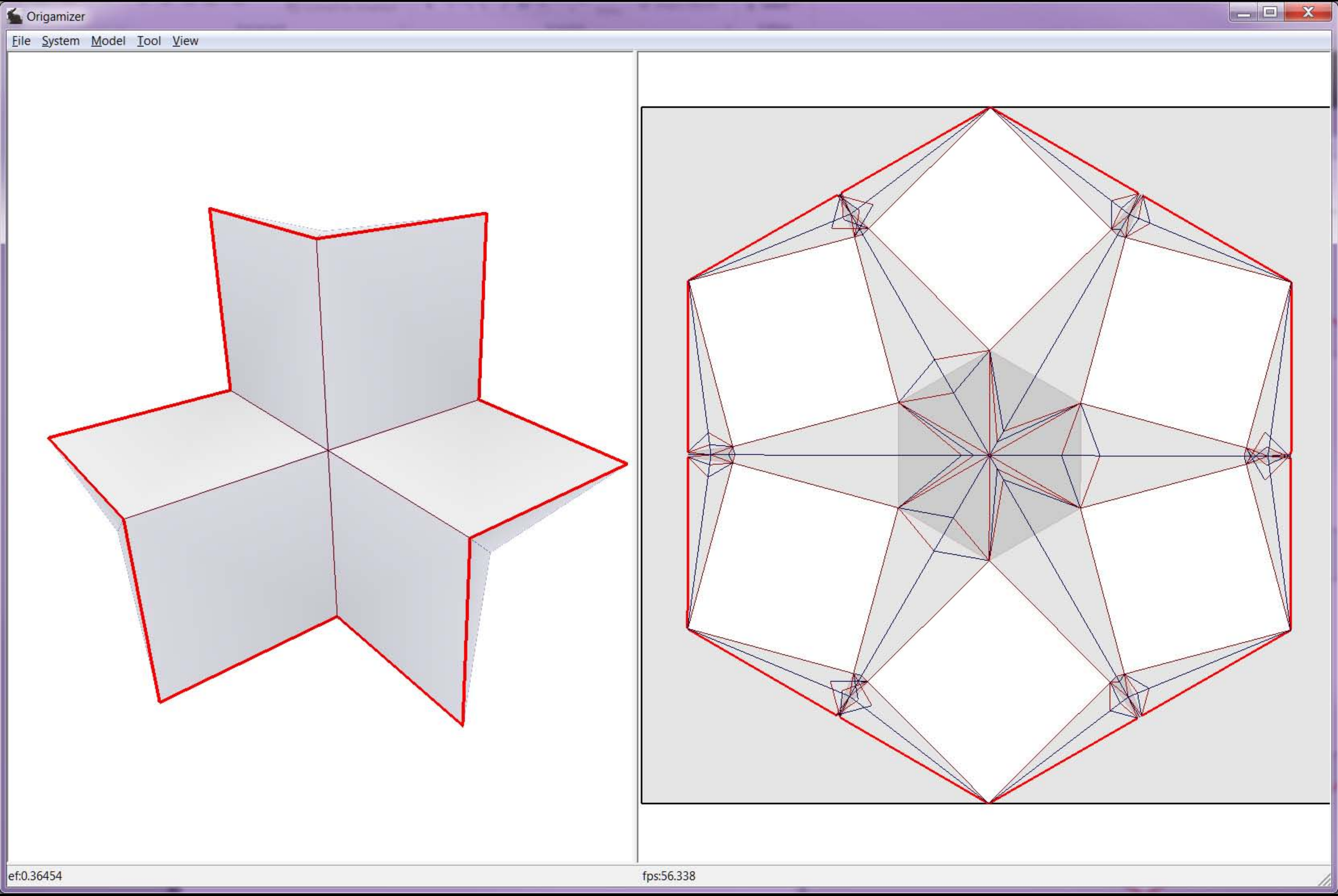
$$\sum_{i=0}^{n-1} \theta_i = 360°$$

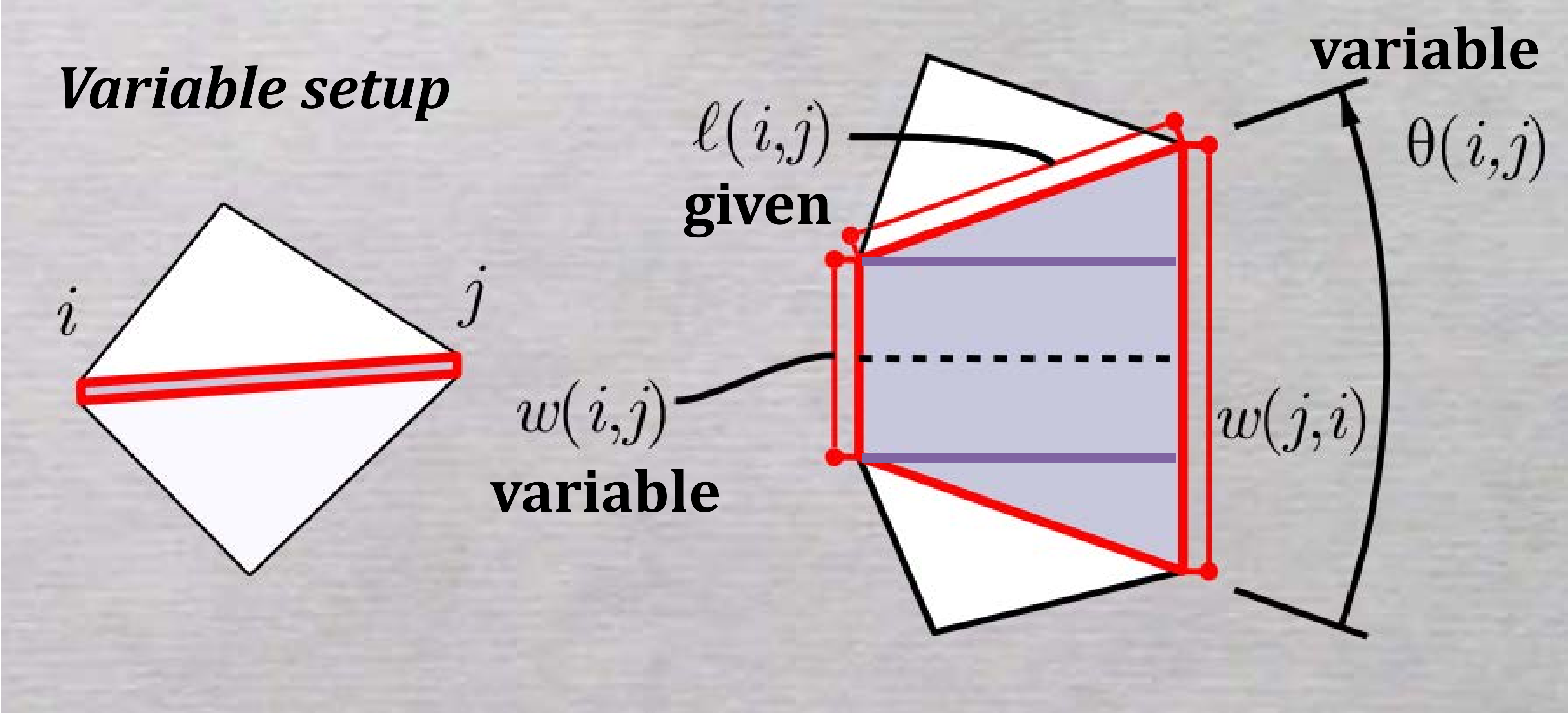
Developability condition



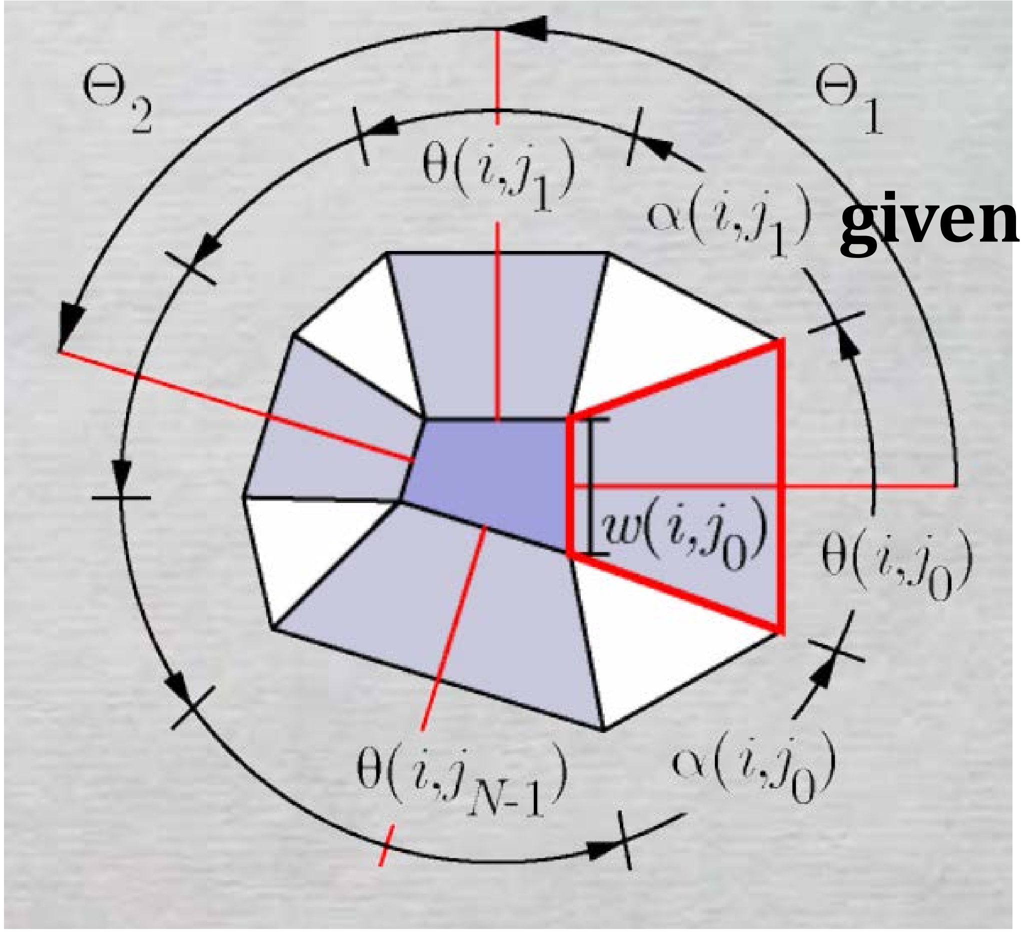
$$\theta_1 - \theta_2 + \theta_3 - \theta_4 + \cdots = 0$$

Flat-foldability condition


Origamizer
File System Model Tool View
ef:0.36454
fps:56.338

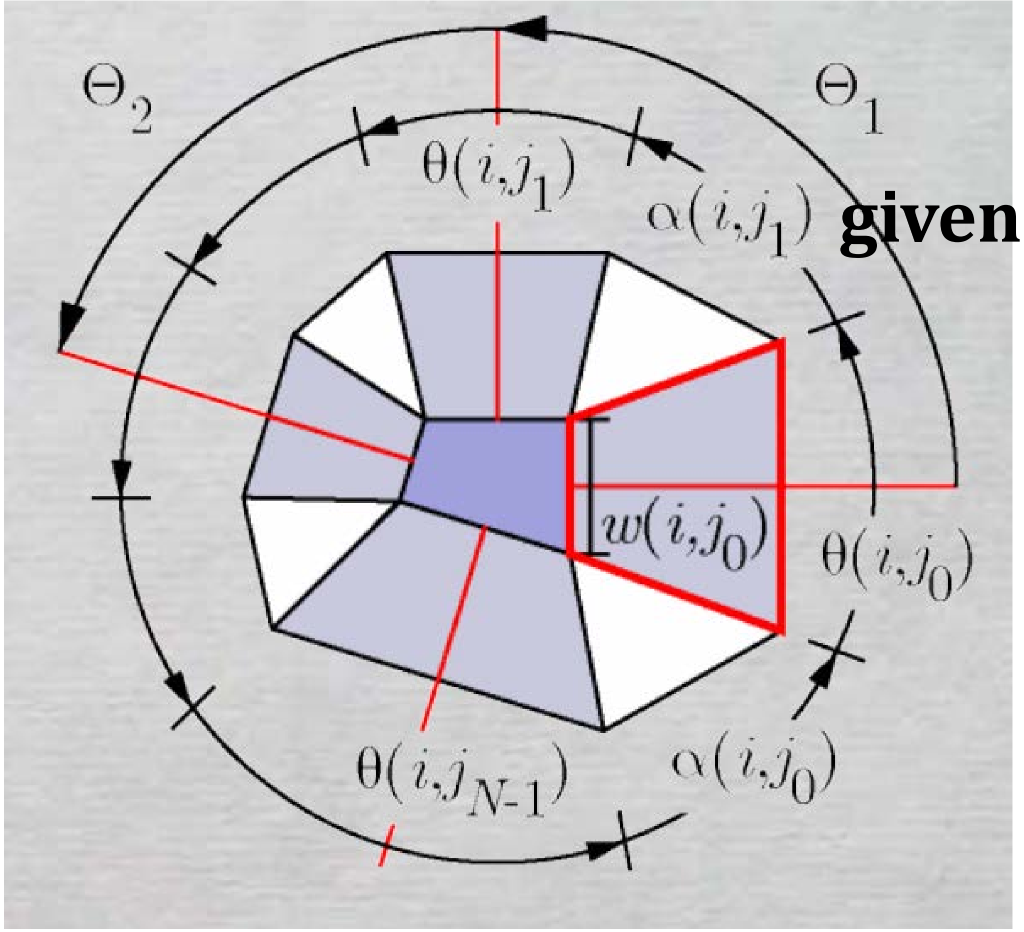


$$\theta(j,i) = -\theta(i,j)$$
$$w(j,i) = w(i,j) + 2\ell(i,j)\sin\tfrac{1}{2}\theta(i,j)$$



Closure around a vertex

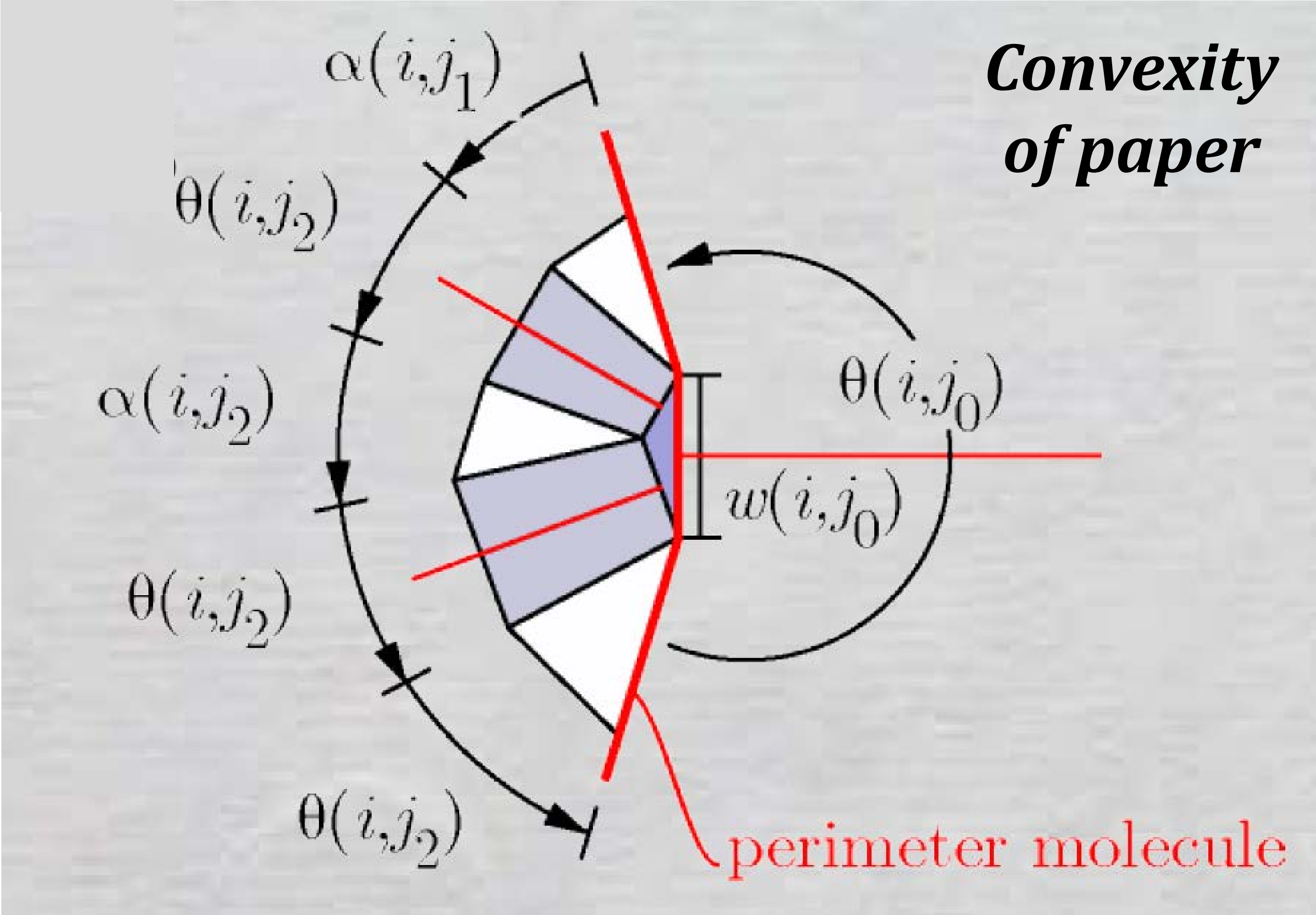
$$\sum_{k=0}^{N-1} \theta(i, j_k) = 360° - \sum_{k=0}^{N-1} \alpha(i, j_k)$$



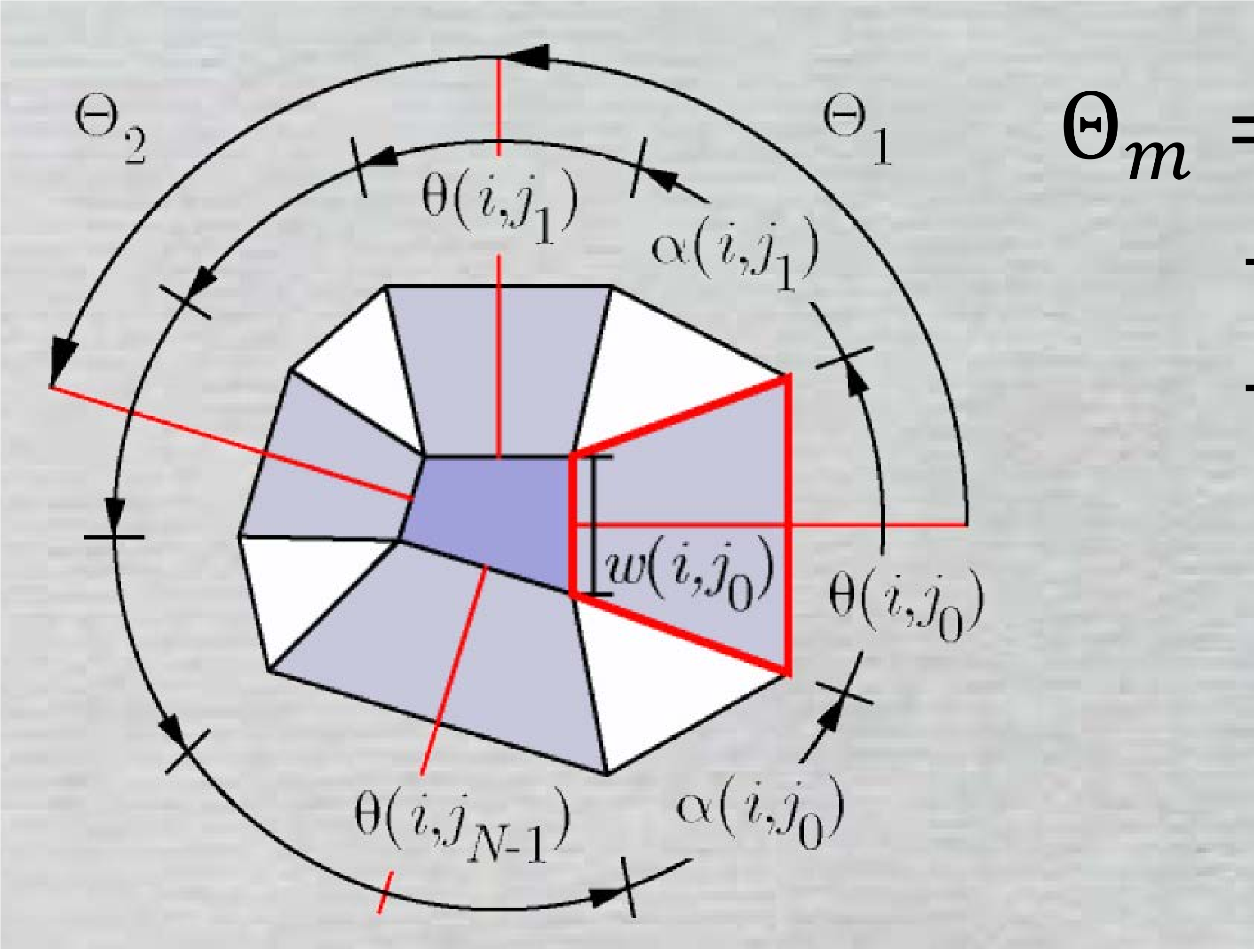
$$\Theta_m = \frac{1}{2}\theta(i, j_m) + \alpha(i, j_m) + \frac{1}{2}\theta(i, j_m)$$

Closure around a vertex

$$\sum_{k=0}^{N-1} w(i, j_k) \cdot \begin{bmatrix} \cos(\Theta_1 + \cdots + \Theta_k) \\ \sin(\Theta_1 + \cdots + \Theta_k) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$



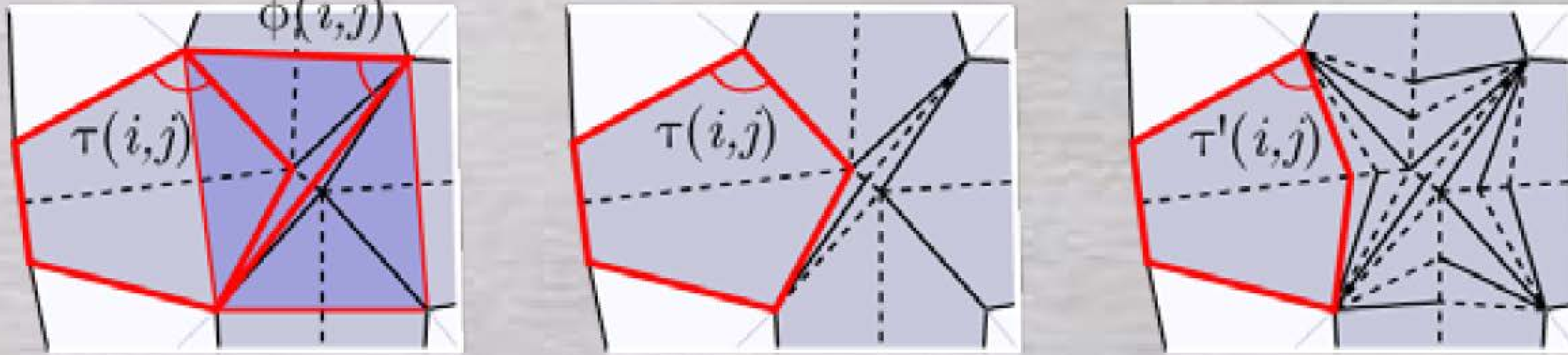
$$\theta(i, j_0) \geq 180°$$
$$w(i, j_0) \geq 0$$



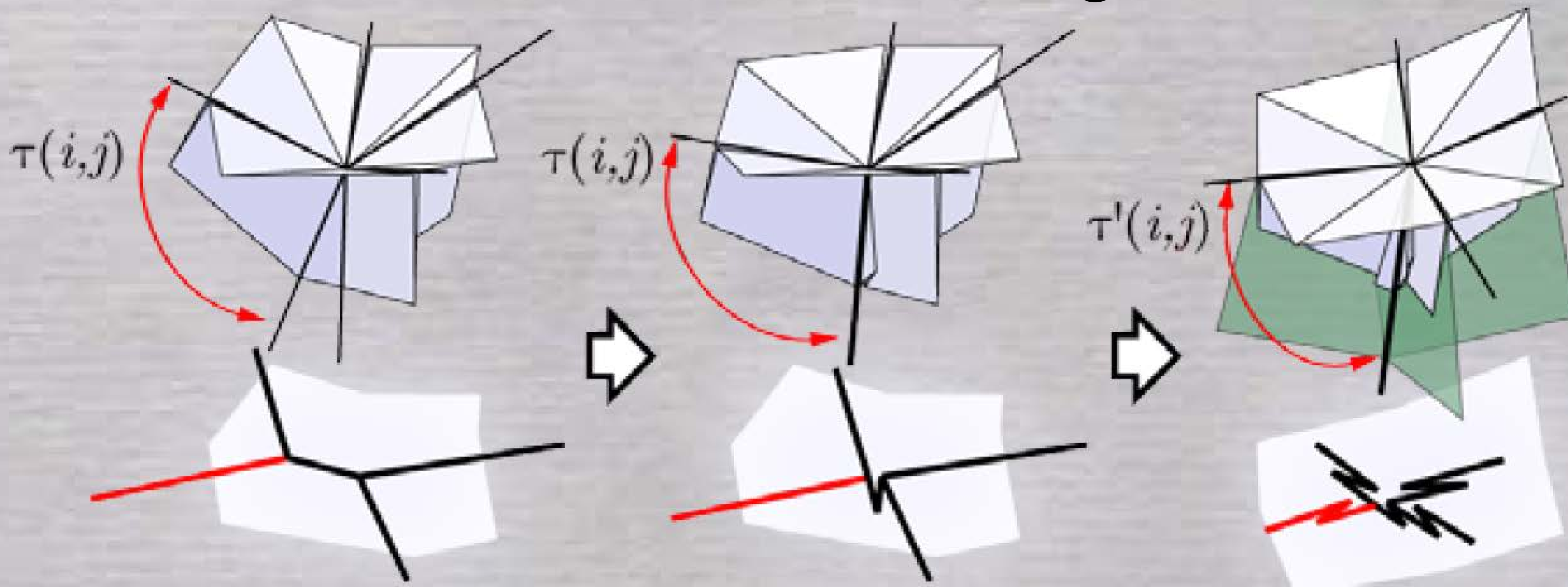
$$\Theta_m = \frac{1}{2}\theta(i, j_m) + \alpha(i, j_m) + \frac{1}{2}\theta(i, j_m)$$

Convexity of edge-tucking molecule

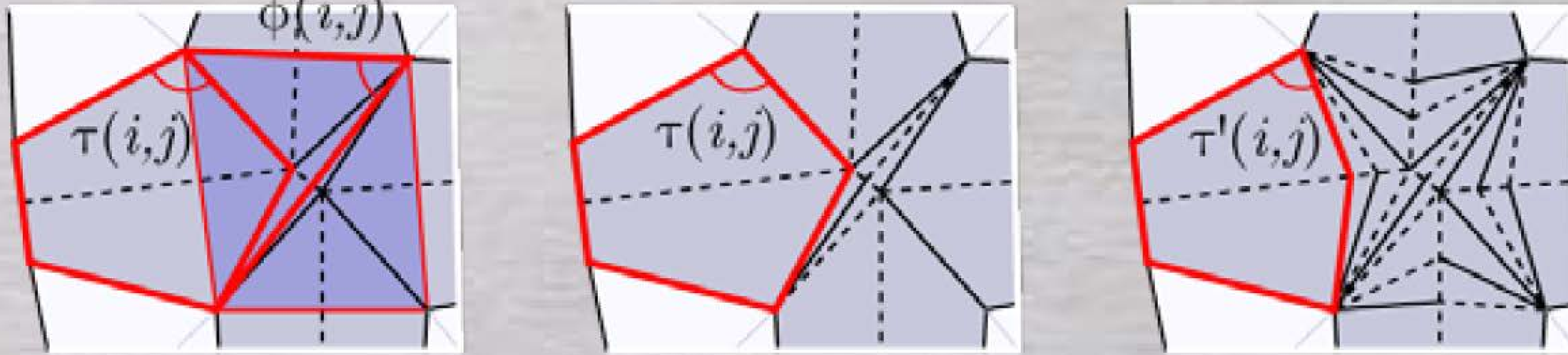
$$-180° \leq \theta(i,j) \leq 180°$$
$$0 \leq w(i,j)$$
$$0 \leq \Theta_m < 180°$$



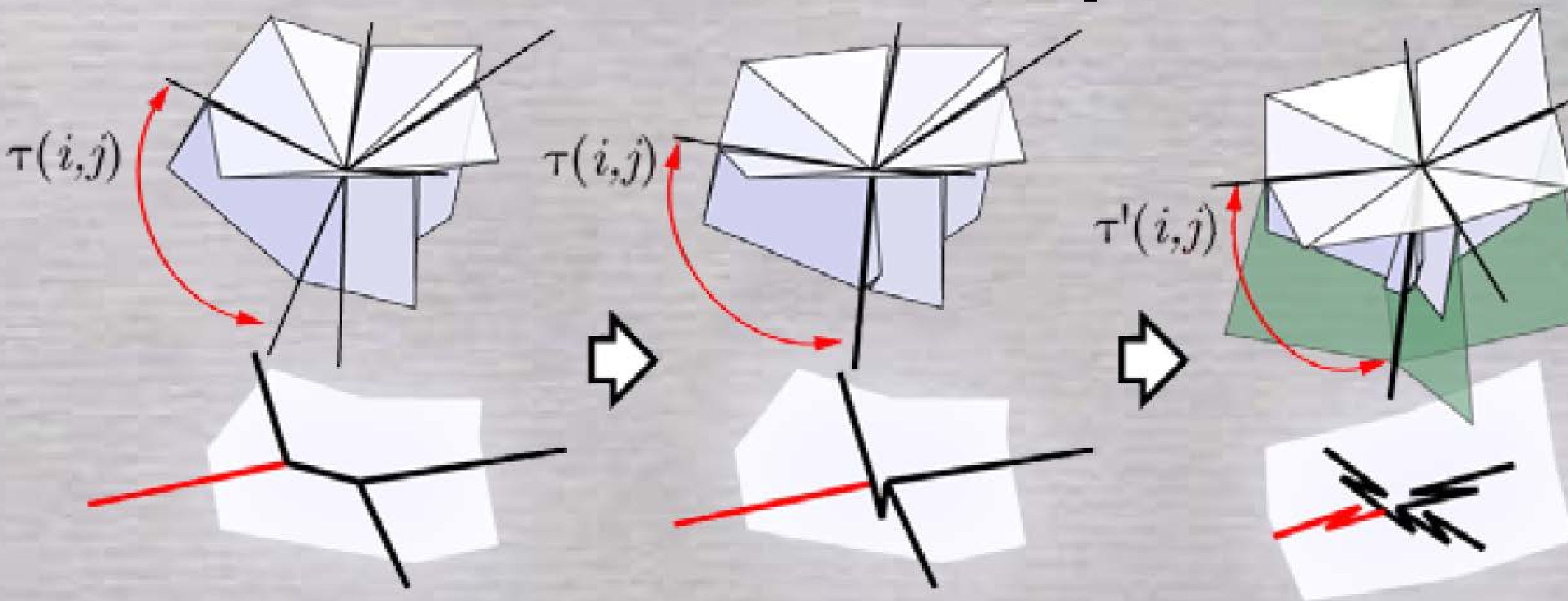
Tuck angle condition



$$\phi(i,j) - \frac{1}{2}\theta(i,j) \leq 180° - \tau'(i,j)$$



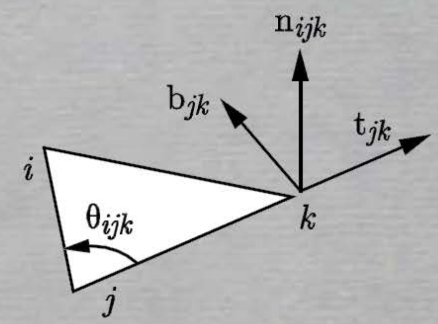
Tuck depth condition



$$w(i,j) \le 2\sin\left(\tau'(i,j) - \frac{1}{2}\alpha(i,j)\right) d'(i)$$

Can we work an example of building a linear system from the local constraints at vertices of an origami pattern, like those shown in the talk?

Solve Non-linear Equation



The infinitesimal motion satisfies:

$$\mathbf{C}\dot{\mathbf{X}} = \begin{bmatrix} \frac{\partial \mathbf{G}}{\partial \mathbf{X}} \\ \frac{\partial \mathbf{F}}{\partial \mathbf{X}} \\ \frac{\partial \mathbf{H}}{\partial \mathbf{X}} \end{bmatrix} \dot{\mathbf{X}} = \begin{bmatrix} \frac{\partial \mathbf{G}}{\partial \boldsymbol{\theta}} & \frac{\partial \mathbf{G}}{\partial \boldsymbol{\rho}} \\ \frac{\partial \mathbf{F}}{\partial \boldsymbol{\theta}} & \frac{\partial \mathbf{F}}{\partial \boldsymbol{\rho}} \\ \frac{\partial \mathbf{H}}{\partial \boldsymbol{\theta}} & \frac{\partial \mathbf{H}}{\partial \boldsymbol{\rho}} \end{bmatrix} \begin{bmatrix} \frac{\partial \boldsymbol{\theta}}{\partial \mathbf{X}} \\ \frac{\partial \boldsymbol{\rho}}{\partial \mathbf{X}} \end{bmatrix} \dot{\mathbf{X}} = \mathbf{0}$$

$$\mathbf{G}_v = 2\pi - \sum_{i=0}^{kv} \theta_i = 0$$

$$\mathbf{F}_v = \sum_{i=0}^{kv} \mathrm{sgn}(i)\theta_i = 0$$

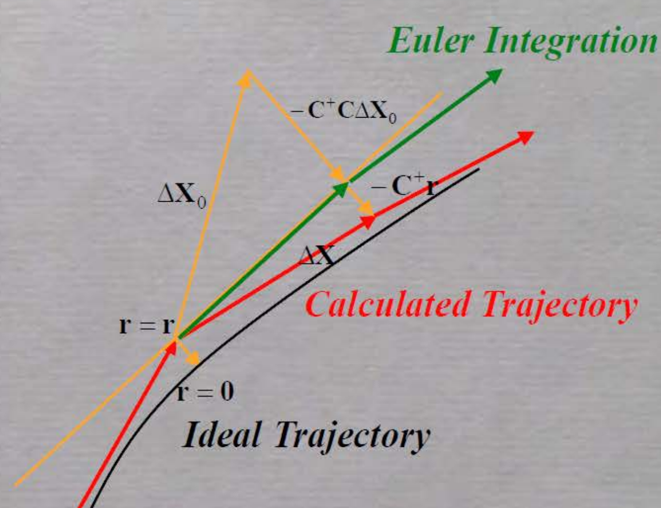
$$\frac{\partial \theta_{ijk}}{\partial \mathbf{x}_i} = -\frac{1}{\ell_{ij}} \mathbf{b}_{ij}^{\mathrm{T}}$$

$$\frac{\partial \theta_{ijk}}{\partial \mathbf{x}_j} = \frac{1}{\ell_{ij}} \mathbf{b}_{ij}^{\mathrm{T}} + \frac{1}{\ell_{jk}} \mathbf{b}_{jk}^{\mathrm{T}}$$

$$\frac{\partial \theta_{ijk}}{\partial \mathbf{x}_k} = -\frac{1}{\ell_{jk}} \mathbf{b}_{jk}^{\mathrm{T}}$$

For an arbitrarily given (through GUI)
Infinitesimal Deformation ΔX_0

$$\Delta \mathbf{X} = -\mathbf{C}^{+}\mathbf{r} + \left(\mathbf{I}_{3N_v} - \mathbf{C}^{+}\mathbf{C}\right)\Delta \mathbf{X}_0$$



When discussing flat-foldability [...], I didn't understand Professor Tachi's explanation about why we “don't need to worry about the NP-Complete part.”

In regards to applications in say manufacturing, would the entire process be do-able by a machine? I.e. making all the crimps etc. Otherwise, I guess it's a bit more of "print by machine, assemble by hand"?

Videos of folding metal from Devin Balkcom.
To view videos: http://www.cs.dartmouth.edu/~devin/movies/djb-origamihat-2004.mpg; http://www.cs.dartmouth.edu/~devin/movies/djb-airplane-2004.mov.

Video of Monolithic Bee from Harvard Microrobotics Lab.
To view videos: http://www.youtube.com/watch?v=VxSs1kGZQqc.

What are some of the main open problems on freeform or rigid origami?

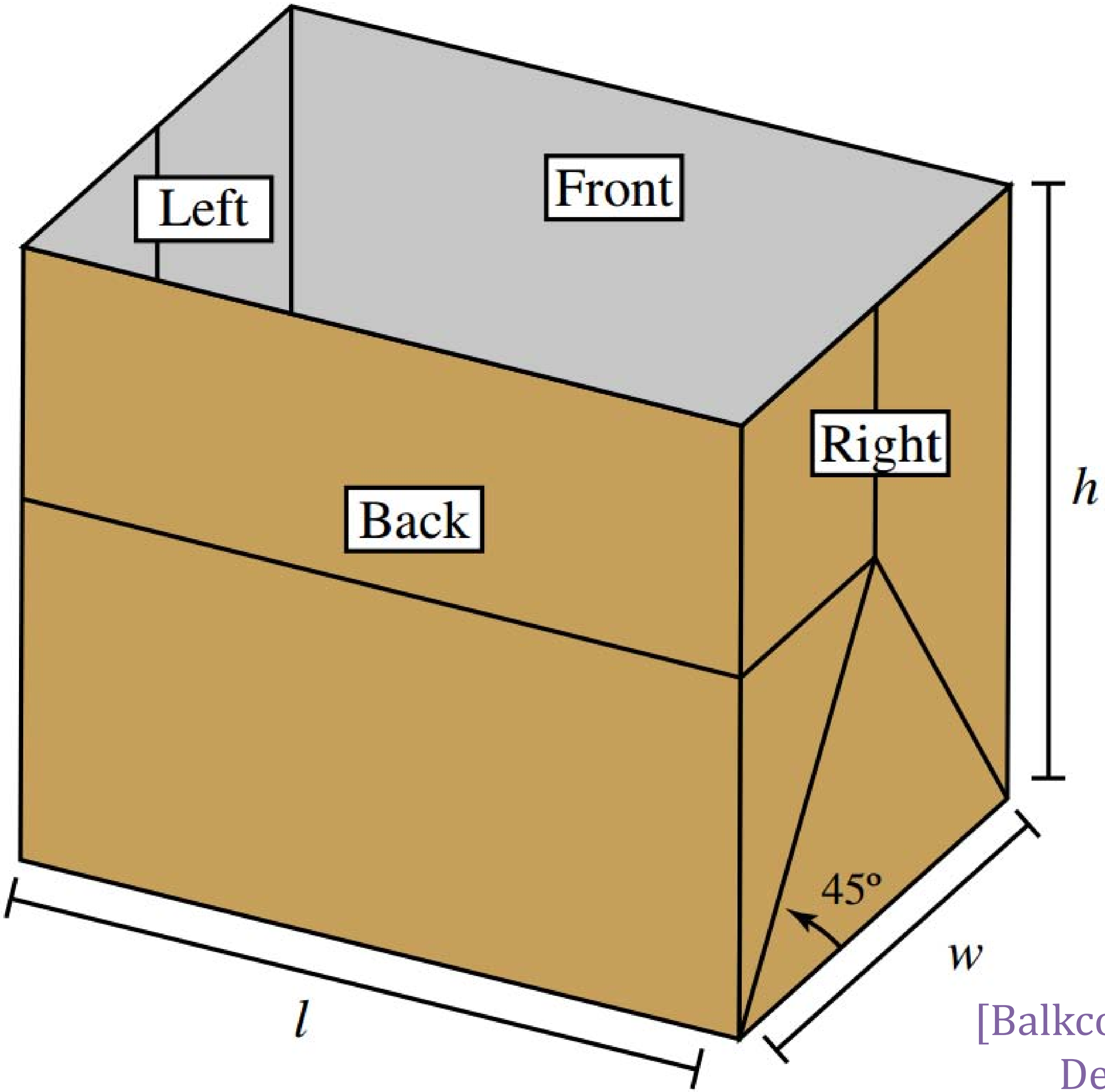
Photographs of Hexapot removed due to copyright restrictions.
Refer to: https://www.kickstarter.com/projects/839545867/hexa-pottm-indoor-outdoor-disposable-paper-cooking.

Images removed due to copyright restrictions.
Refer to: Diagrams (p. 14 and 16) from Hyde, Rob. "A Giant Leap for Space Telescopes." *Science & Technology Review* (2003): 12–8.

Photograph of Robert J. Lang and his telescope prototype removed due to copyright restrictions.
Refer to: Bell, Susan. "Know How to Fold 'Em: How Origami Changed Science, From Heart Stents to Airbags," *LA Weekly*, April 26, 2012.

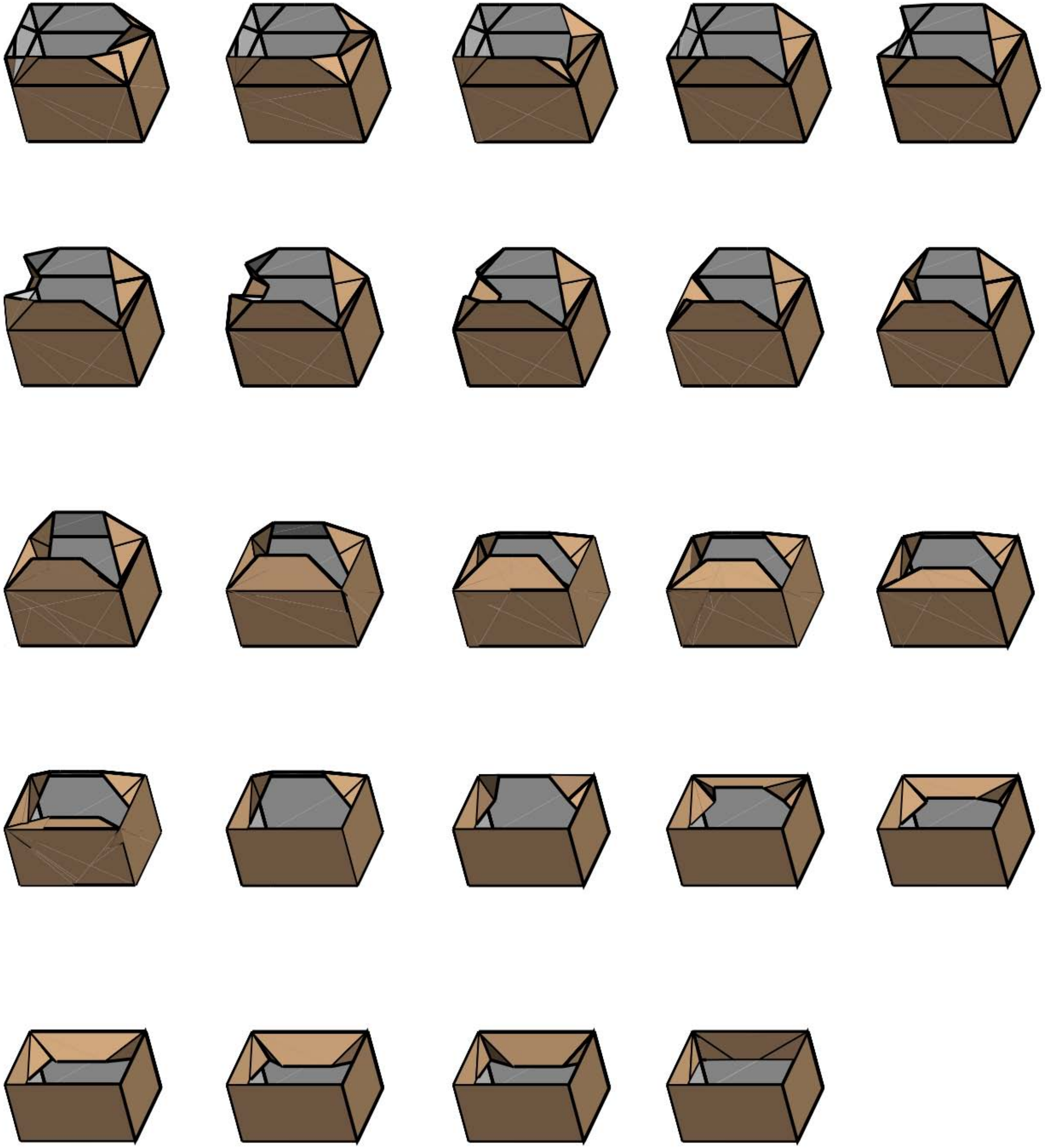
Courtesy of Zhong You, and Kaori Kuribayashi. Used with permission.

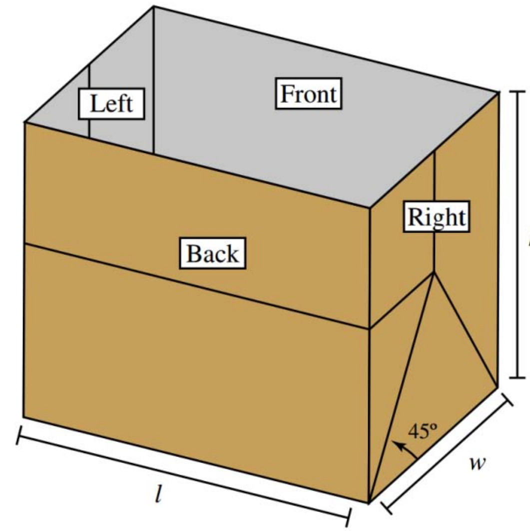
[You & Kuribayashi 2003]



[Balkcom, Demaine,
Demaine 2004]

Image of tall bag crease pattern and partial fold removed due to copyright restrictions.
Refer to: Fig. 8 from Balkcom, Devin J., Erik D. Demaine, et al. "Folding Paper Shopping Bags." *Origami4: Proceedings of the 4th International Meeting of Origami Science, Math, and Education* (2006): 315–34.





Courtesy of Devin J. Balkcom, Erik D. Demaine, and Martin L. Demaine. Used with permission.

[Balkcom, Demaine, Demaine 2004]

Image of twist folding of a cubical bag removed due to copyright restrictions.
Refer to: Fig. 10 from Balkcom, Devin J., Erik D. Demaine, et al. “Folding Paper Shopping Bags." *Origami4: Proceedings of the 4th International Meeting of Origami Science, Math, and Education* (2006): 315–34.

Illustrations and photographs of rigid folding of bag removed due to copyright restrictions.
Refer to: Fig. 6 from Wu, Weina, and Zhong You. "A Solution for Folding Rigid Tall Shopping Bags." *Proceedings of the Royal Society A* 467, no. 2133 (2011): 2561–74.

Illustrations and photographs of rigid folding of bag removed due to copyright restrictions.
Refer to: Fig. 7 from Wu, Weina, and Zhong You. "A Solution for Folding Rigid Tall Shopping Bags." *Proceedings of the Royal Society A* 467, no. 2133 (2011): 2561–74.

Has anyone considered origami patterns that use a subset of the folds to create a particular shape A, then use another subset to crease particular shape B? Ideally, the number of folds used in both A and B is a significant portion of the total folds.

[+] **Universal hinge patterns:** box pleating, polycubes; orthogonal maze folding.
NP-hardness: introduction, reductions; simple foldability; crease pattern flat foldability; disk packing (for tree method).

Download Video: 360p, 720p

Slides, page 2/20 • [previous page] • [next page] • [PDF]
Video times: • 5:39–7:13 • 7:36–7:47 • 9:42–15:03

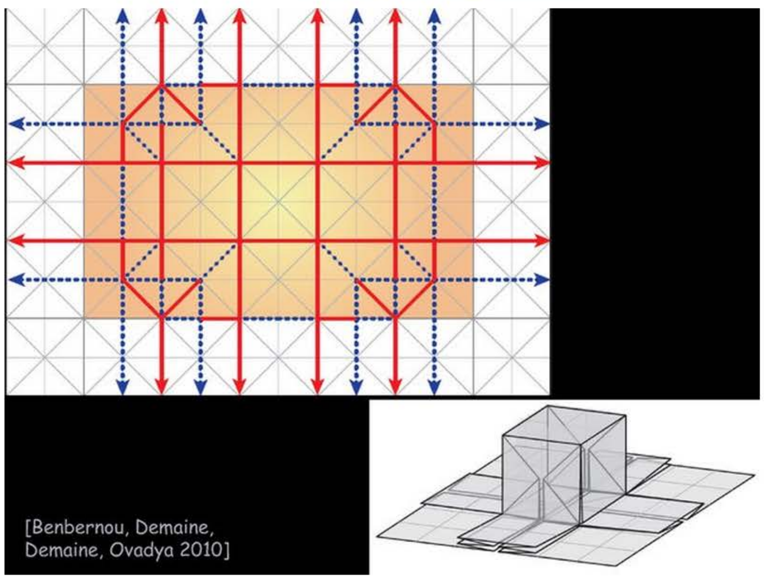
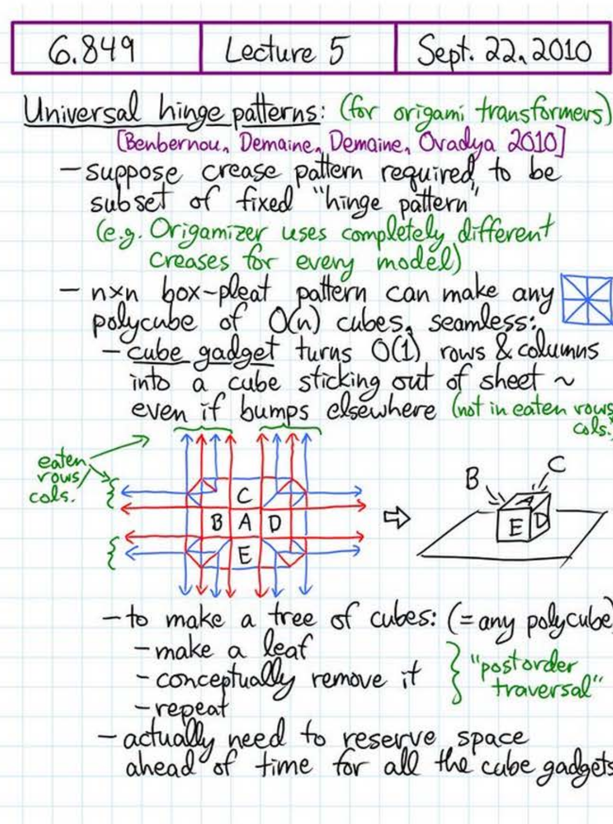


Figure 1-2 of Aviv Ovadya's MEng thesis

Handwritten notes, page 1/7 • [previous page] • [next page] • [PDF]
Video times: • 1:27–13:43



6.849	Lecture 5	Sept. 22, 2010

Universal hinge patterns: (for origami transformers)
[Benbernou, Demaine, Demaine, Ovadya 2010]
- suppose crease pattern required to be subset of fixed "hinge pattern"
  (e.g. Origamizer uses completely different creases for every model)
- n×n box-pleat pattern can make any polycube of O(n) cubes, seamless:
  - cube gadget turns O(1) rows & columns into a cube sticking out of sheet ~ even if bumps elsewhere (not in eaten rows/cols.)

- to make a tree of cubes: (= any polycube)
  - make a leaf
  - conceptually remove it } "postorder traversal"
  - repeat
- actually need to reserve space ahead of time for all the cube gadgets

Handwritten notes, page 1/7 • [previous page] • [next page] • [PDF]