Crease pattern of Mooser's Train removed due to copyright restrictions. Refer to: Fig. 12.4 from Lang, Robert J. *Origami Design Secrets: Mathematical Methods for an Ancient Art*. 2nd ed. A K Peters / CRC Press, 2011.



Courtesy of Robert J. Lang. Used with permission.

folding by Robert Lang

Crease pattern of Mooser's Train removed due to copyright restrictions. Refer to: Fig. 12.4 from Lang, Robert J. *Origami Design Secrets: Mathematical Methods for an Ancient Art*. 2nd ed. A K Peters / CRC Press, 2011.



Robert Lang, 1987





## Are there known universal hinge patterns to build polysome-other-shapes-that-arenot-cubes?

Folded state of box-please gadget removed due to copyright restrictions.



Courtesy of Erik Demaine, Martin Demaine, and Sarah Stengle. Used with permission.

Yes/No

Demaine, Demaine, Stengle 2011





Courtesy of Erik Demaine, and Martin Demaine. Used with permission.

Science/Art

#### Demaine & Demaine, 2011





Martin Gardner

Demaine, Demaine 2012

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#### Demaine & Demaine, 2012<sub>8</sub>

## I didn't understand the point of NP-hardness. Are there examples of actual problems that can't be calculated?

# Could we go through one of the NP proofs with a little less hand waving?



[Arkin, Bender, Demaine, Demaine, Mitchell, Sethia, Skiena 2000] 11

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[Arkin, Bender, Demaine, Demaine, Mitchell, Sethia, Skiena 2000] 12

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### **Minor question: in the** orthogonal paper reduction, doesn't this require not folding some of the creases, if we want to make 2 consecutive strips the same direction?



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[Bern & Hayes 1996] <sub>14</sub>



[Bern & Hayes 1996] <sub>15</sub>

### In the reflector gadget, it looks like all the left sides of the wires, where left is taken relative to the free end of the wire, are equal. How does the reflector negate one of them, then?



Image by MIT OpenCourseWare.

It looks like the global flat foldability proof proves that globally flat-foldable  $\Rightarrow$  NAE satisfiability  $\Rightarrow$  locally flat-foldable, but I don't see where NAE satisfiability  $\Rightarrow$  globally flat-foldable. (It looks like all that matters is the order of sheets, though, and that those all work out.)



[Bern & Hayes 1996] <sub>18</sub>

# For global flat foldability, I understand how the gadgets prove (1), but how do they prove (2)?

<u>Clobal flat foldability</u>: [Bern & Hayes 1996] Deciding flat foldability of given crease pattern is strongly NP-hard Constructing valid layer ordering for given flat-foldable mountain-valley pattern is strongly NP-hard



#### **NAE clause**



[Bern & Hayes 1996]

<u>2D map folding</u>: [Arkin et al 2004] Is rectangular paper with axis-parallel creases again every crease pattern is flat foldable: Zig-Zag in x then y OPEN: characterize flat-foldable mountain-valley patterns — even 2×n! [Edmonds 1997] in 2D: Simple folds are not as powerful (in contrast to 1D, where we can simulate crimp/end folds) Yv Xv



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### top edge view



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### SSESNSNSWSNWNSN

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