Has the conjecture based on “fractal paper” been resolved?

Construction of Common Unfolding of a Regular Tetrahedron and a Cube

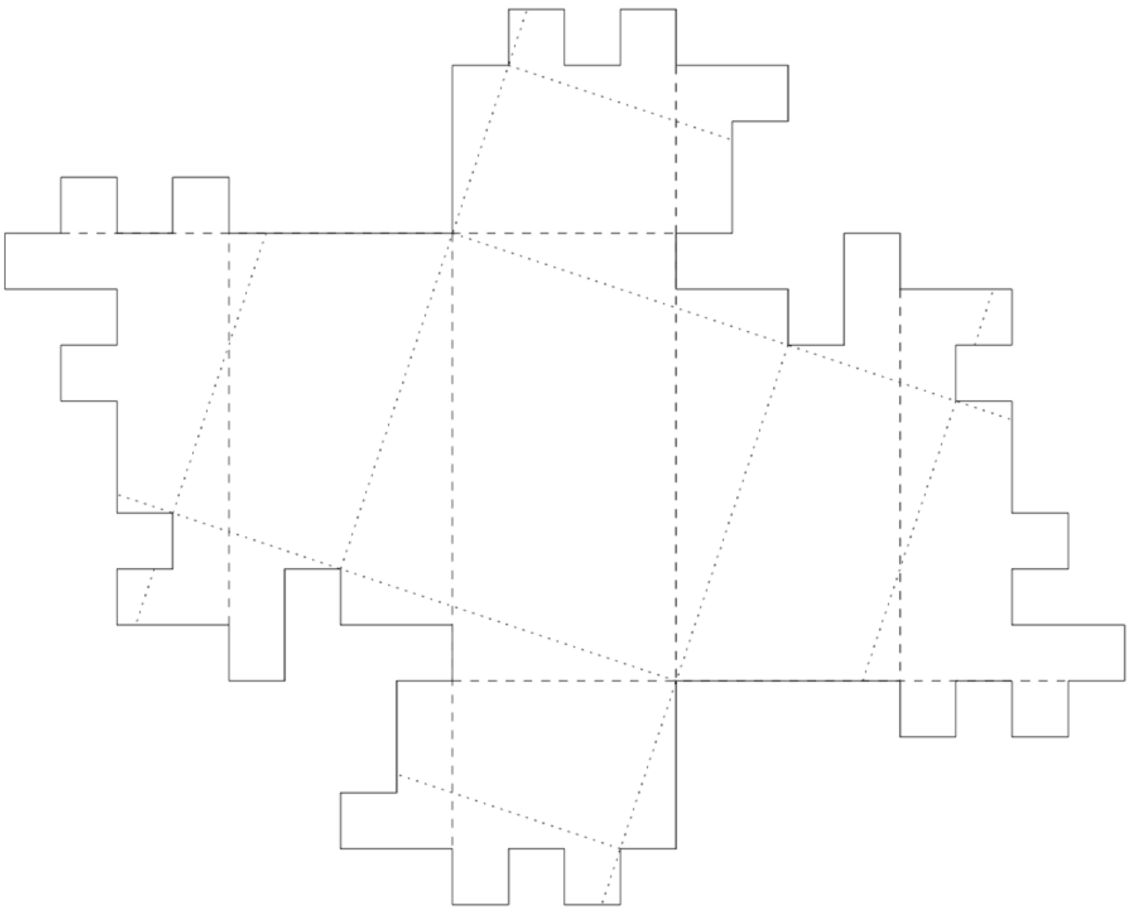
Toshihiro Shirakawa* Takashi Horiyama† Ryuhei Uehara‡

Any new results in a net for 3 different boxes?

CCCG 2011, Toronto ON, August 10–12, 2011

Common Developments of Several Different Orthogonal Boxes

Zachary Abel* Erik Demaine† Martin Demaine‡ Hiroaki Matsui§ Günter Rote¶ Ryuhei Uehara||



Common unfolding of
$4 \times 4 \times 8$ box and
$\sqrt{10} \times 2\sqrt{10} \times 2\sqrt{10}$ box

[Abel, Demaine, Demaine, Matsui, Rote, Uehara 2011]

Common Developments of Several Different Orthogonal Boxes

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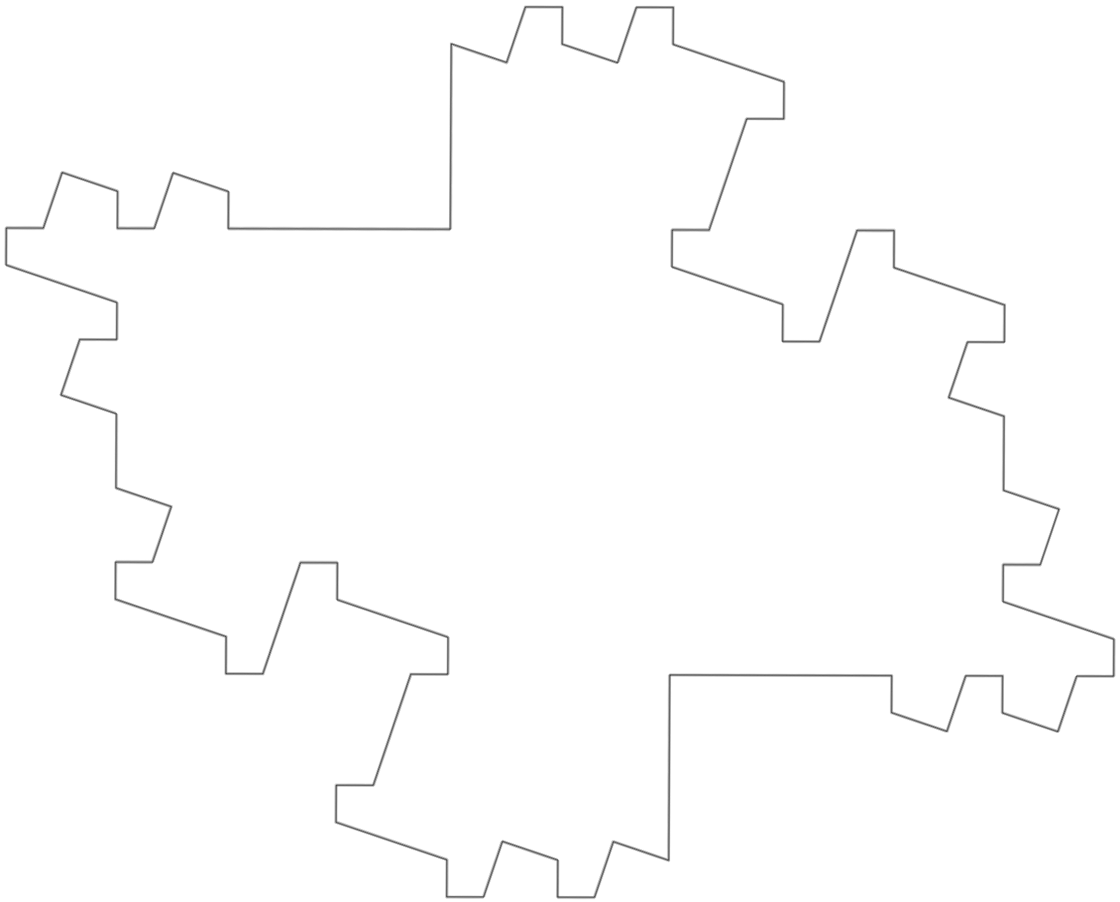

Common unfolding of
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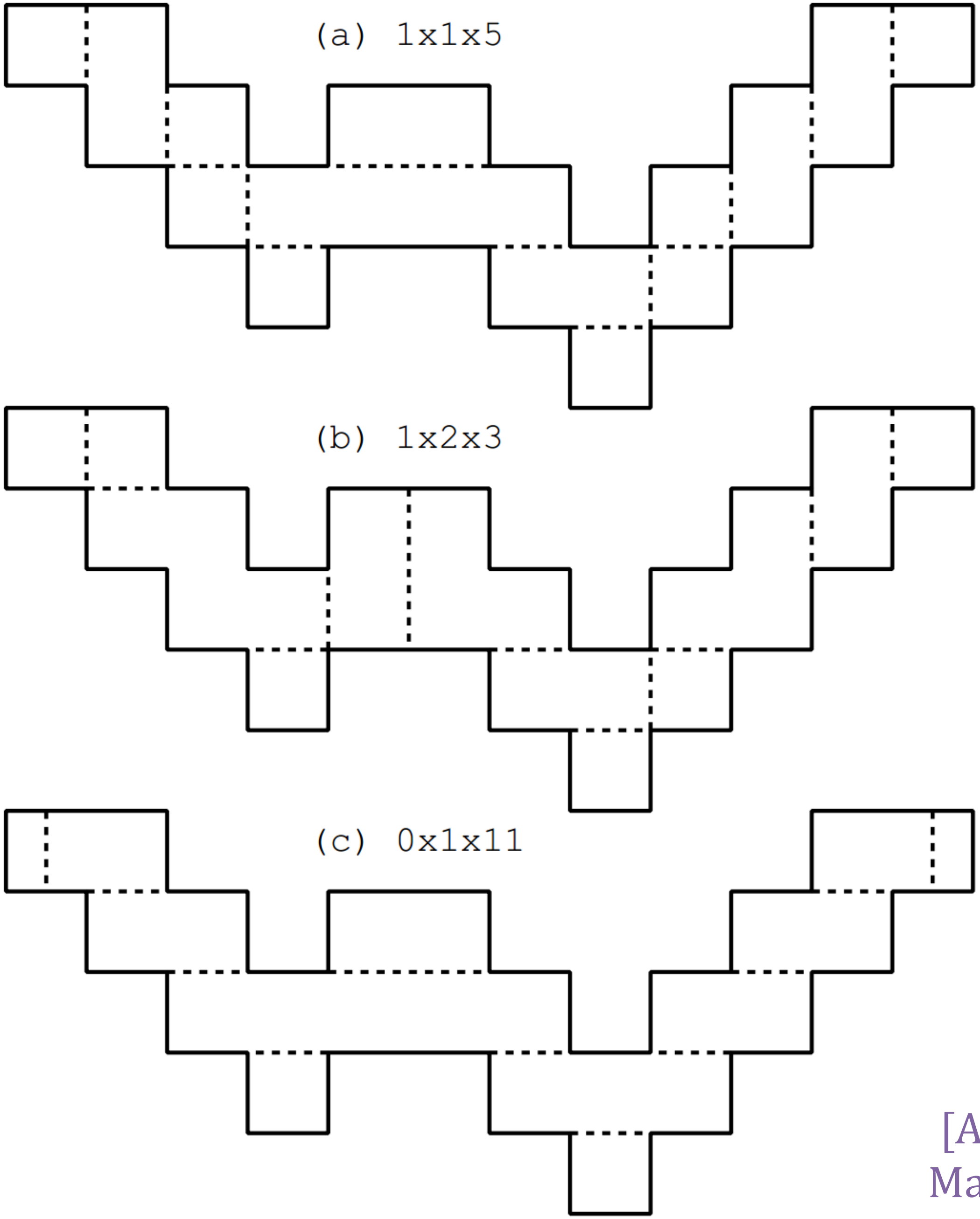


[Abel, Demaine, Demaine, Matsui, Rote, Uehara 2011]

Input : None;
Output: Polygons that consist of 22 squares and fold to boxes of size $1 \times 1 \times 5$ and $1 \times 2 \times 3$;

```
let L_1 be a set of one unit square;
for i = 2, 3, 4, ..., 22 do
    L_i := ∅;
    for each common partial development P in L_{i-1} do
        for every polygon P^+ of size i obtained by attaching a unit square to P do
            check if P^+ is a common partial development, and add it into L_i if it is a new one;
        end
    end
end
output L_22;
```

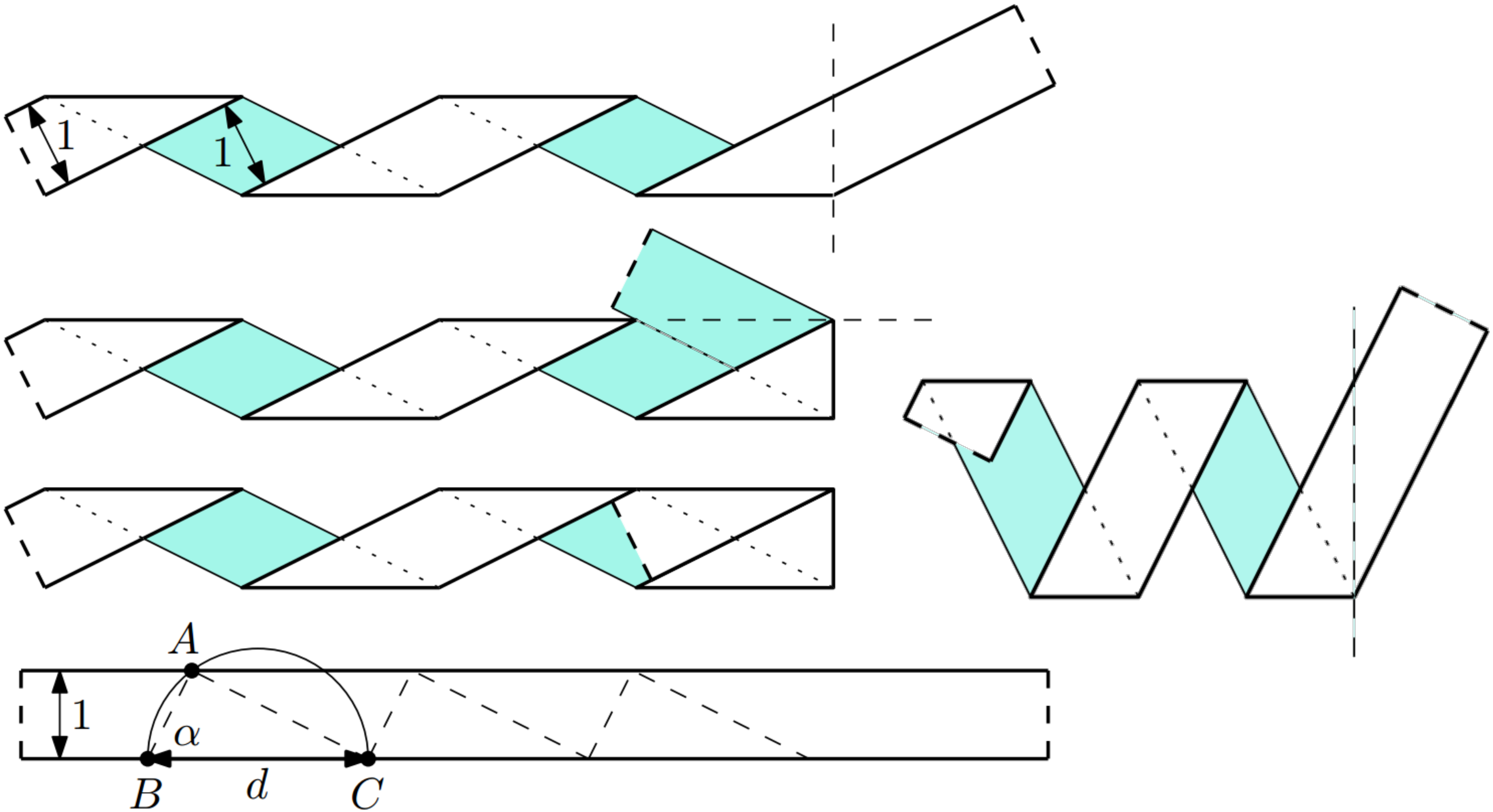
[Abel, Demaine, Demaine, Matsui, Rote, Uehara 2011]

i	1	2	3	4	5	6	7	8	9
L_i	1	1	2	5	12	35	108	368	1283
i-ominos	1	1	2	5	12	35	108	369	1285

i	10	11	12	13	14
L_i	4600	16388	57439	193383	604269
i-ominos	4655	17073	63600	238591	901971

i	15	16	17	18
L_i	1632811	3469043	5182945	4917908
i-ominos	3426576	13079255	50107909	192622052

i	19	20	21	22
L_i	2776413	882062	133037	2263



[Abel, Demaine, Demaine, Matsui, Rote, Uehara 2011]

Common Developments of Three Different Orthogonal Boxes

Toshihiro Shirakawa   Ryuhei Uehara*

Abstract

We investigate common developments that can fold into plural incongruent orthogonal boxes. It was shown that there are infinitely many orthogonal polygons that fold into two incongruent orthogonal boxes in 2008. In 2011, it was shown that there exists an orthogonal polygon that folds into three boxes of size $1 \times 1 \times 5$, $1 \times 2 \times 3$, and $0 \times 1 \times 11$. It remained open whether there exists an orthogonal polygon that folds into three boxes of positive volume. We give an affirmative answer to this open problem: there exists an orthogonal polygon that folds into three boxes of size $7 \times 8 \times 56$, $7 \times 14 \times 38$, and $2 \times 13 \times 58$. The construction idea can be generalized, and hence there exists an infinite number of orthogonal polygons that fold into three incongruent orthogonal boxes.

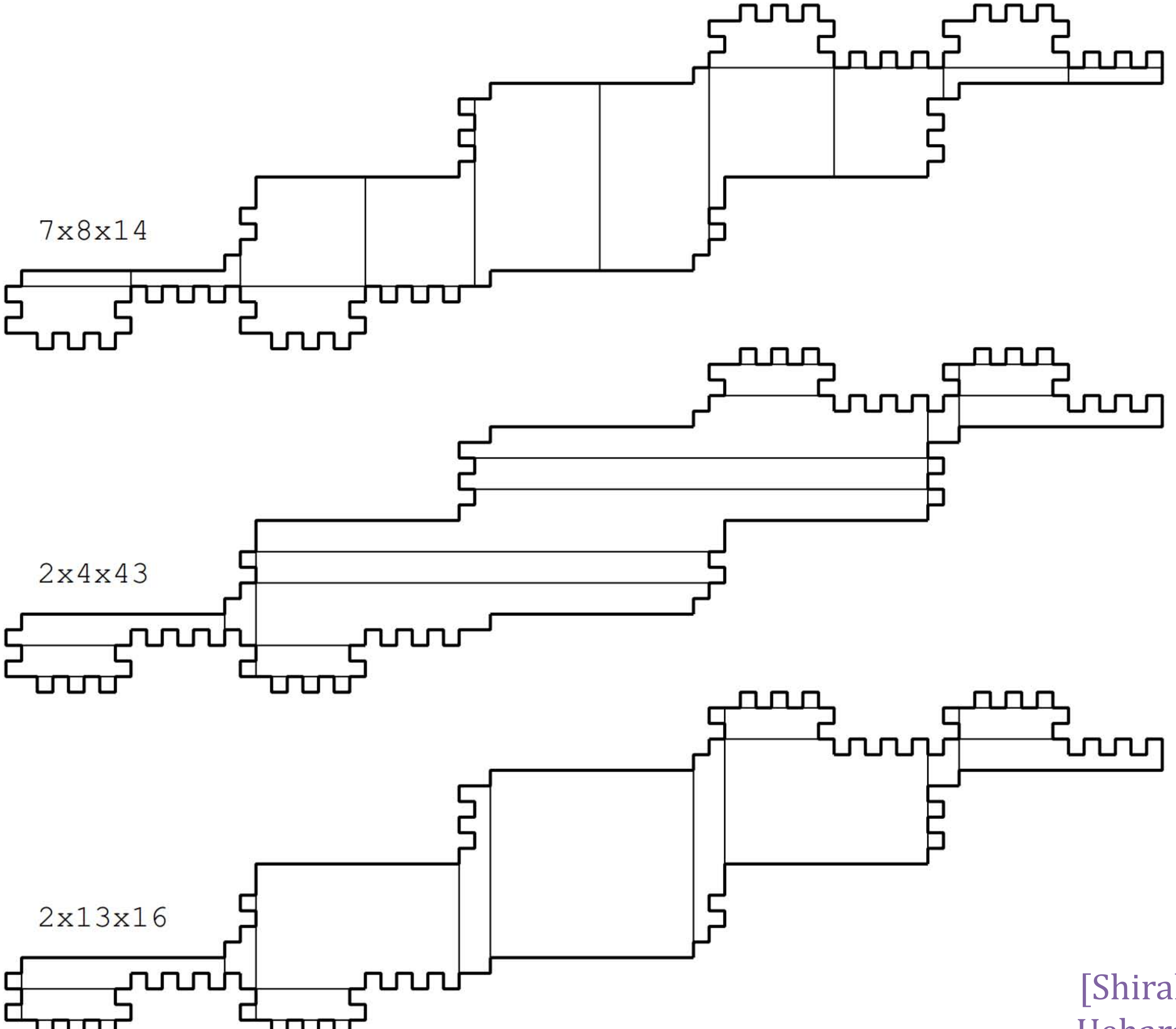
1 Introduction

Since Lubiw and O'Rourke posed the problem in 1996

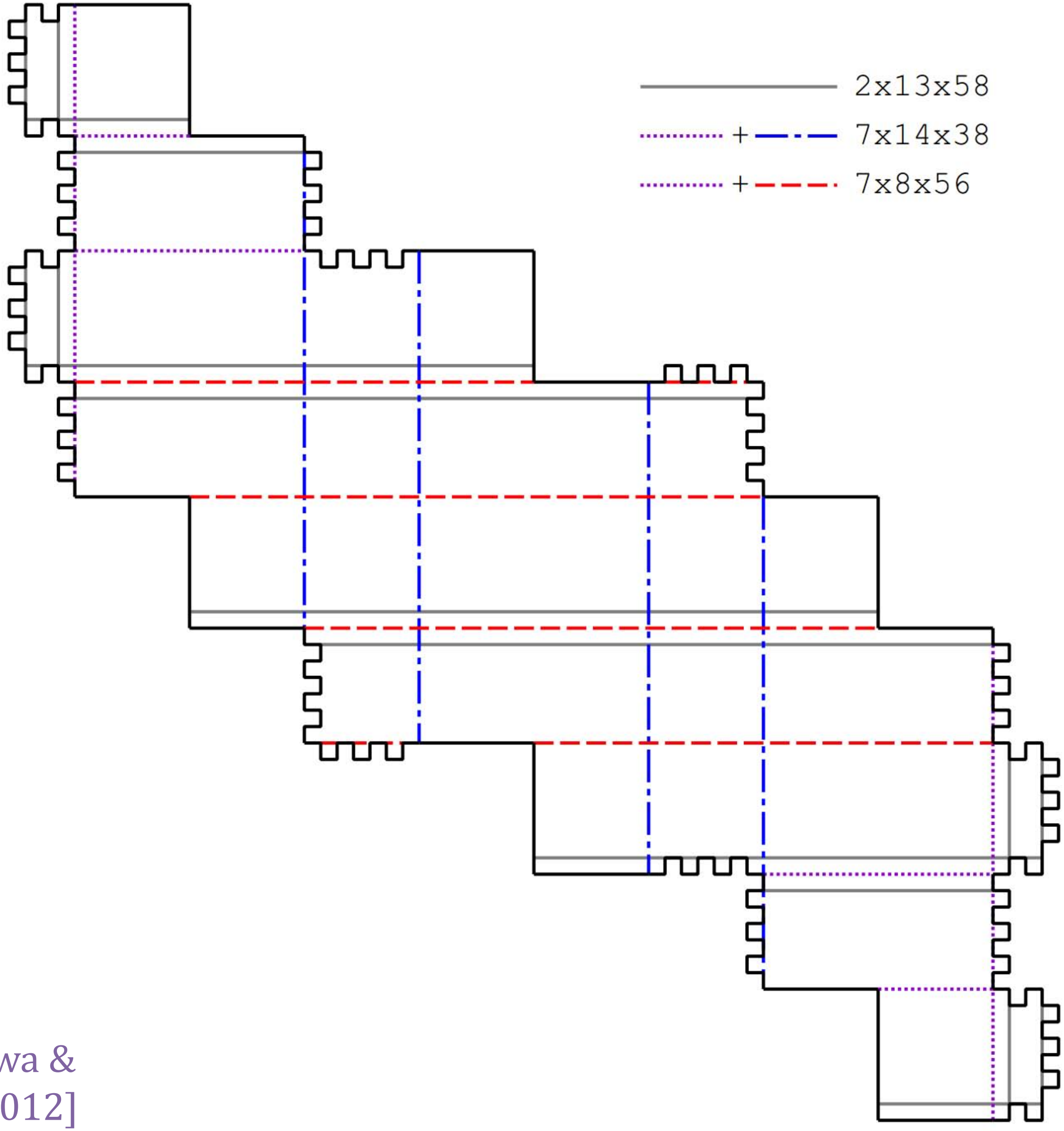
Figure 1: Cubigami.

three incongruent orthogonal boxes of size $7 \times 8 \times 56$, $7 \times 14 \times 38$, and $2 \times 13 \times 58$ (Figure 2)[1].

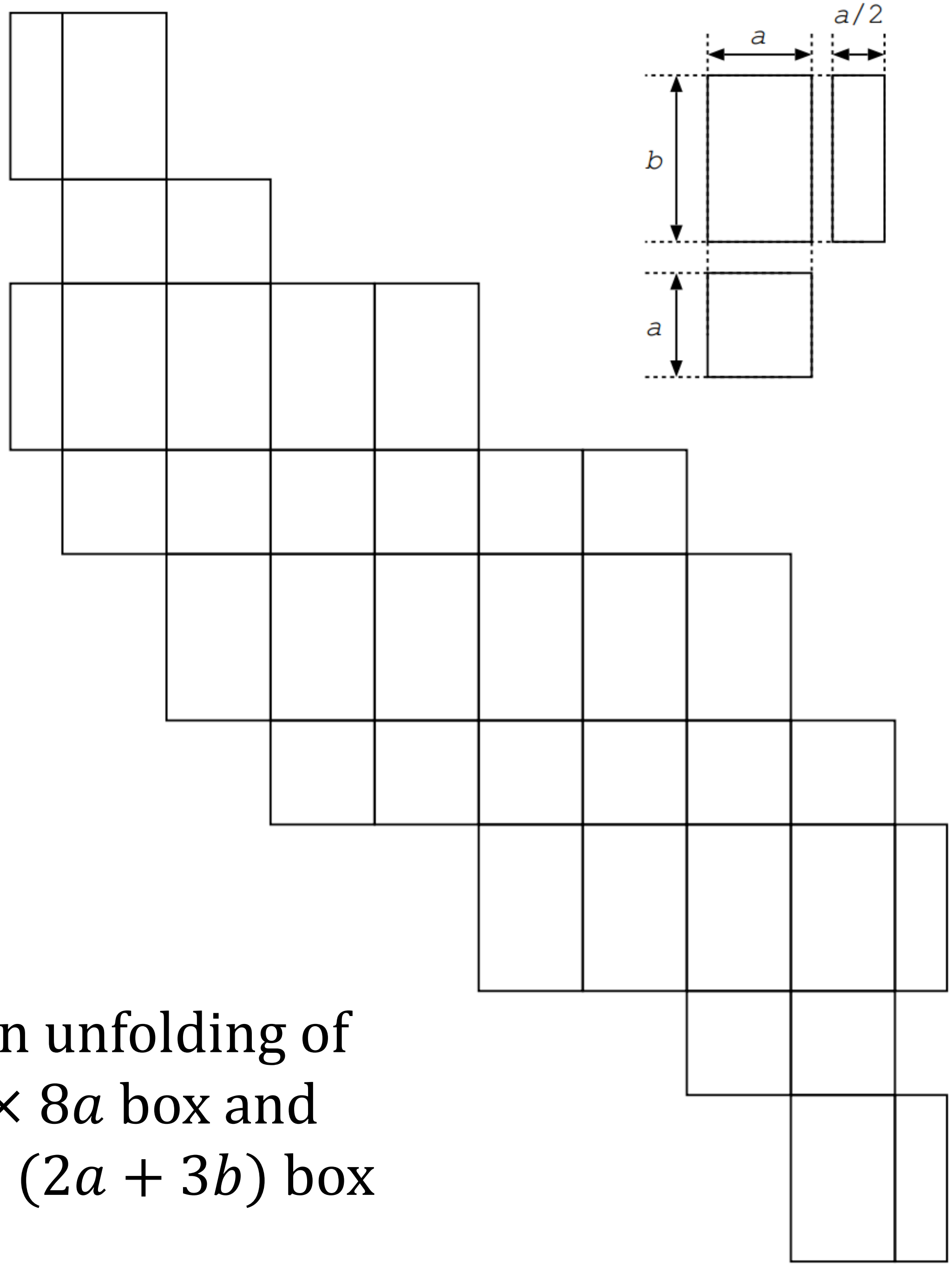
The construction idea can be generalized. Therefore, we conclude that there exist infinitely many orthogonal polygons that can fold into three incongruent orthogo-



[Shirakawa & Uehara 2012]

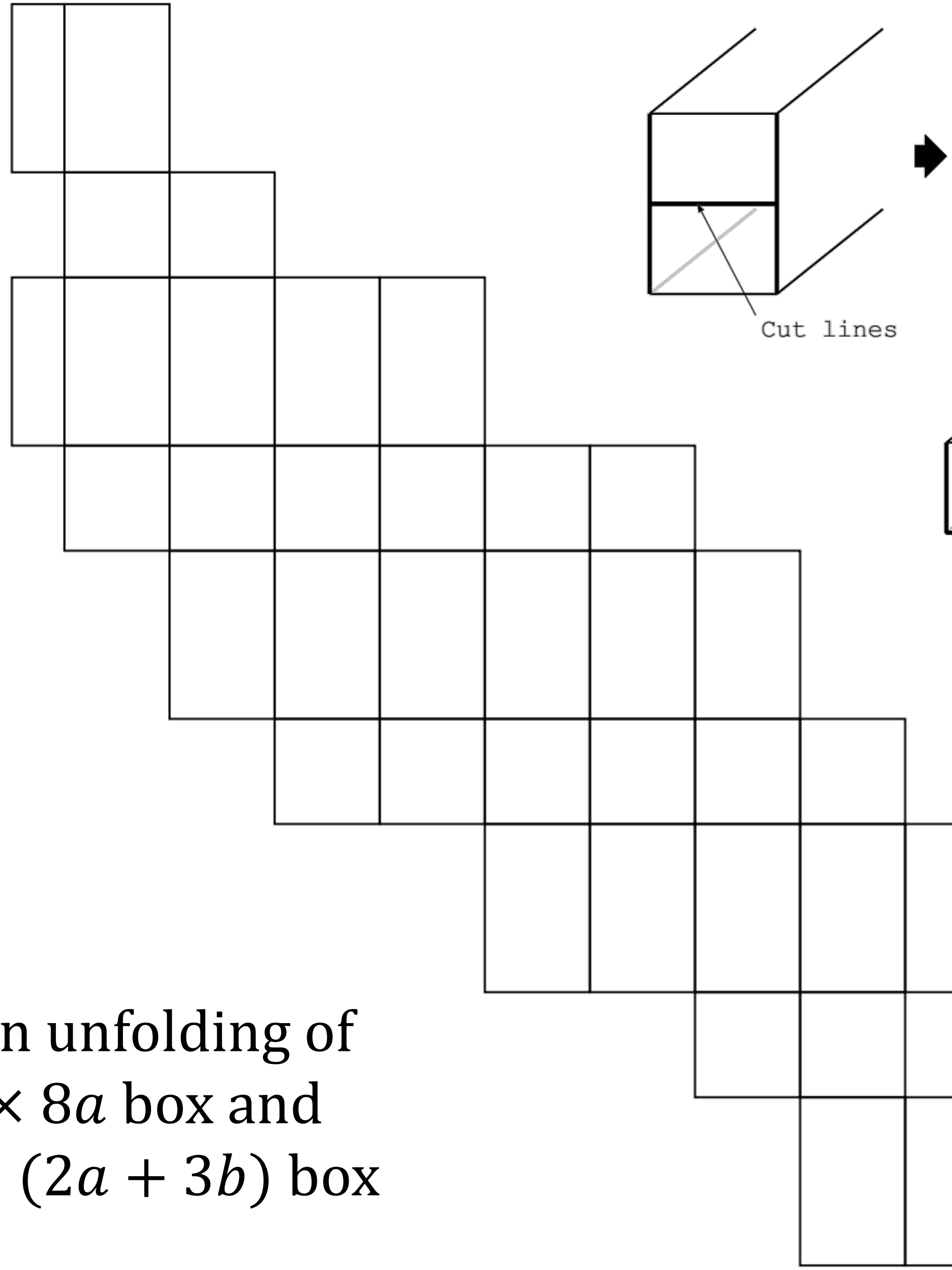


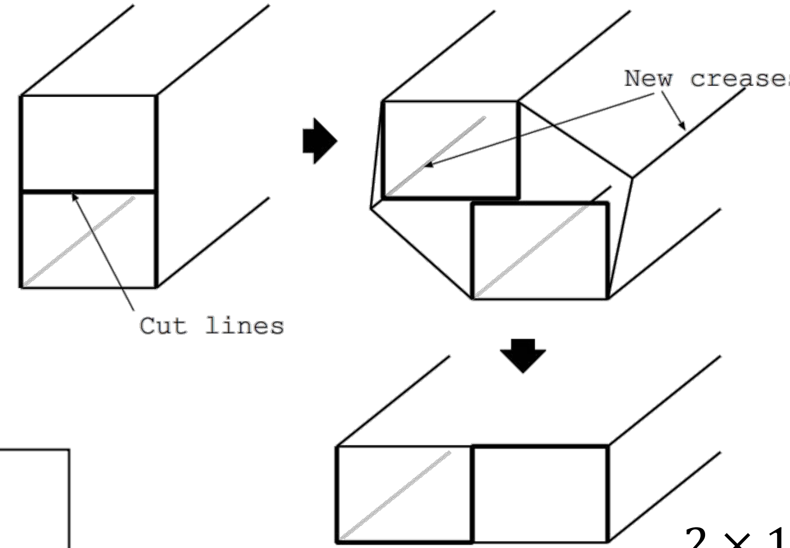
[Shirakawa & Uehara 2012]



Common unfolding of
$a \times b \times 8a$ box and
$a \times 2a \times (2a + 3b)$ box

[Shirakawa & Uehara 2012]



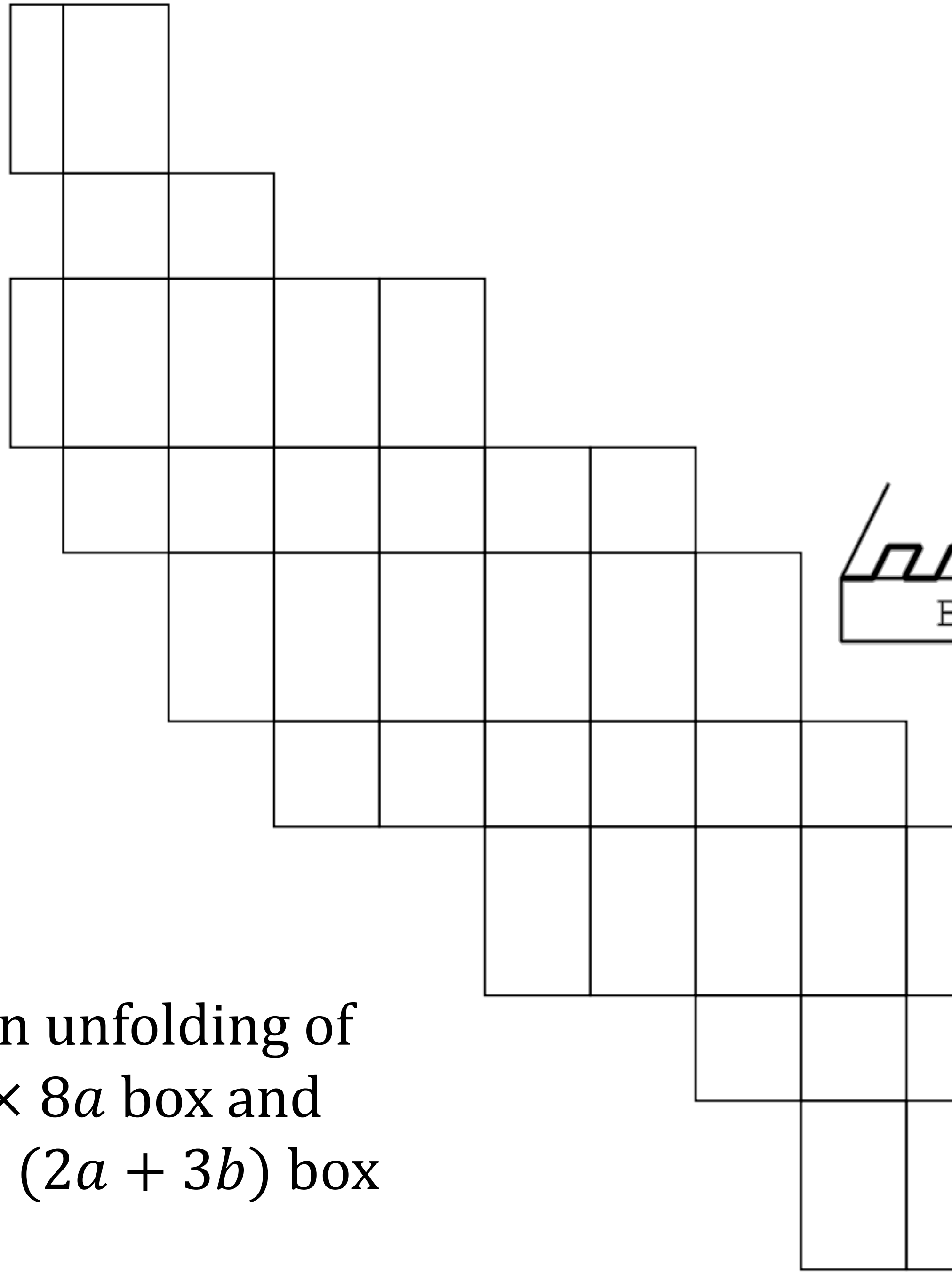


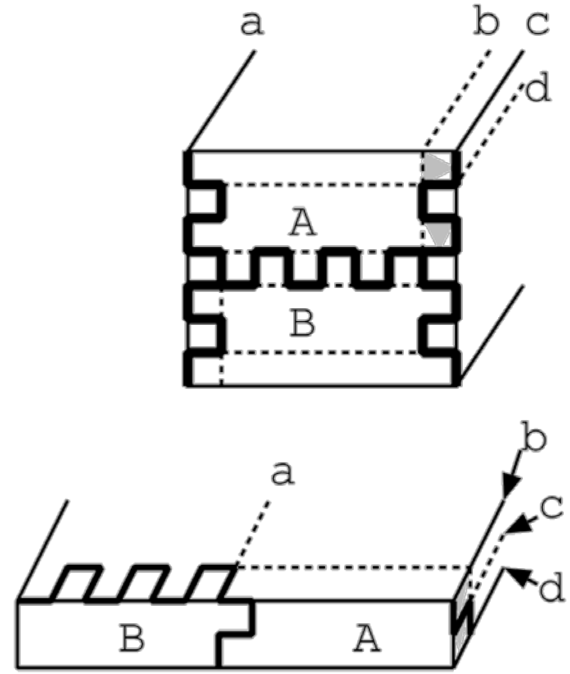
2×1
$\rightarrow 1 \times 2$

Common unfolding of
$a \times b \times 8a$ box and
$a \times 2a \times (2a + 3b)$ box

[Shirakawa & Uehara 2012]

Courtesy of Toshihiro Shirakawa and Ryuhei Uehara. Used with permission.

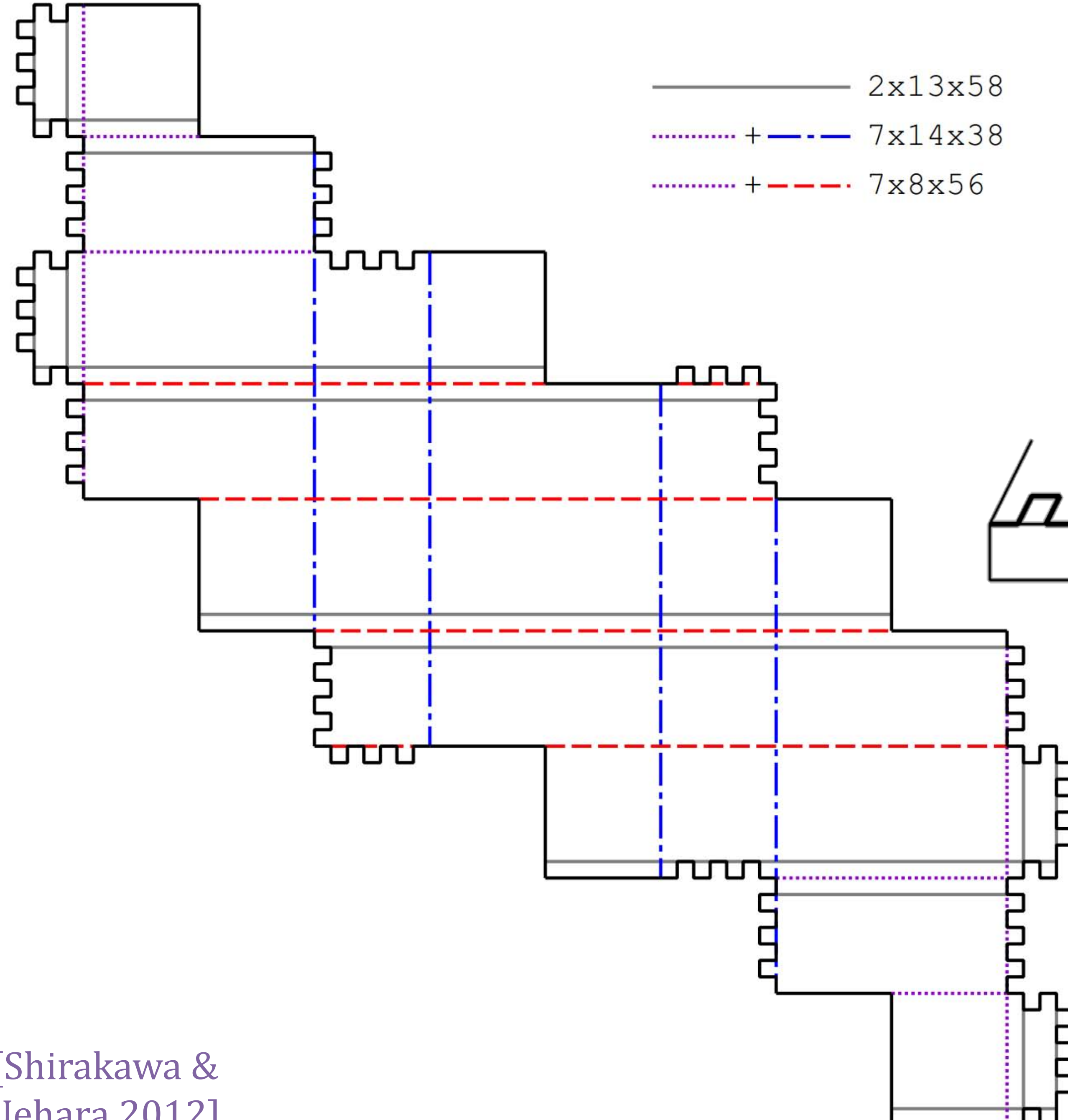


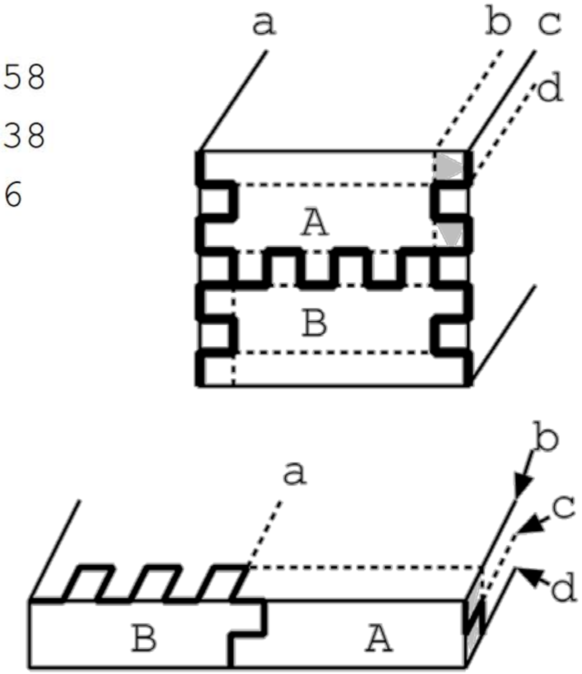


7×8
$\rightarrow 2 \times 13$

Common unfolding of
$a \times b \times 8a$ box and
$a \times 2a \times (2a + 3b)$ box

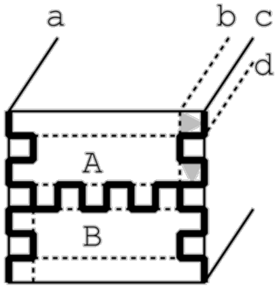
[Shirakawa & Uehara 2012]



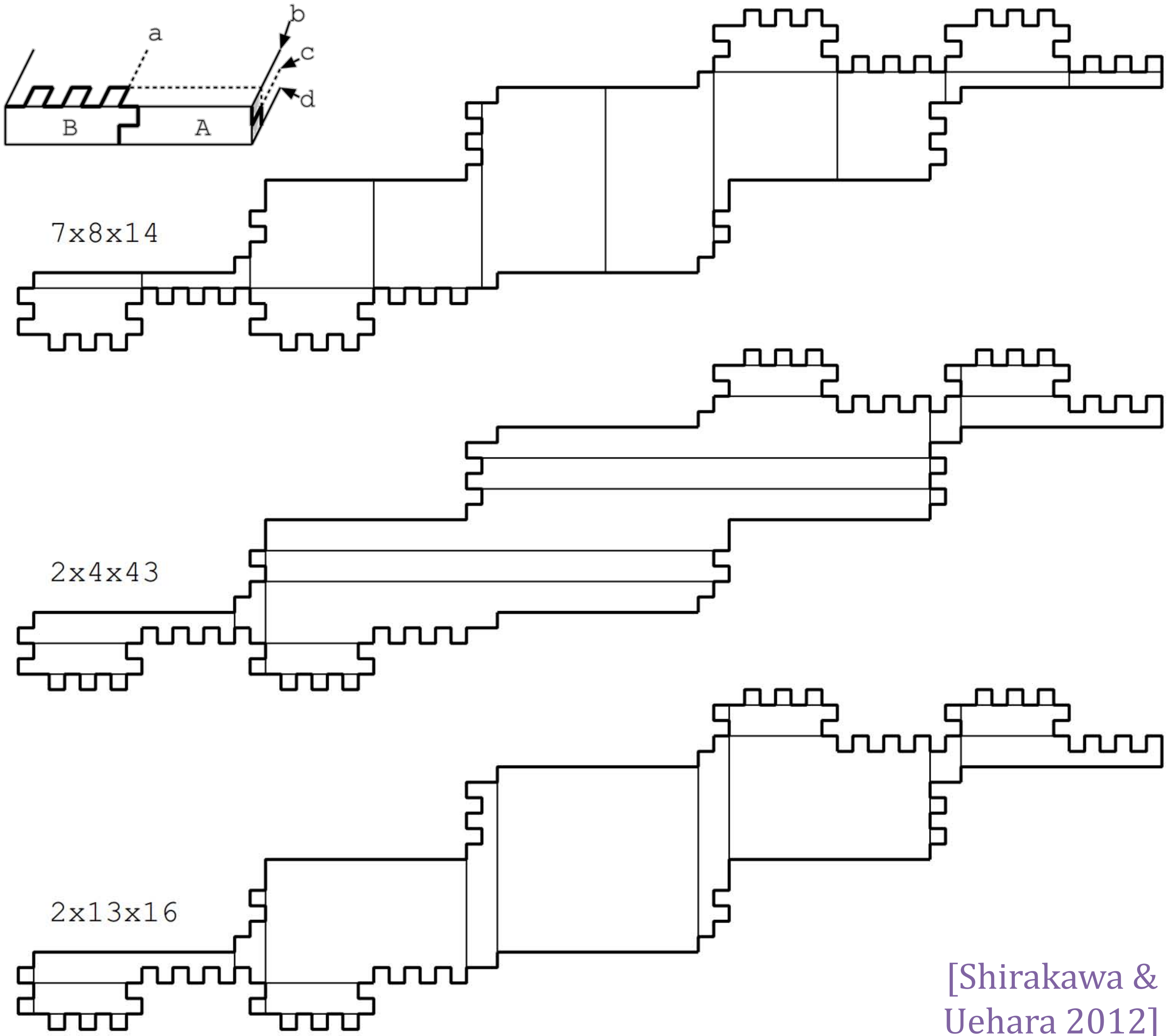


7×8
$\rightarrow 2 \times 13$

[Shirakawa & Uehara 2012]



7×8
$\rightarrow 2 \times 13$



[Shirakawa & Uehara 2012]

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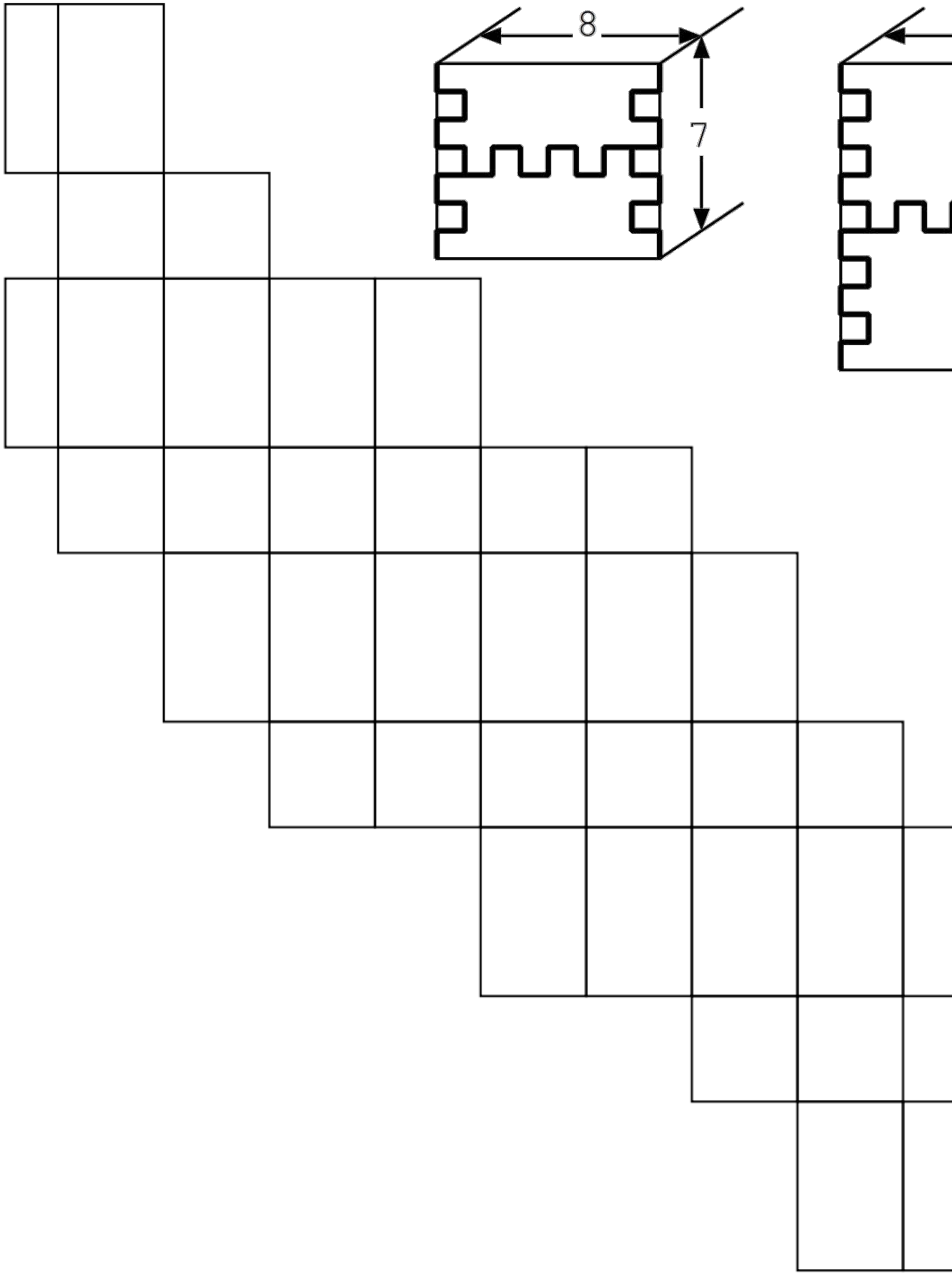

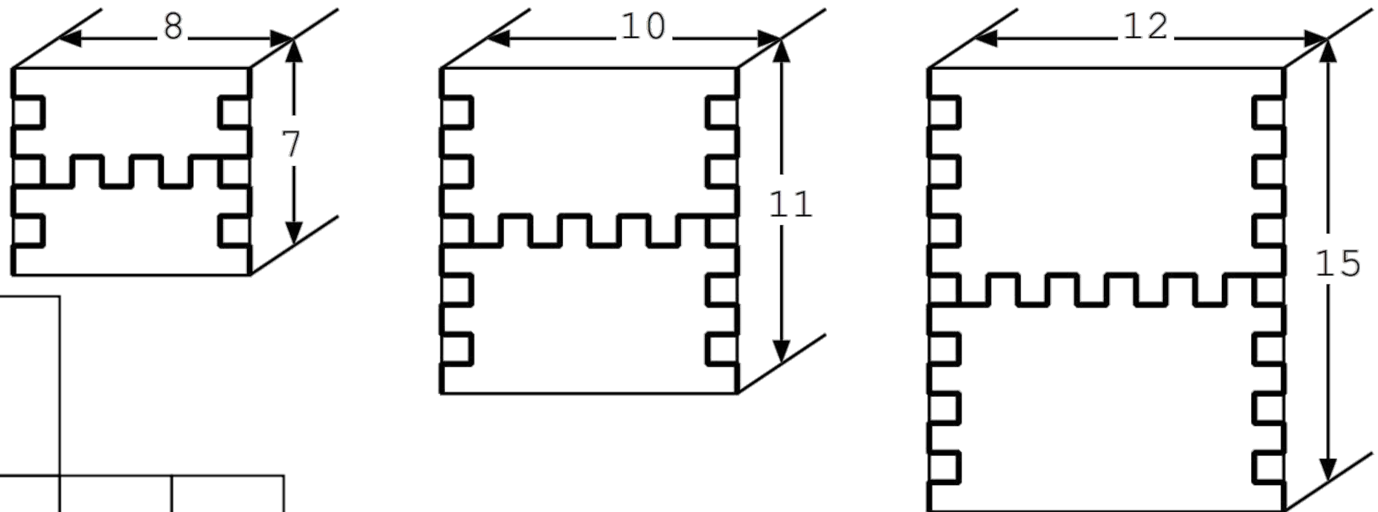

$$(4k+7)\times 2(k+4)\times 8(4k+7)$$
$$(4k+7)\times 2(4k+7)\times 2(7k+19)$$
$$2(k+1)\times(4k+3)\times 2(16k+29)$$

Common unfolding of three boxes

I’m kind of unsettled by the non-area-preserving unfolding. If it were a true limit then we’d be able to get arbitrarily close to the non-preserved area by unfolding into sufficiently many pieces. But this isn't the case: either we get the non-preserved area by unfolding into infinitely many pieces, or we get the original area, by unfolding into finitely many pieces.

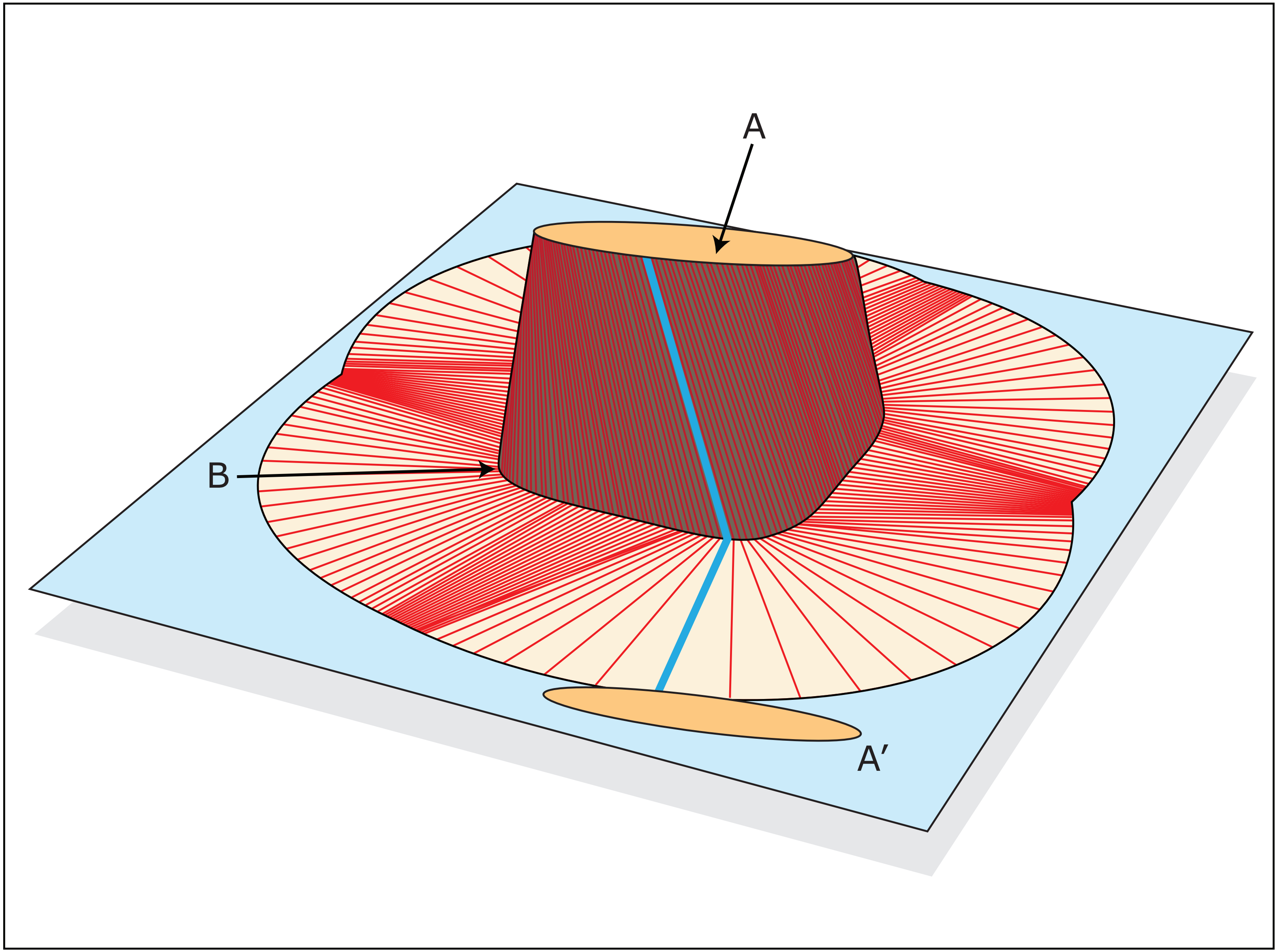

Image by MIT OpenCourseWare.

[Benbernou, Cahn, O’Rourke 2004]

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http://vimeo.com/14648143 "Ordis 2007"

Theo Jansen's *Strandbeests*

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http://vimeo.com/14647032 "Umerus 2009"

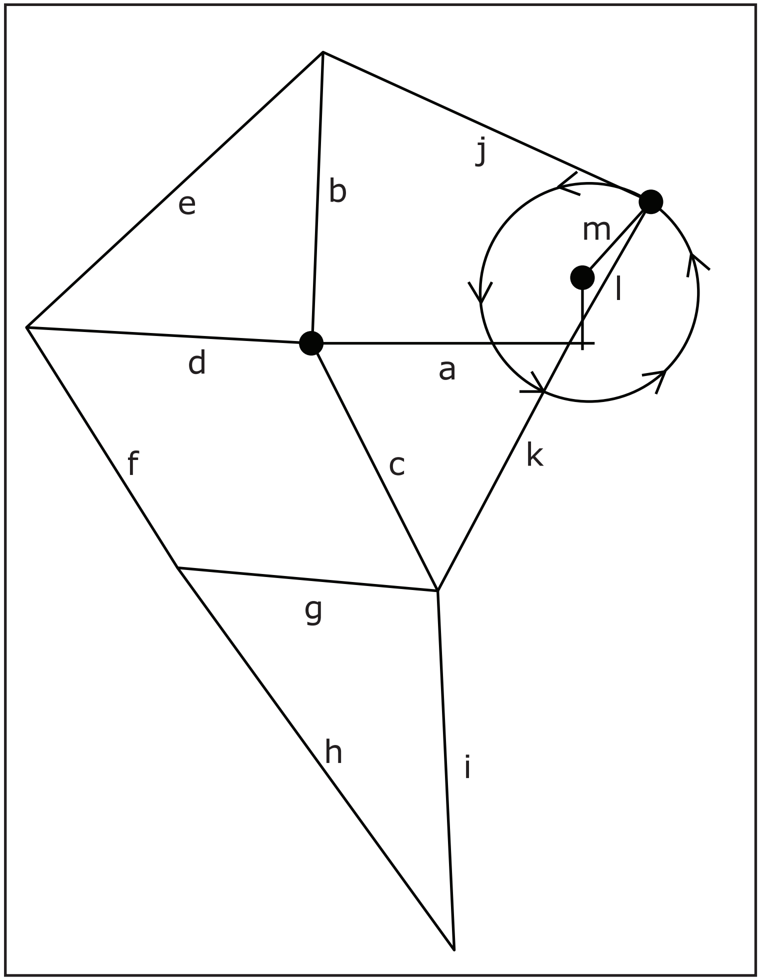
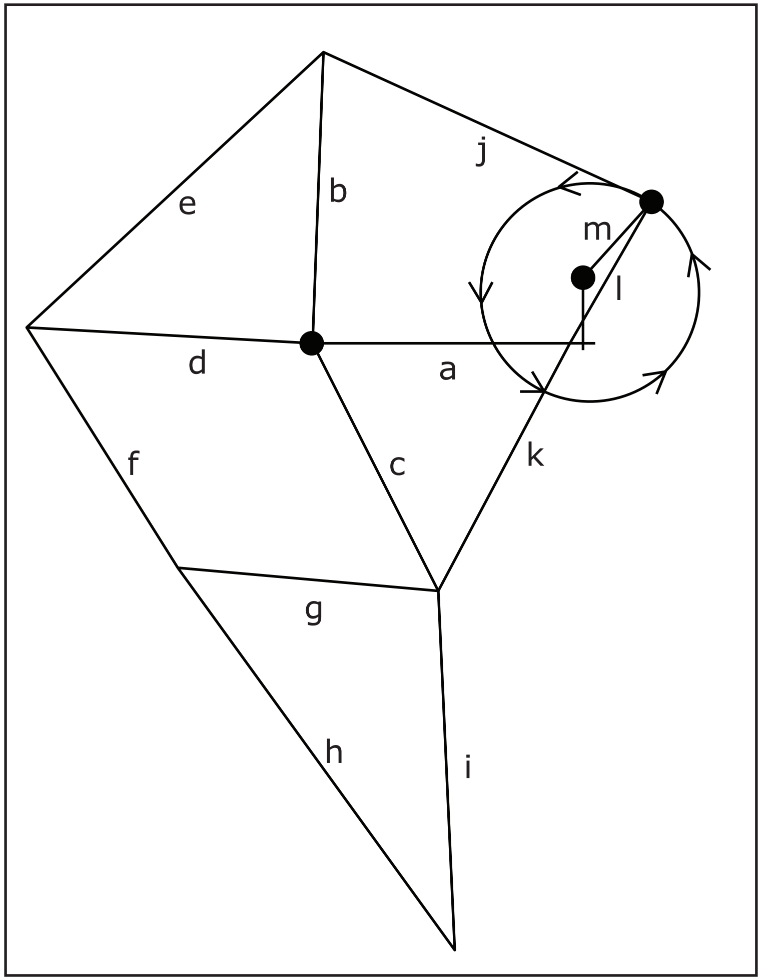


Image by MIT OpenCourseWare.
See also http://www.strandbeest.com/beests_leg.php/.

$a = 38$
$b = 41.5$
$c = 39.3$
$d = 40.1$
$e = 55.8$
$f = 39.4$
$g = 36.7$
$h = 65.7$
$i = 49$
$j = 50$
$k = 61.9$
$l = 7.8$
$m = 15$

[Theo Jansen]

“Eleven holy numbers”



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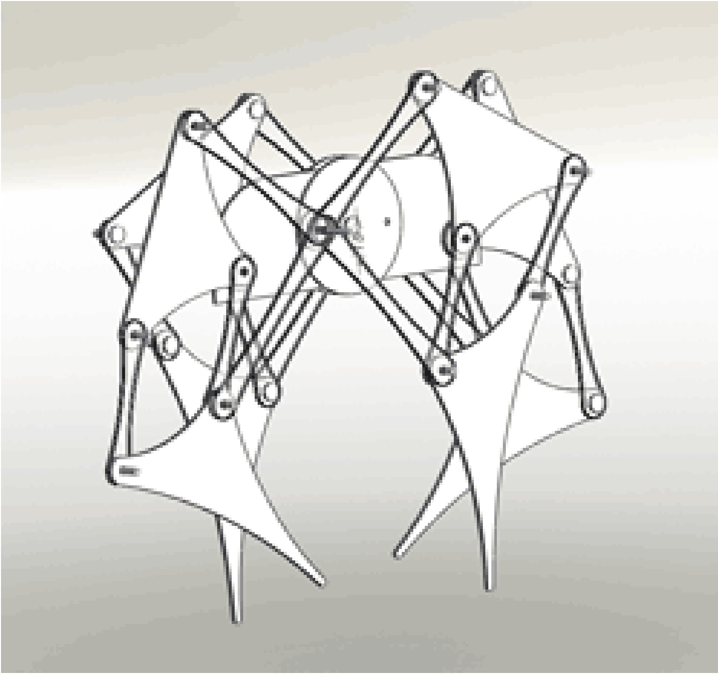
See also http://www.strandbeest.com/beests_leg.php/.

Diagram removed due to copyright restrictions.

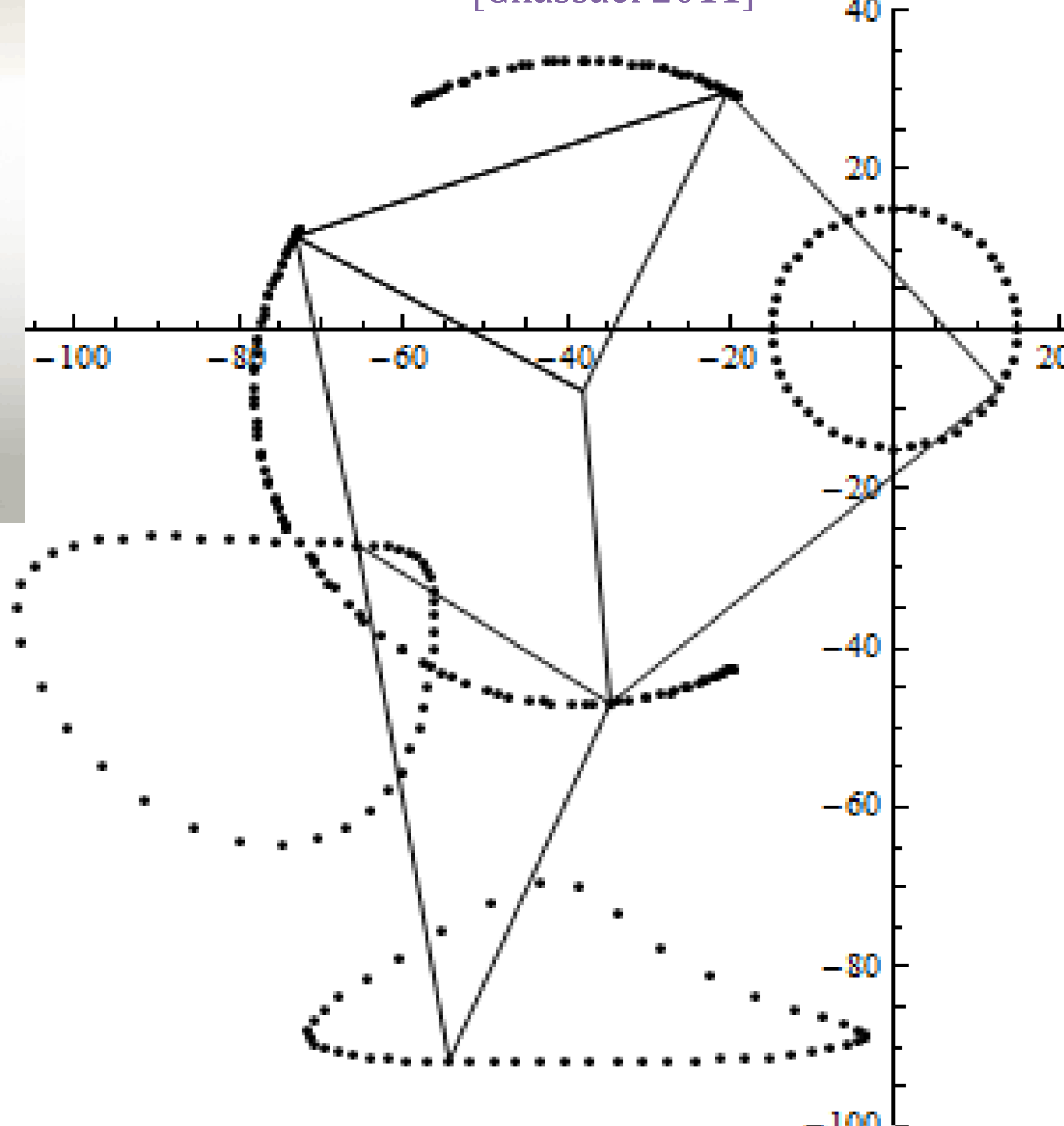
[Theo Jansen]



Courtesy of Jansen Walker by 4volt.com. License CC BY-NC-SA.

[4volt.com]

[Ghassaei 2011]

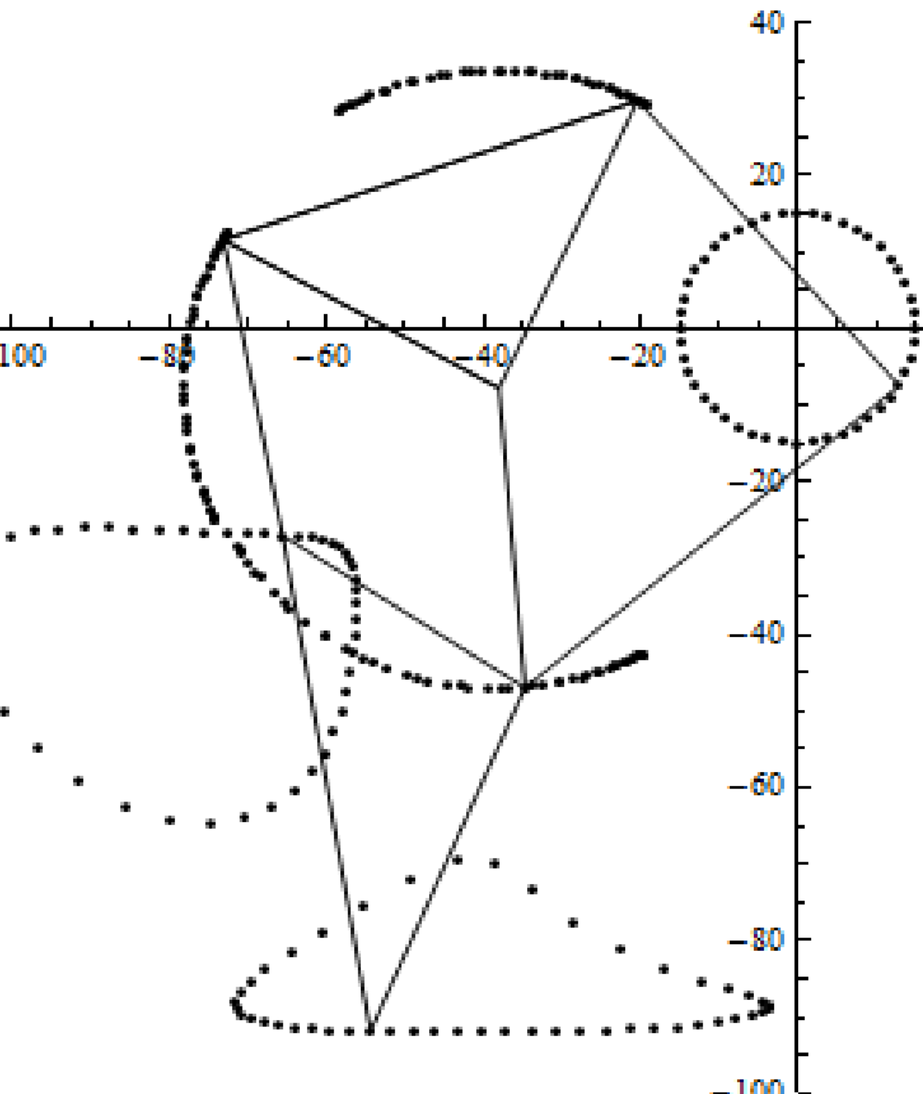


Courtesy of Amanda Ghassaei. Used with permission.

Theo Jansen's *Strandbeests*

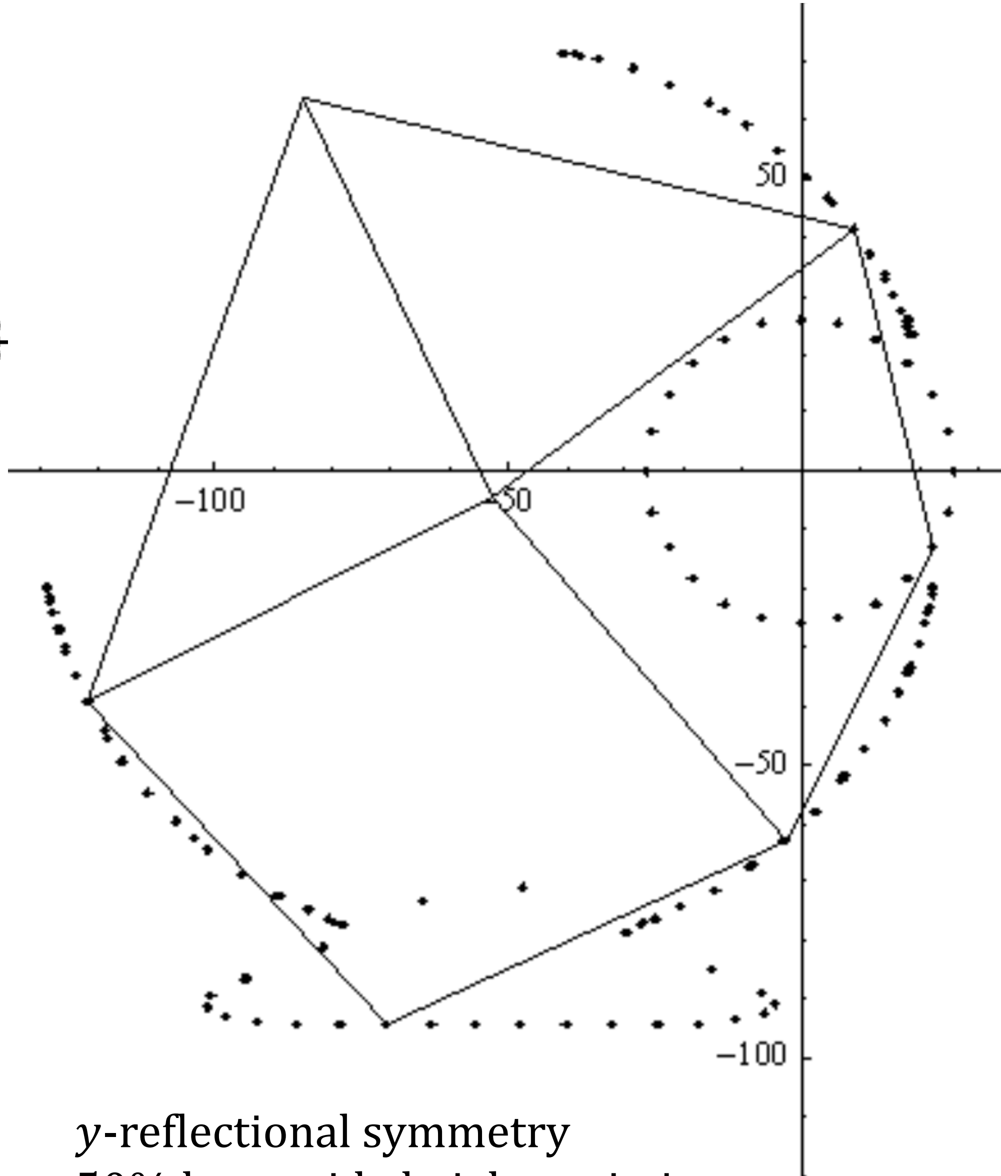
http://youtu.be/NM4q-f68TlY "strandbeests ... mechanism" petabyte99

Jansen mechanism



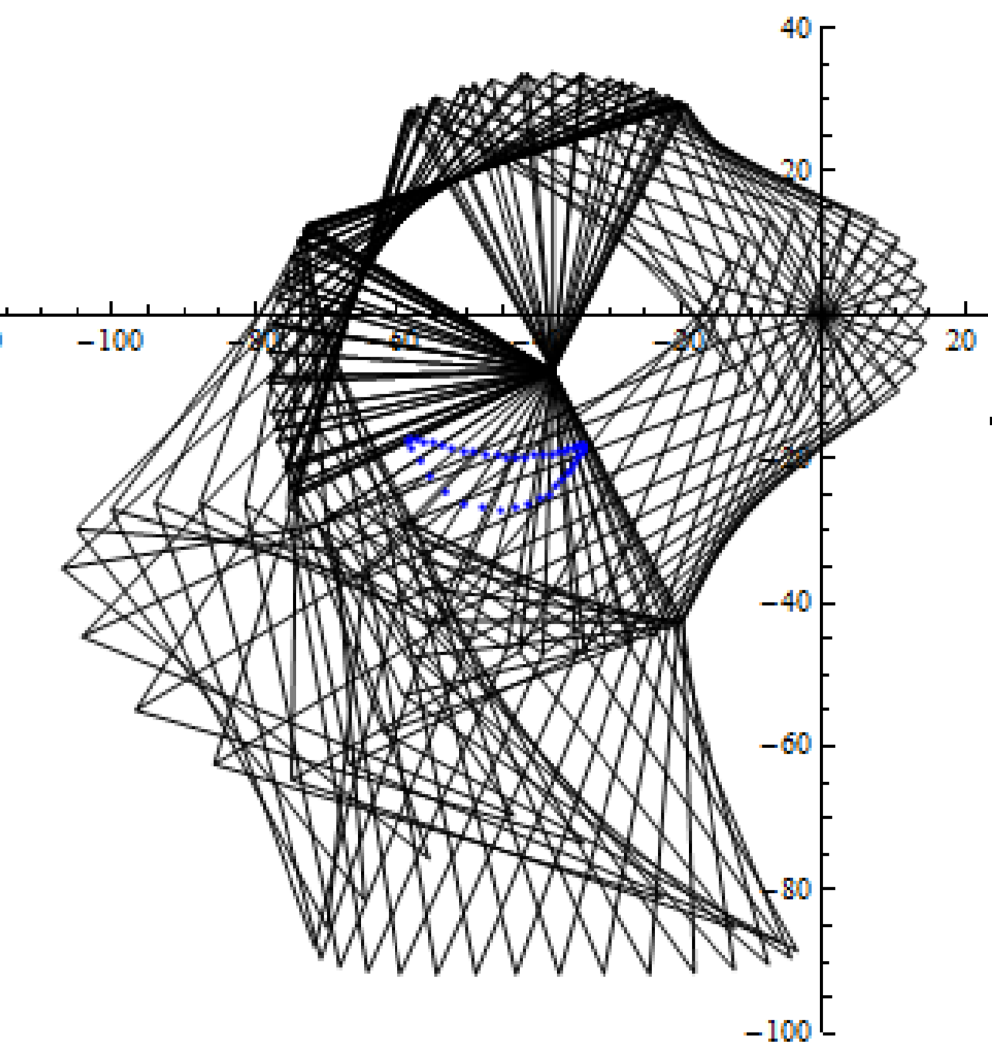
2 legs lie in plane
33% higher step
4% faster stride

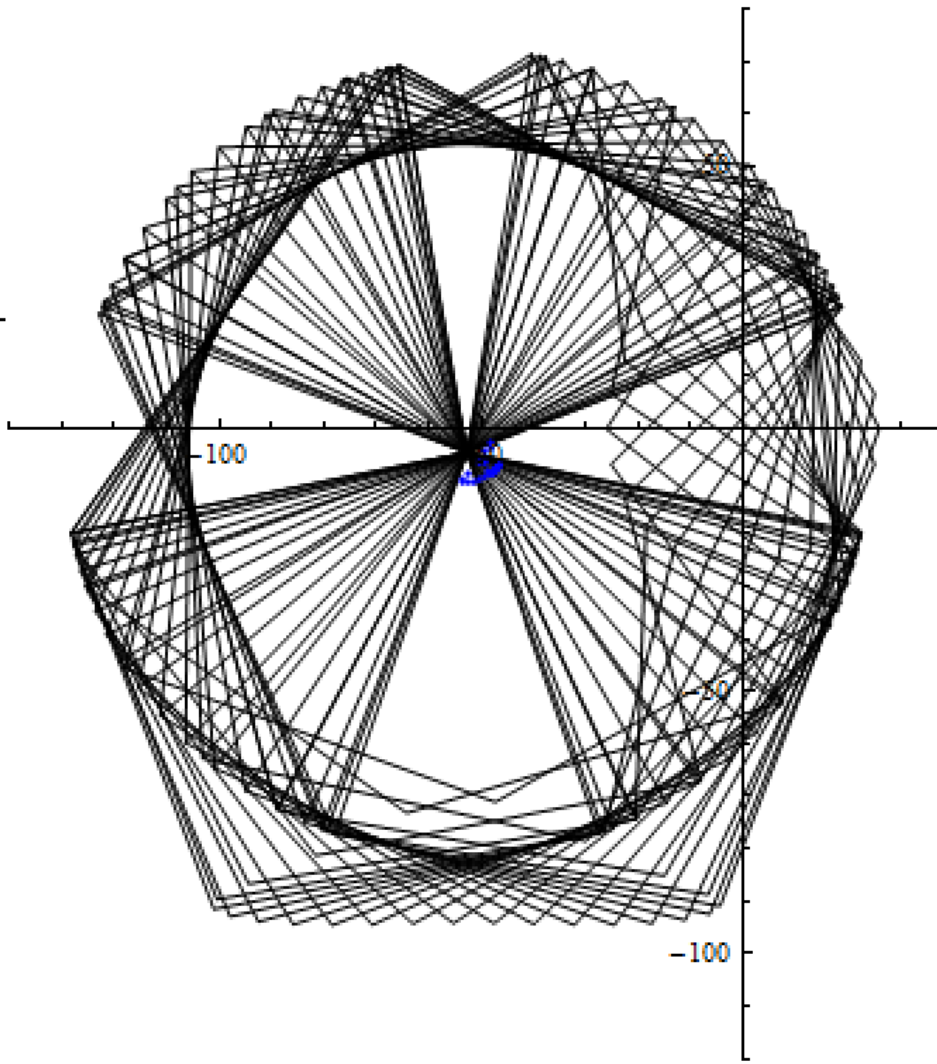
Ghassaei mechanism [2011]



y-reflectional symmetry
50% less stride height variation
50% less stride x velocity variation

Jansen mechanism **Ghassaei mechanism** [2011]





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center of mass

85% less center of mass movement

Theo Jansen's *Strandbeests*

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http://vimeo.com/24278413 "Animaris Gubernare — Tumble"

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http://vimeo.com/51811740 "Animaris Adulari"

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http://vimeo.com/52745220 "about the wings"

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http://vimeo.com/44057387 "Adulari lifting itself …"

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http://vimeo.com/44057388 "Wagging Neck"

Theo Jansen's *Strandbeests*

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http://vimeo.com/14646877 "Untitled"

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http://vimeo.com/11150979 “Rhinoceros”

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Refer to: http://www.strandbeest.com/shop/index_usa.php.
To view video: http://www.youtube.com/watch?v=tHXy1nmVXg4 &
http://www.youtube.com/watch?v=i8KVXy-vluU.

Photographs of Theo Jansen 3D-printed models removed due to copyright restrictions.
Refer to: http://www.strandbeest.com/shop/beasts_3d.php.

Kinetic Creatures http://www.kineticcreatures.com

Kinetic Creatures

http://vimeo.com/52366409

Land Crawler eXtreme Locomotion Demo Video

http://youtu.be/U5dpGAw4cOU vagabondworks

Poster for "Ocean Beasts" exhibit at The Simons Center (July-August 2012) removed due to copyright restrictions.

Machine with 23 Scraps of Paper

Margot's Other Cat

Arthur Ganson

Machine with Roller Chain

Machine with Oil

6.849 Geometric Folding Algorithms: Linkages, Origami, Polyhedra
Fall 2012