平成26年12月5日~12月7日
日米先端科学(JAFoS)シンポジウム

ORIGAMI
Paper Folding and Its Generalization

@Ori-zuru!

Japan Advanced Institute of Science and Technology (JAIST)

School of Information Science

Ryuhei Uehara

What's ORIGAMI?

- "Ori" means folding, and "kami(=gami)" means paper, which may be born in 1500s in Asia?
- As you know, ORIGAMI is now available even in English…

Sometimes, ORIGAMI seems to be wider than original Japanese… which may be better to understand our work!!

“ORIGAMI”…?

- Normal Origami
- Difficult Origami
- Impossible Origami

By Satoshi Kamiya (TV Champion)

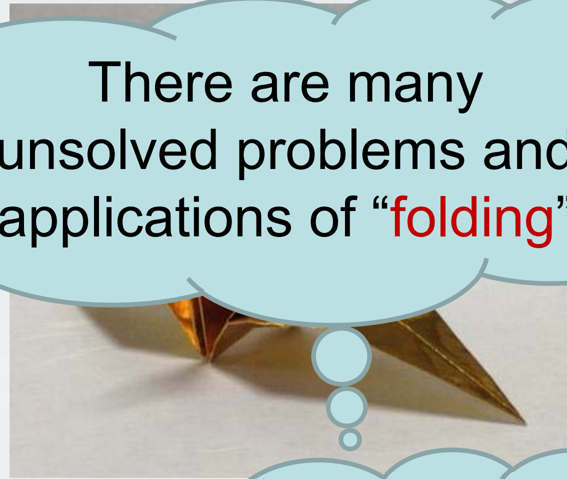
Kawasaki Rose

Maekawa Devil

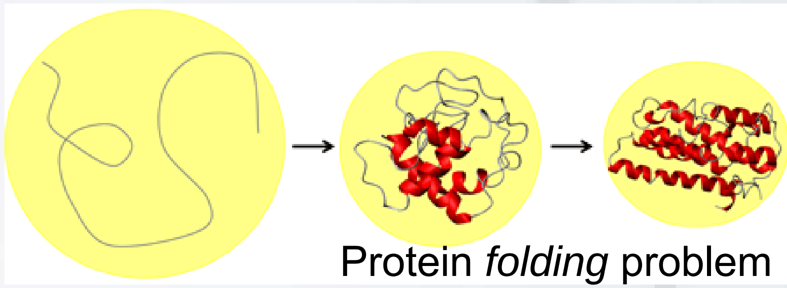
“ORIGAMI”…?

- Normal Origami
- Useful/important Origami

There are many unsolved problems and applications of “folding”



“Origami Science” based on the basic operations of “folding”



"ORIGAMI"…?

➤ Useful/important Origami

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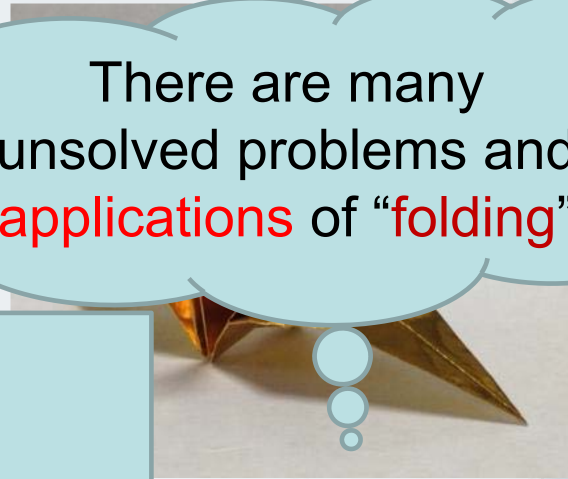
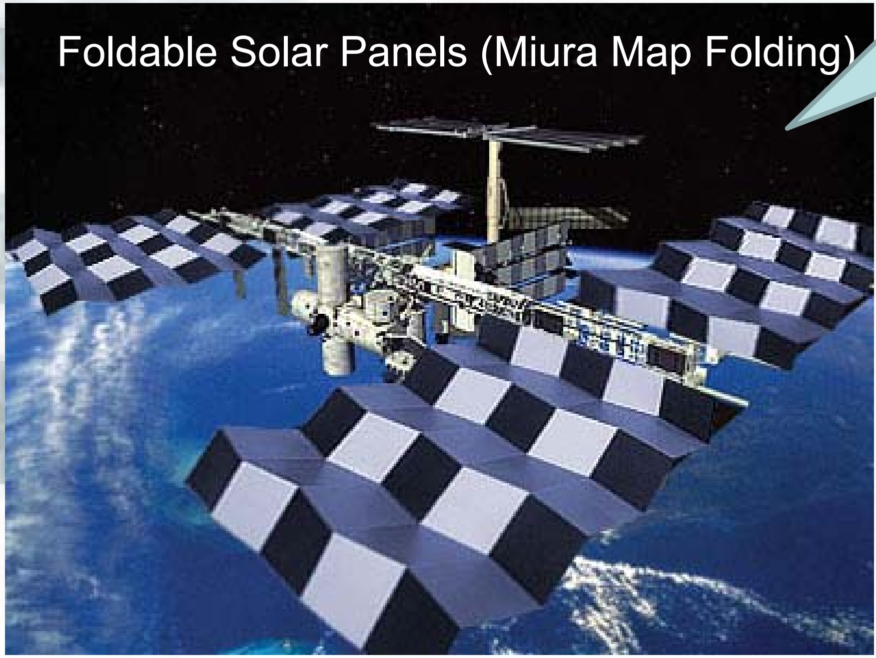
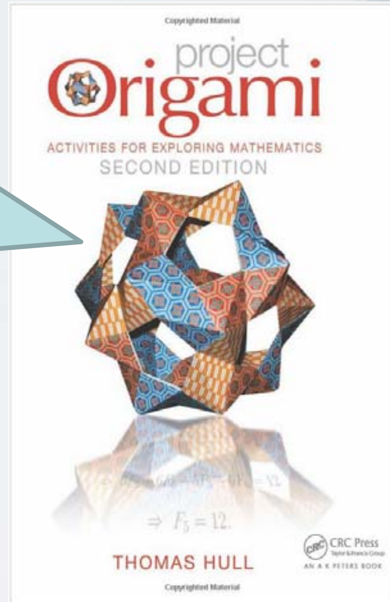




Tomohiro Tachi:
Working on "Rigid Origami" architecture
E.g., *Generalization of Mira-ori*

Thomas Hull:
Working on "Mathematical Origami"
Modern Origami from Mathematical viewpoint



Ryuhei Uehara:
Working on "Computational Origami"

Who's Ryuhei?

Name: Ryuhei Uehara

Affiliation: School of Information Science,
Japan Advanced Institute of Science and Technology (JAIST)

Title: Professor, Director of JAIST Gallery

In this gallery, we have around ten thousands of puzzles due to NOB Yoshigahara, one of the most popular three puzzle collections (another is in England, and the last one is in USA.)
This gallery itself is designed as a big puzzle, so you will enjoy the nice experience of being in the big puzzle. Of course you can also enjoy some puzzles, including ones in Uehara-lab ☺

This “latin-cross” can fold into 23 different convex shapes in 85 different folding ways!!

…tational O…

Experimental results (by computer!!)

…t favo…

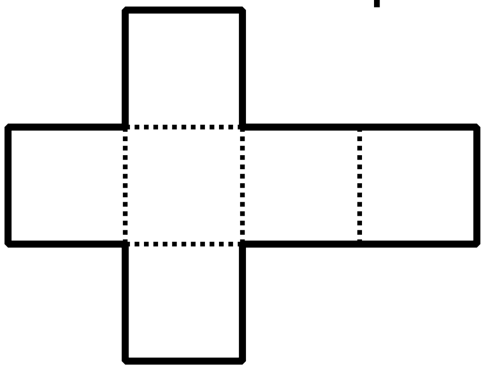
…ygon *P* and polyhedron *Q*

As… does *P* folds into *Q* (or vice versa)?

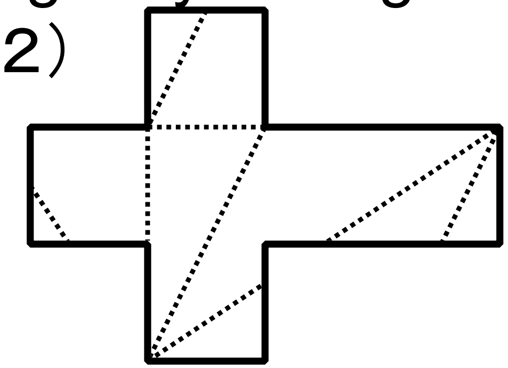
This problem is quite counterintuitive in general…

Exercise：What shape do you get by folding…

（1）



（2）



Background

➢ My most favorite unsettled problem：

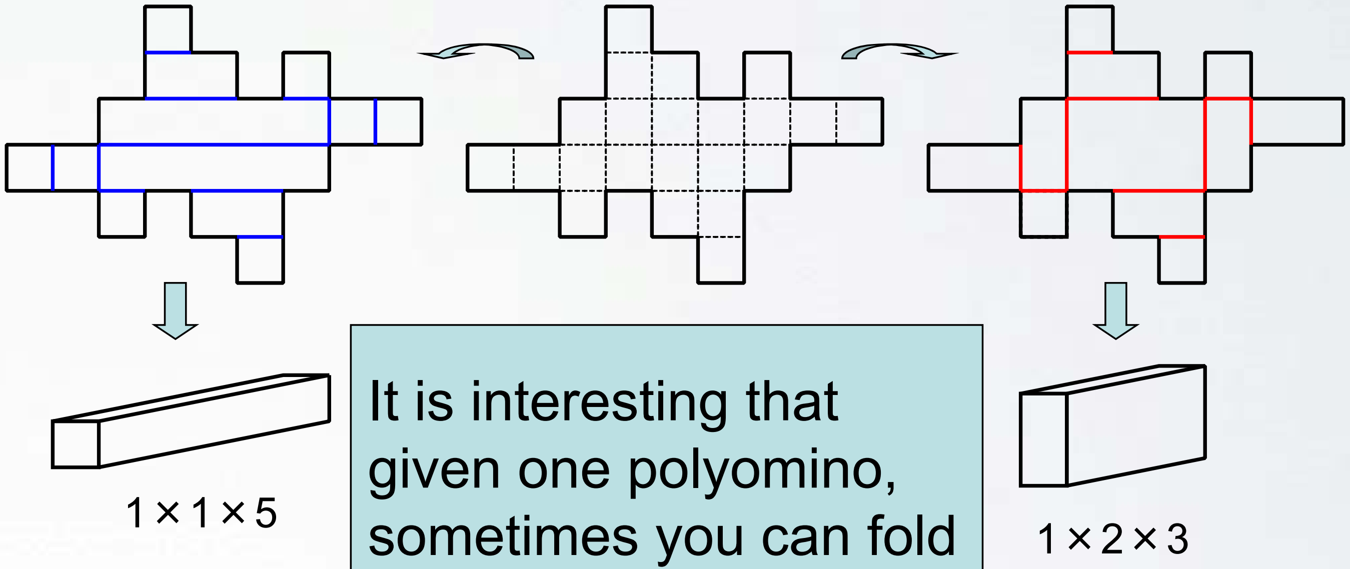
Given: polygon *P* and polyhedron *Q*

Asked: does *P* folds into *Q* (or vice versa)?

- We have no idea so far even if *P* and *Q* are explicitly given. Especially, we cannot pre-determine *where the folding lines* (or *creases*) are placed on *Q*?
- We only have partial results when *P* and *Q* are very restricted.

One of my major works in computational origami

- Polyominoes (set of unit squares) that fold into two or more boxes!

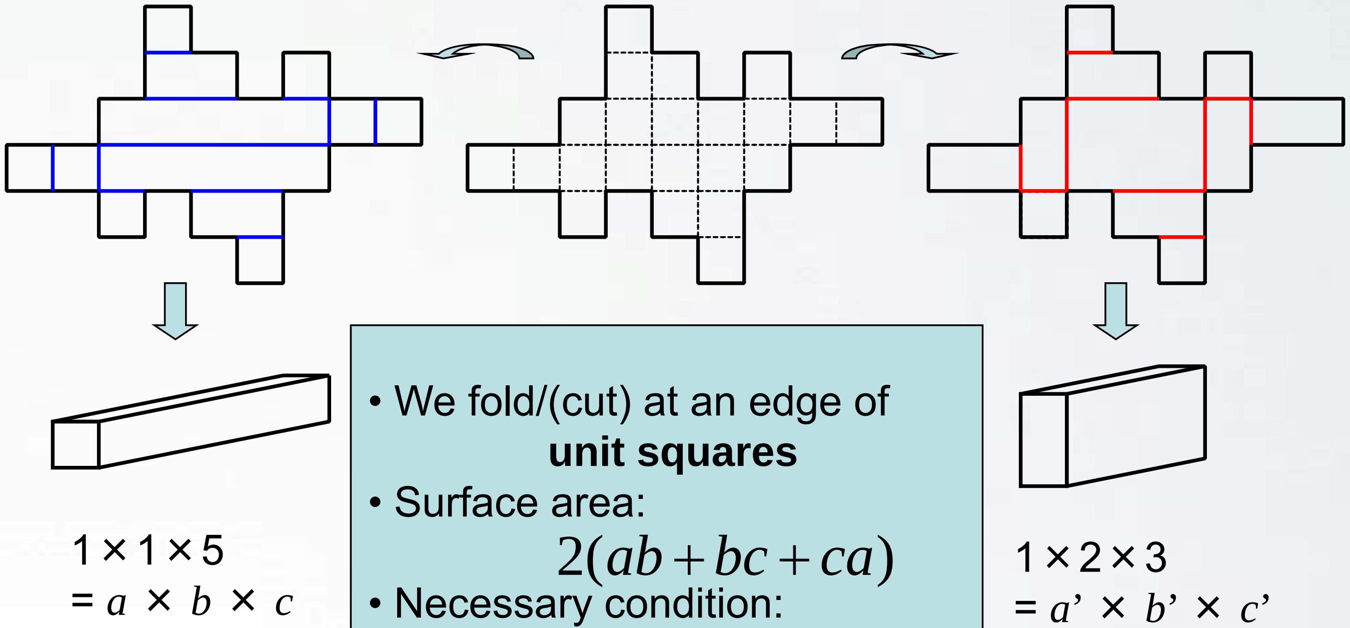


It is interesting that given one polyomino, sometimes you can fold two boxes!?

It is necessary that..

Example:
1×1+1×5+1×5
=1×2+2×3+1×3
=11 (Area is 22)

- Two boxes have the same surface area!



- We fold/(cut) at an edge of **unit squares**
- Surface area:

$$2(ab+bc+ca)$$

- Necessary condition:

$$ab+bc+ca=a'b'+b'c'+c'a'$$

It seems to be better to have many combinations…

Note:

- Surface areas;

If you try to find for three boxes,

If you try to find for four boxes,

Area	Trios	Area	Trios
22	(1,1,5),(1,2,3)	46	(1,1,11),(1,2,7),(1,3,5)
30	(1,1,7),(1,3,3)	70	(1,1,17),(1,2,11),(1,3,8),(1,5,5)
34	(1,1,8),(1,2,5)	94	(1,1,23),(1,2,15),(1,3,11),(1,5,7),(3,4,5)
38	(1,1,9),(1,3,4)	118	(1,1,29),(1,2,19),(1,3,14),(1,4,11),(1,5,9),(2,5,7)

Using computer programs,

- we can generate all (2263) common developments of two boxes of size $1 \times 1 \times 5$ and $1 \times 2 \times 3$ in 5 hours in 2014.
- we could not for area 30 and more...

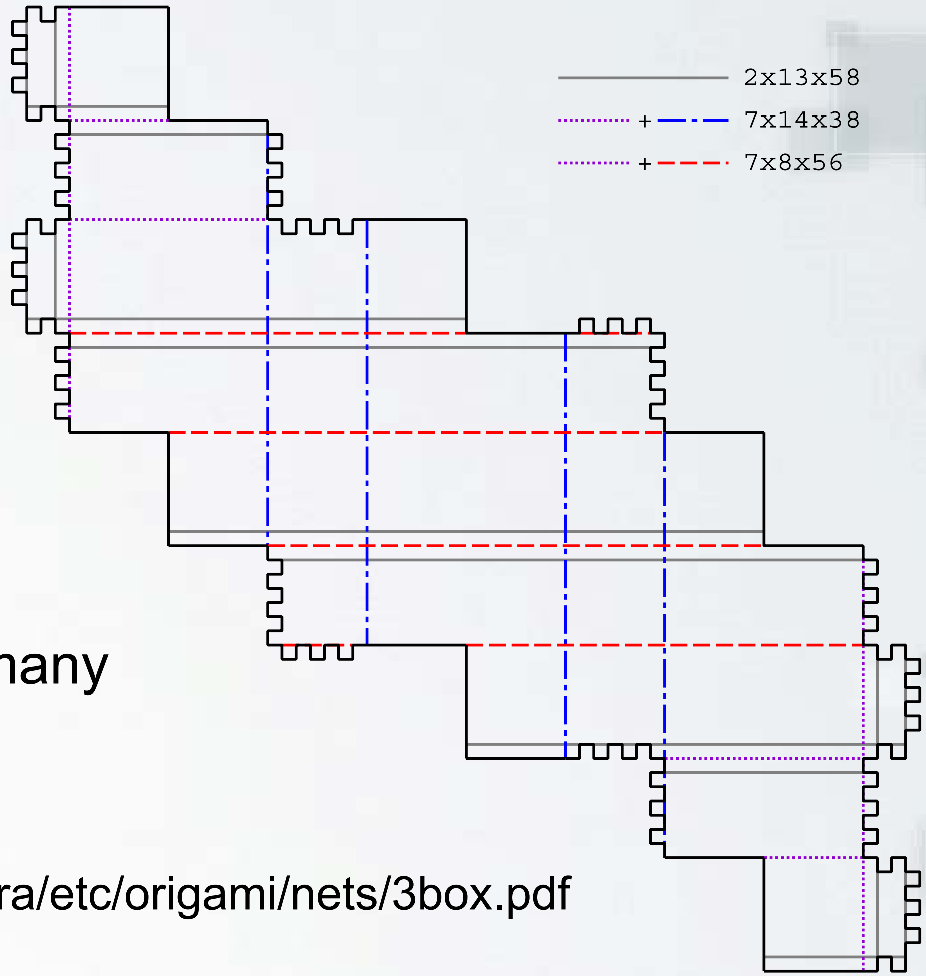
Developments of *three* boxes(!)

- In February 2012, our group found:

Without computer ☺

There exists
a polygon that
folds to 3 boxes!!

… although it require many
unit squares….



I put it at
http://www.jaist.ac.jp/~uehara/etc/origami/nets/3box.pdf

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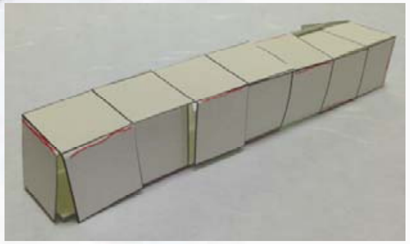
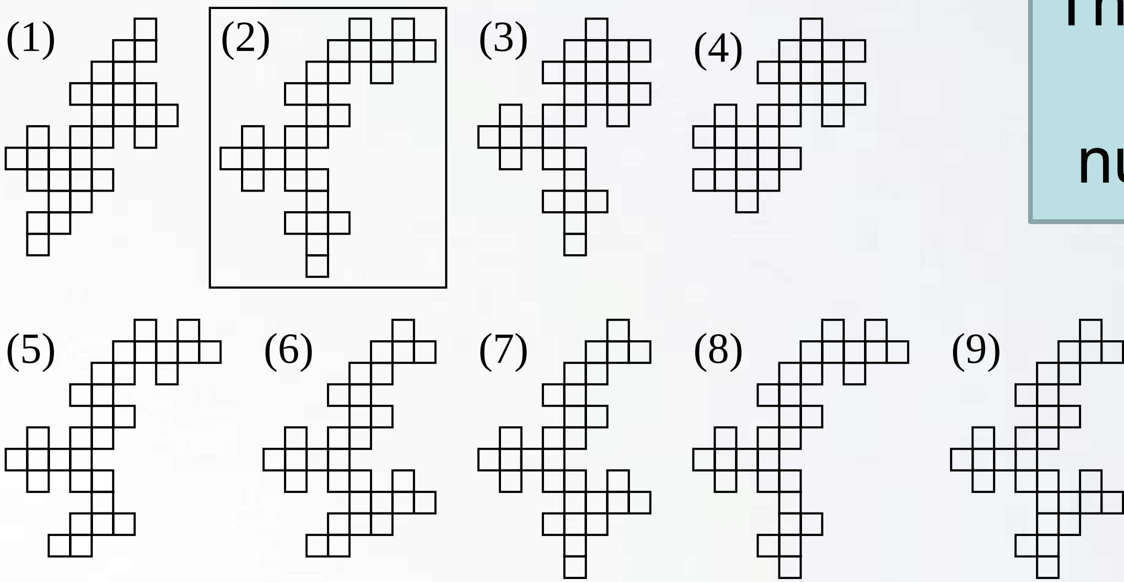
- we could not for area 30...

On June, 2014…

- We completed all common developments of two boxes of size 1 × 1 × 7 and 1 × 3 × 3 of area 30.
- 1080 common developments of these two boxes are found by a supercomputer (Cray XC 30) in three months ☺

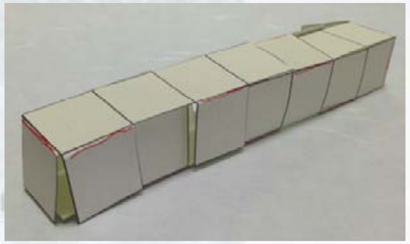


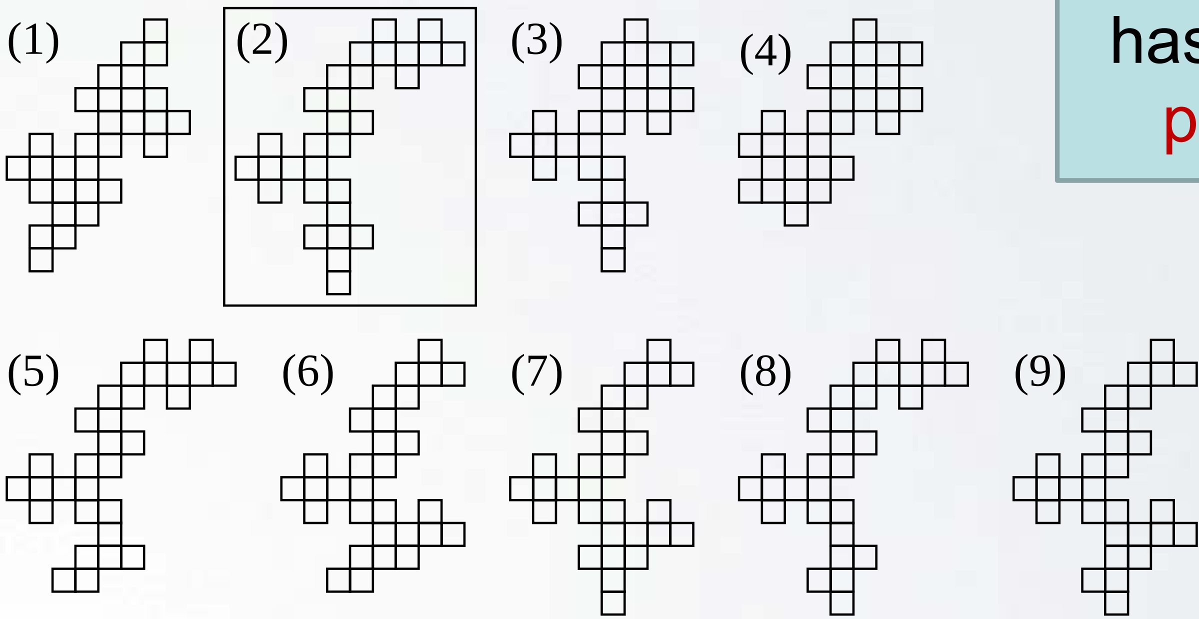


The number 30 is a magic number s.t.…

On June, 2014…

…And 9 of 1080 allow us to fold a cube of size $\sqrt{5} \times \sqrt{5} \times \sqrt{5}$





Moreover, (2) has a special property!!

The current nicest polygon…

- It admits to fold three different boxes in 4 different folding ways!!