Origami Structure: Kinematics and Applications

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Burqin
Karamay
Yining
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Mongolia
Hailar
Qiqihar
Harbin
Changchun
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Hohhot
Beijing
North Korea
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Huang R.
Tianjin
Dalian
Shijiazhuang
Yantai
South Korea
Pak.
Yinchuan
Taiyuan
Qingdao
Golmud
Xining
Jinan
Lianyungang
Indus R.
Lanzhou
Zhengzhou
Shiquanhe
Xian
Yellow Sea
China
Nanjing
Hefei
Shanghai
30°
Yangtze R.
Brahmaputra R.
Wuhan
Hangzhou
Chengdu
Lhasa
East China Sea
Nepal
Chongqing
Nanchang
Changsha
Fuzhou
Bhutan
Guiyang
Ganges R.
Xiamen
Taiwan
Bangladesh
Kunming
Xun R.
Guangzhou
Kao hsiung
India
Irrawaddy R.
Nanning
Hong Kong
Macau
Thanlwin R.
Vietnam
Zhanjiang
Laos
Gulf of Tonkin
Haikou
Hainan
Philippines
Bay of Bengal
Myanmar (Burma)
Mekong R.
Luzon

2015

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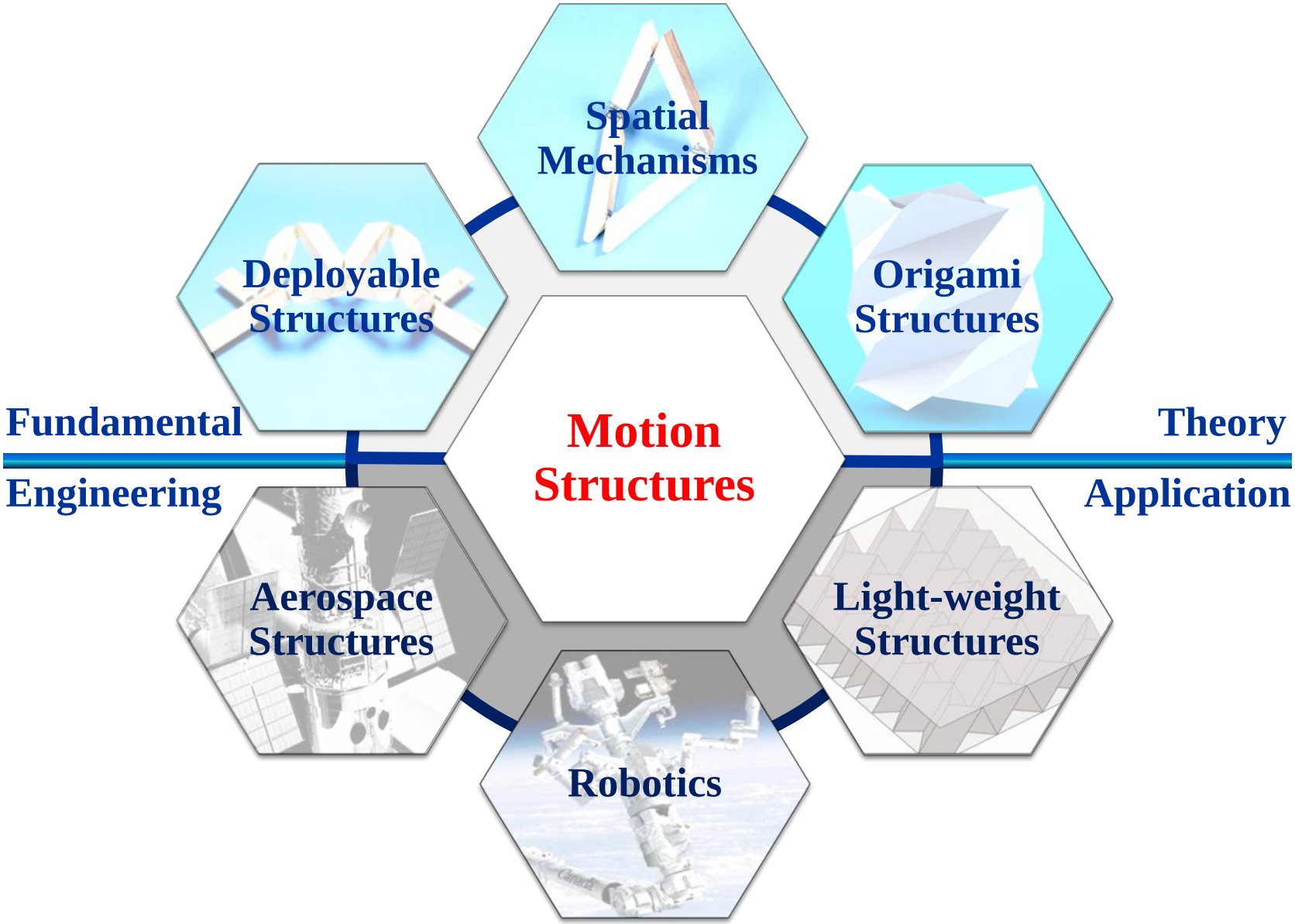
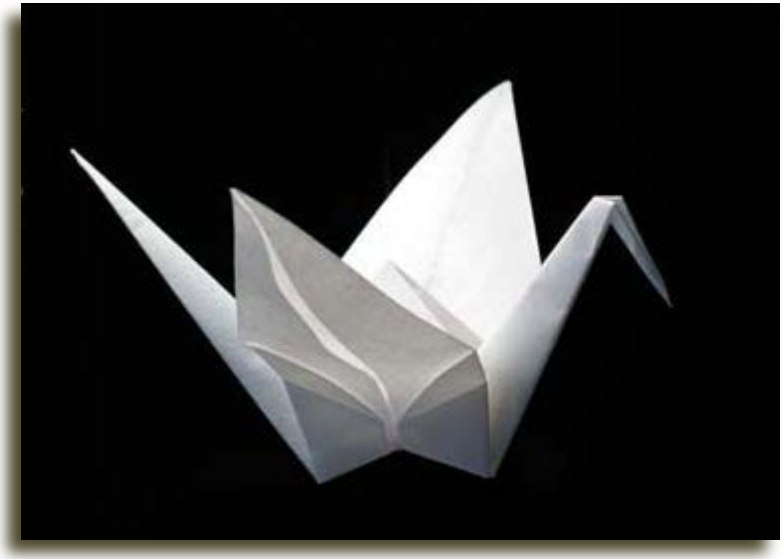

Spatial Mechanisms
Deployable Structures
Origami Structures
Fundamental
Theory
Motion Structures
Engineering
Application
Aerospace Structures
Light-weight Structures
Robotics

Contents

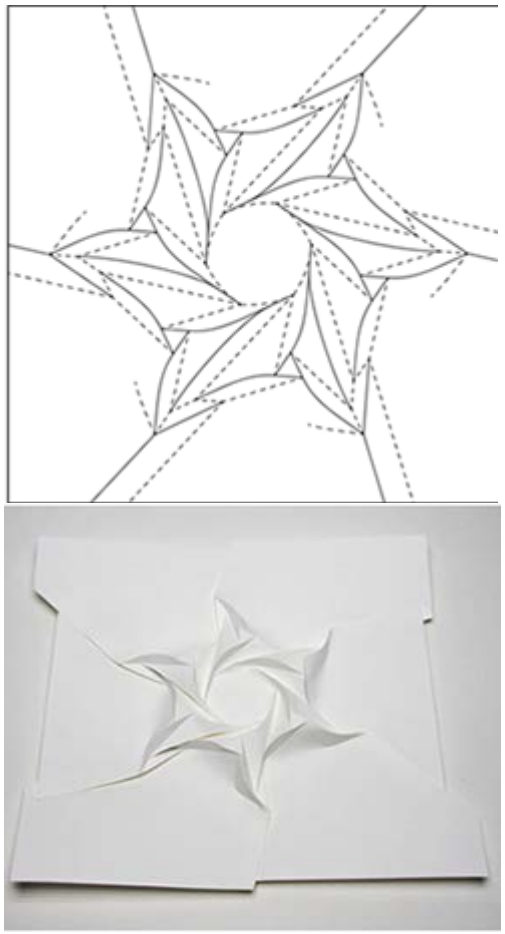
- Origami: Art, Mathematics, Engineering
- Kinematics of rigid origami
- Engineering applications of origami structures
- Future development

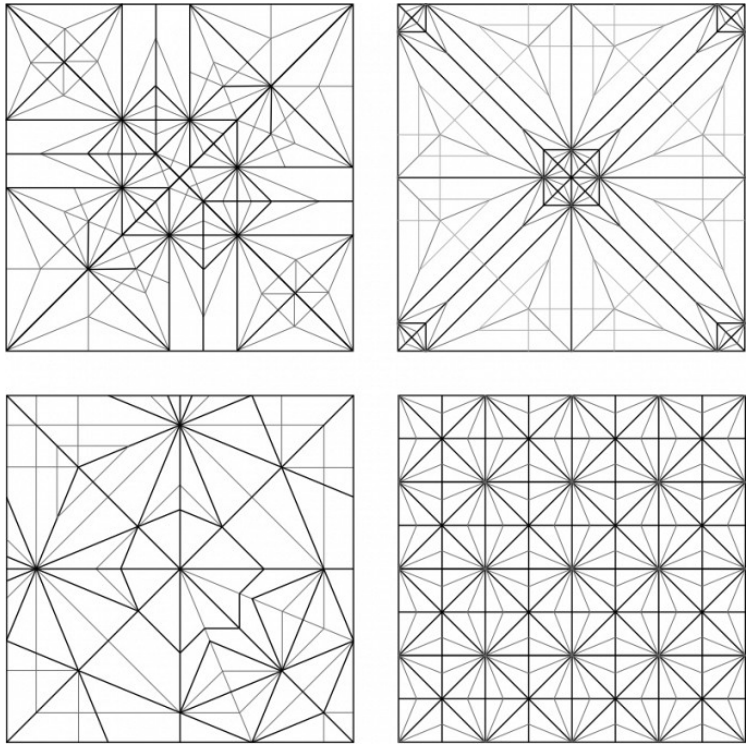
Origami



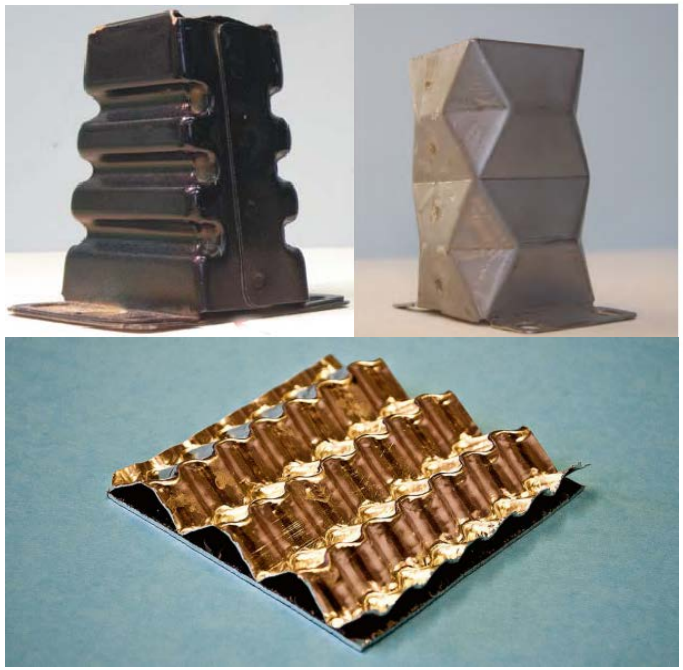
Origami: Art

Origami: Mathematics

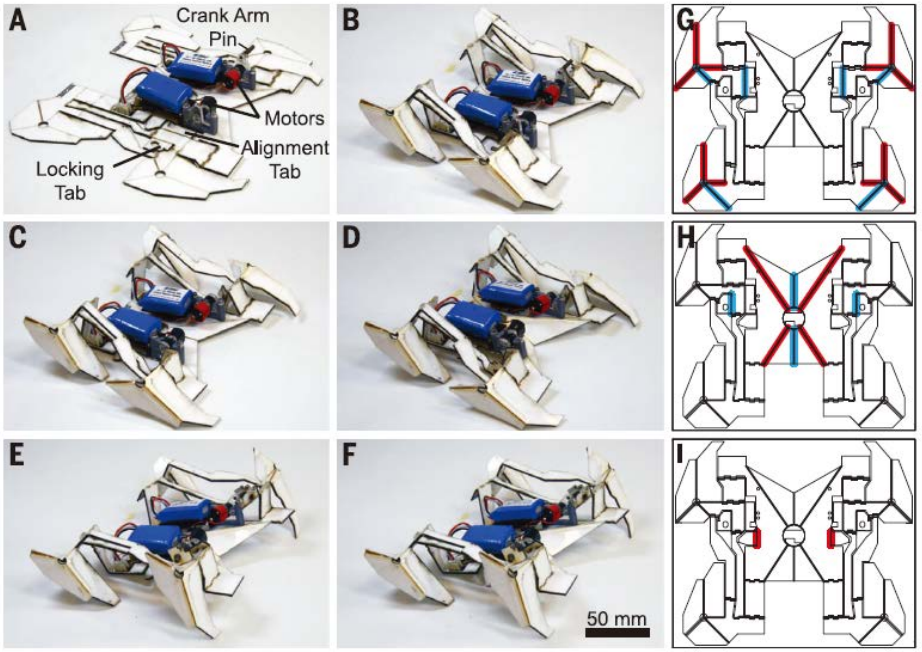




Origami: Engineering



You, Z. (2014). Folding structures out of flat materials. *Science*, 345(6197), 623-624.



Felton, S., Tolley, M., Demaine, E., Rus, D., & Wood, R. (2014). A method for building self-folding machines. *Science*, *345*(6197), 644-646.

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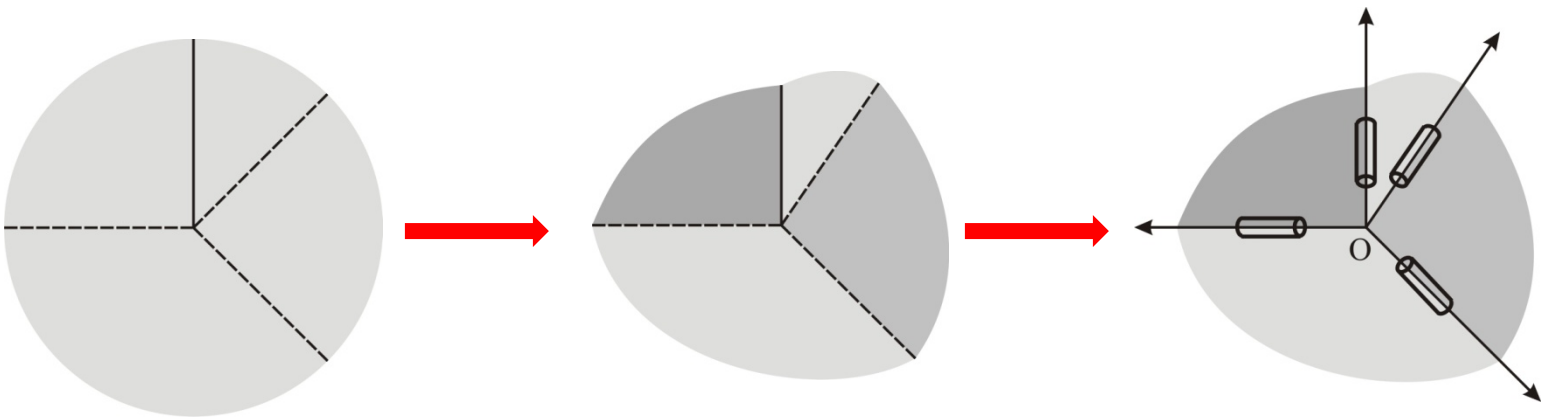
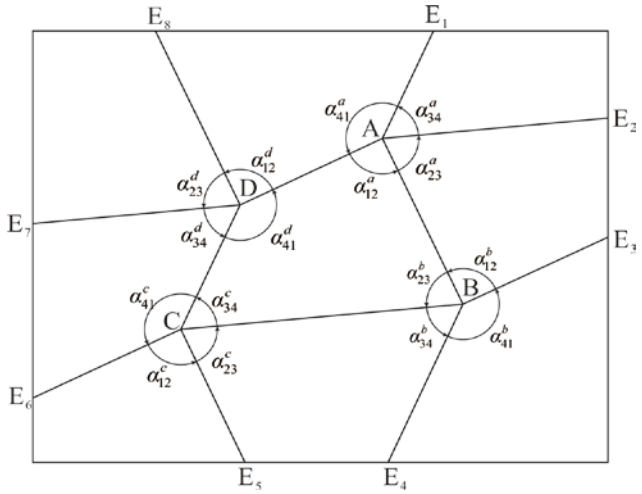
Rigid Origami

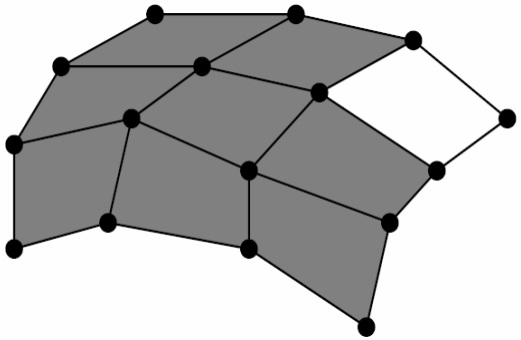


Rigid Origami = Mechanism Motion

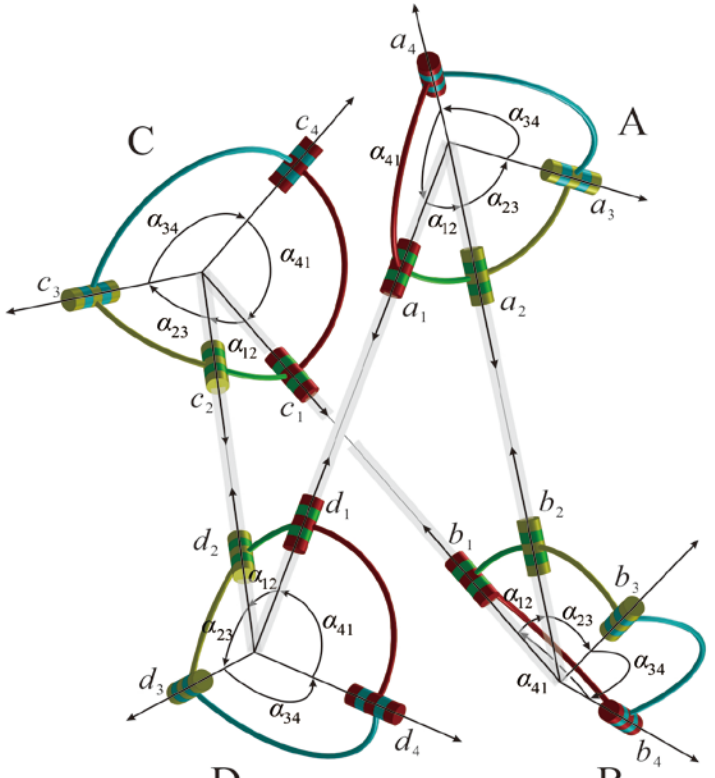
Rigid origami pattern: $\alpha + \beta + \gamma + \delta = 2\pi$

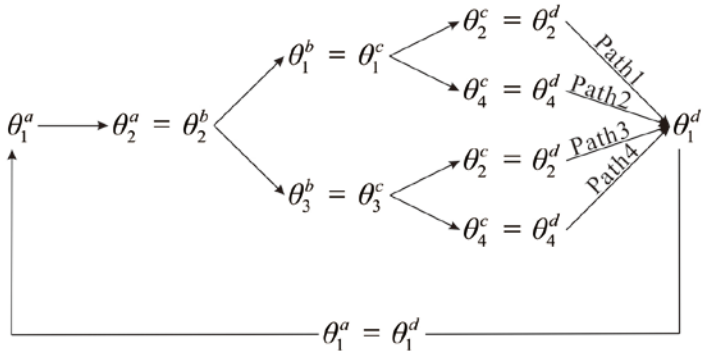
Rigid Origami Patterns



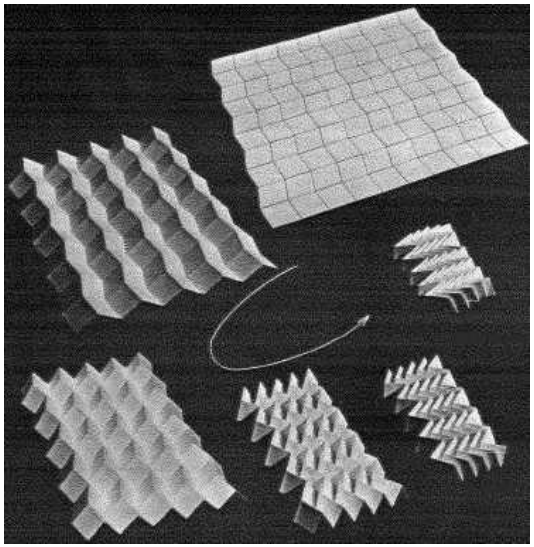


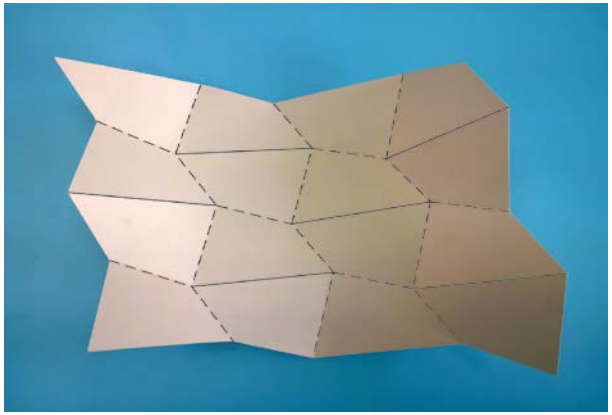
The deformable polygons in discrete differential geometry

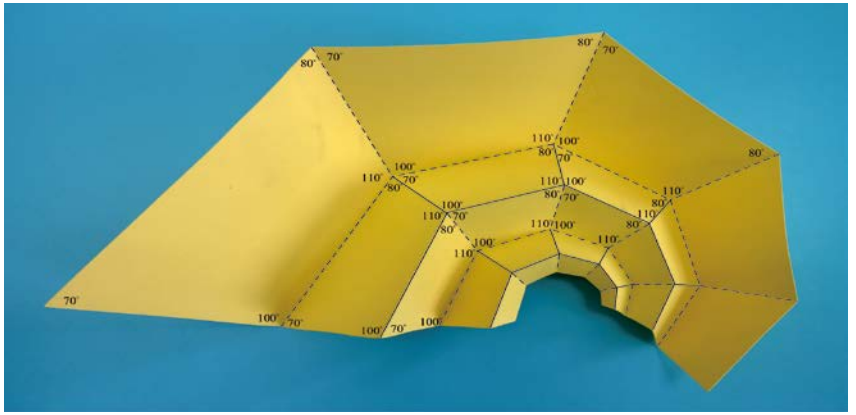




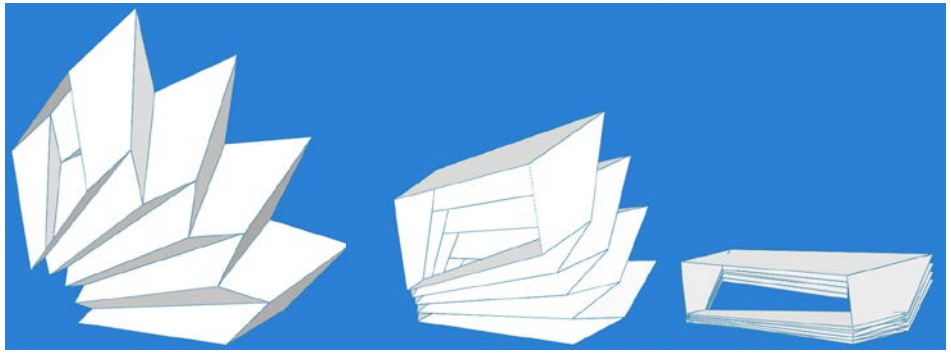
Rigid Origami: Planar structures

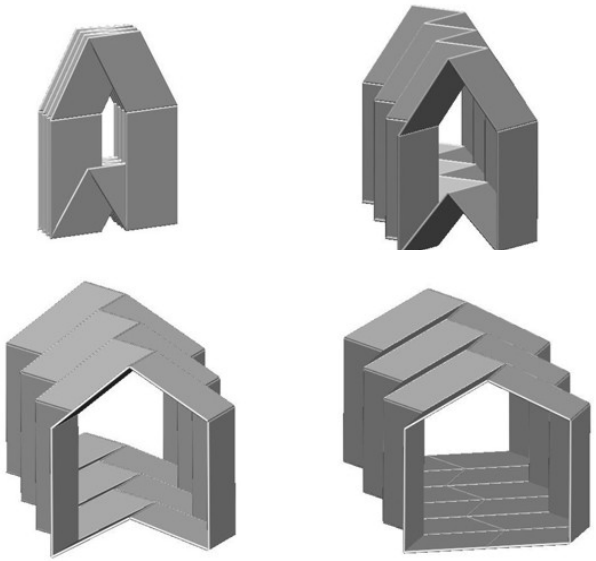




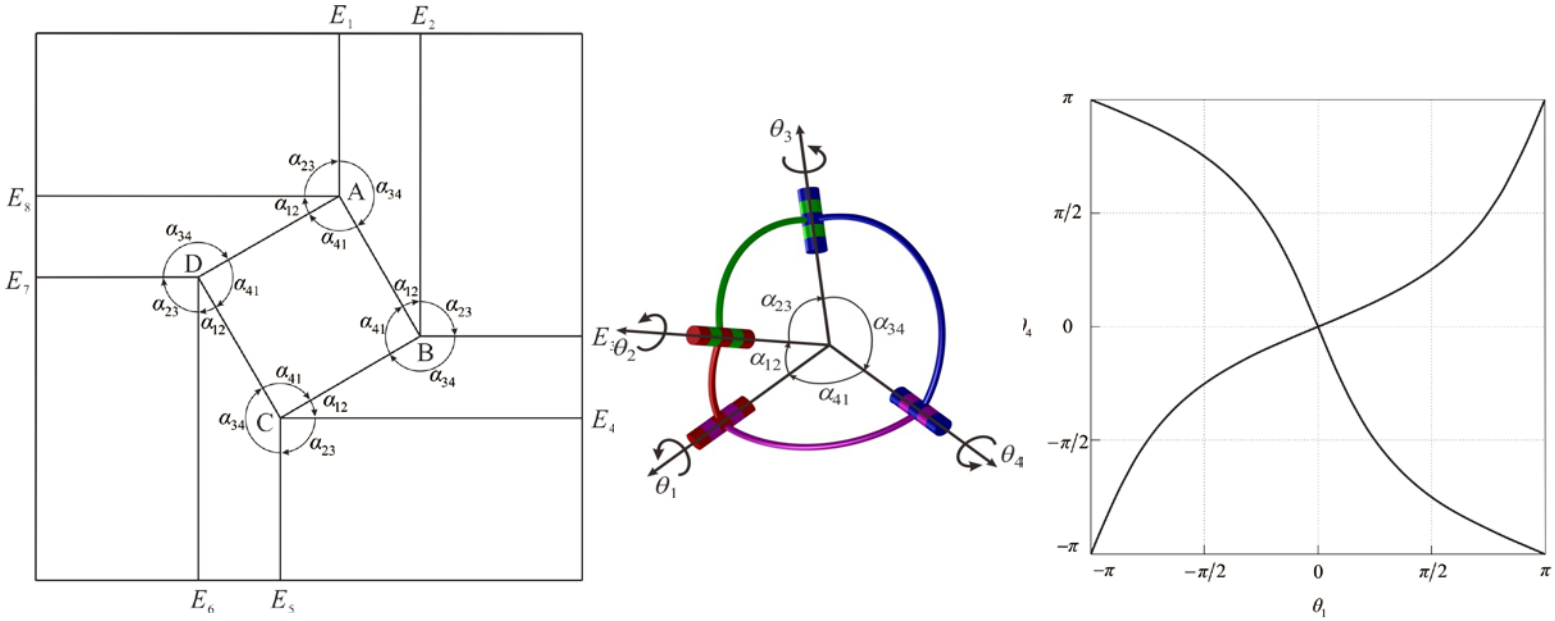


Rigid Origami: Tubular structures





Square-twist pattern



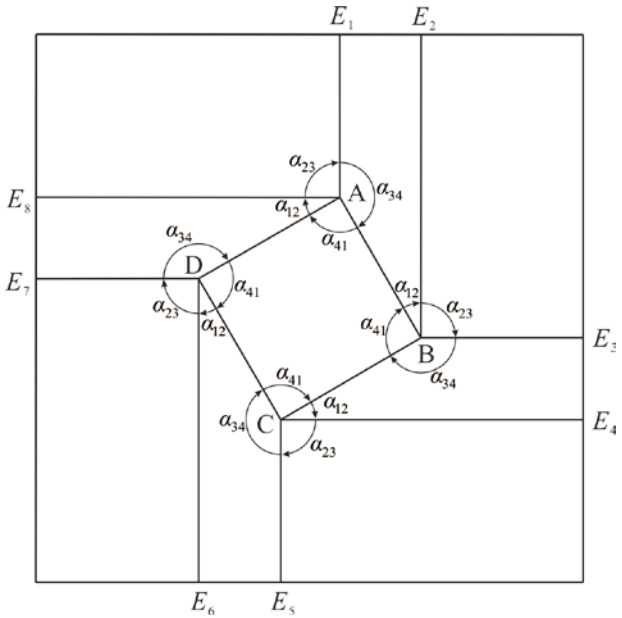
Conditions for square-twist pattern:

$$\begin{cases} \alpha_{12} + \alpha_{34} = \pi, \\ \alpha_{23} = \alpha_{41} = \dfrac{\pi}{2}. \end{cases}$$

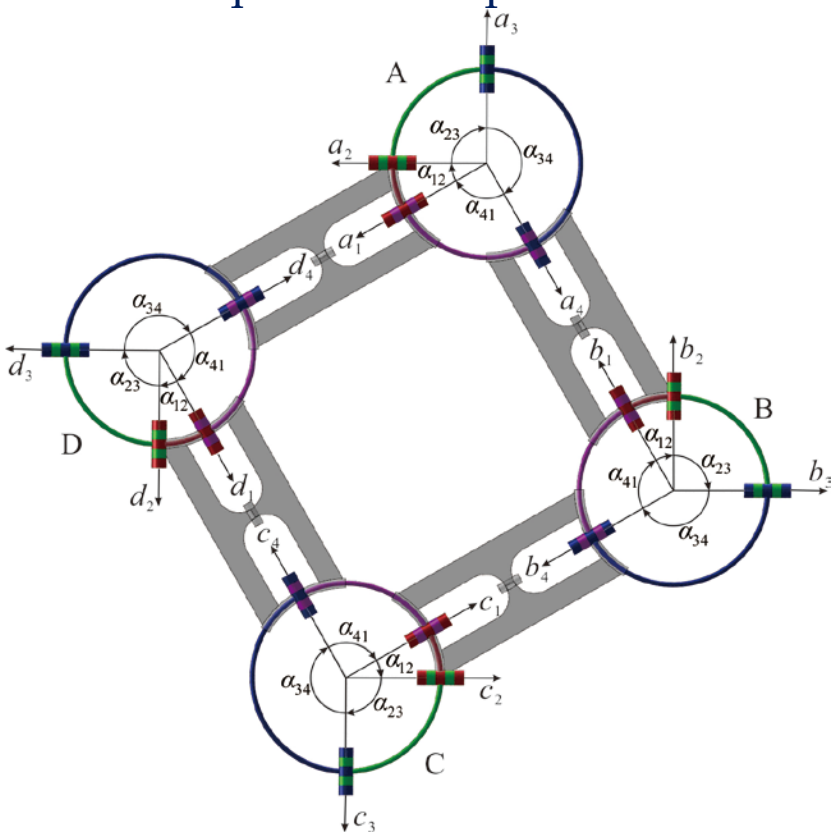
$$\theta_1' = -\theta_4, \theta_4' = \theta_1.$$

four-fold rotational symmetry.

Square-twist pattern



Corresponding mechanism network of square twist pattern



Compatibility condition:

$$(\theta_1^a)\rightarrow(\theta_4^a)=(\theta_1^b)\rightarrow(\theta_4^b)=(\theta_1^c)\rightarrow(\theta_4^c)=(\theta_1^d)\rightarrow(\theta_4^d)$$

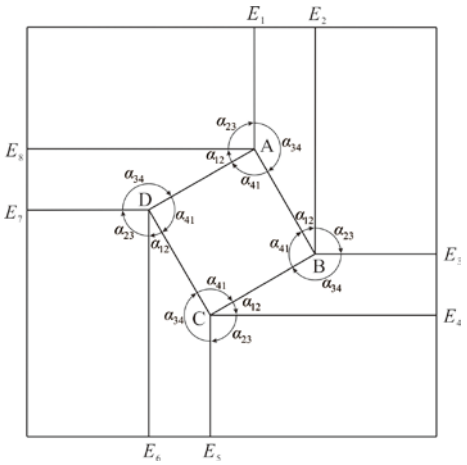
$$(\theta_1^a)=(\theta_4^d)$$

Square -twist Pattern

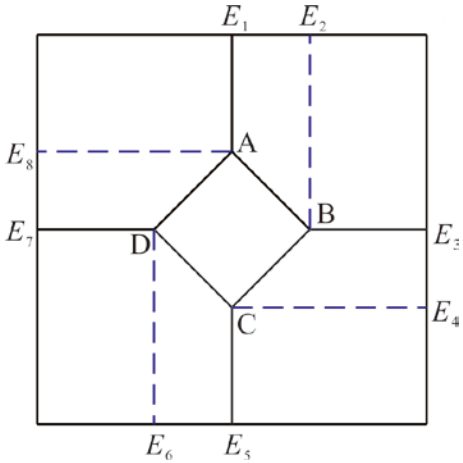
$$0 \le \theta_M \le \pi, -\pi \le \theta_V \le 0.$$

Maekawa-Justin theorem: $M - V = \pm 2$

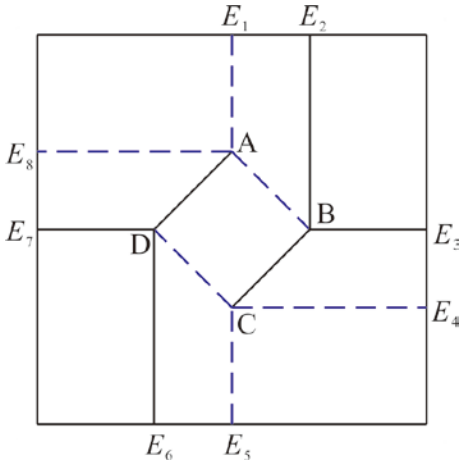
Big-Little-Big Angle theorem



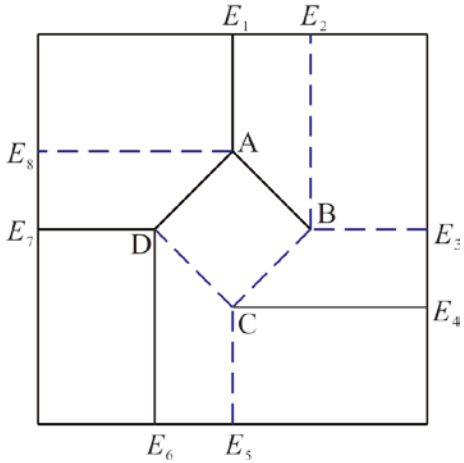
Different arrangement of Mountain-Valley fold lines



Type 1



Type 2



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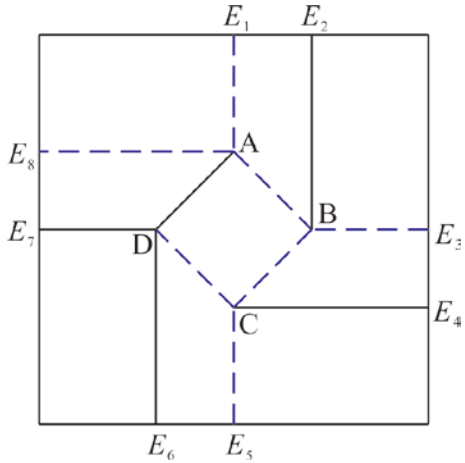
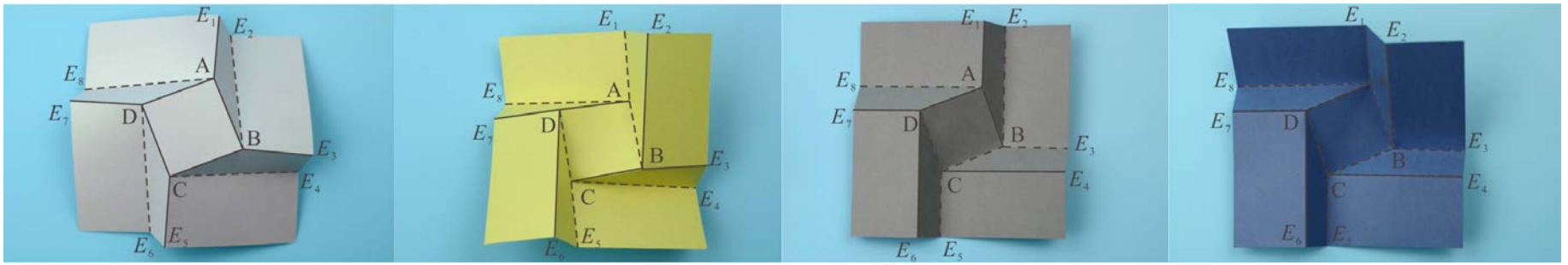
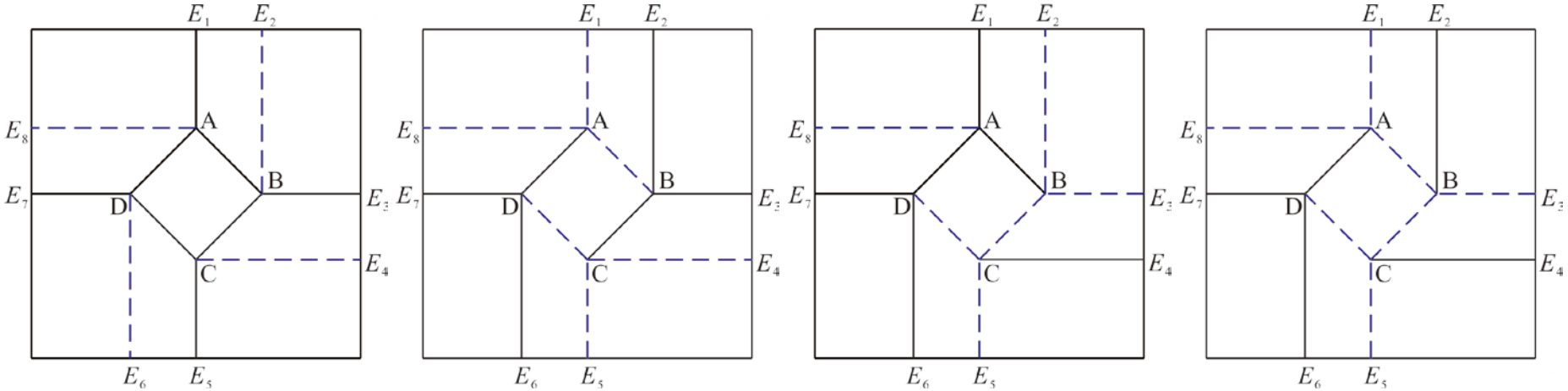


Type 4

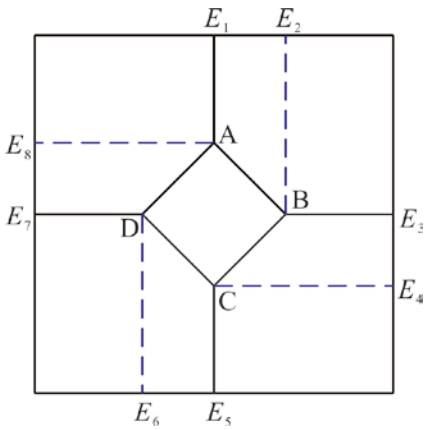
Square -twist Pattern

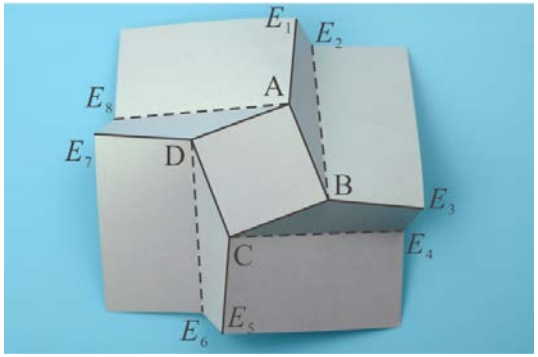


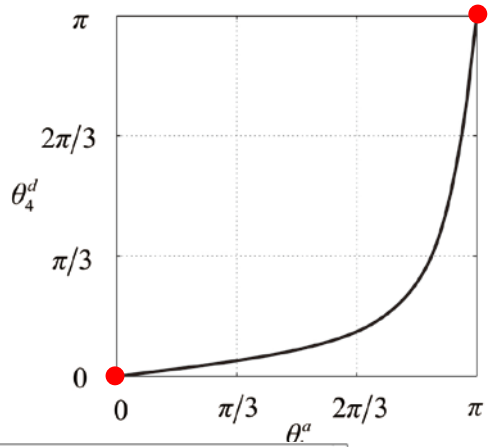


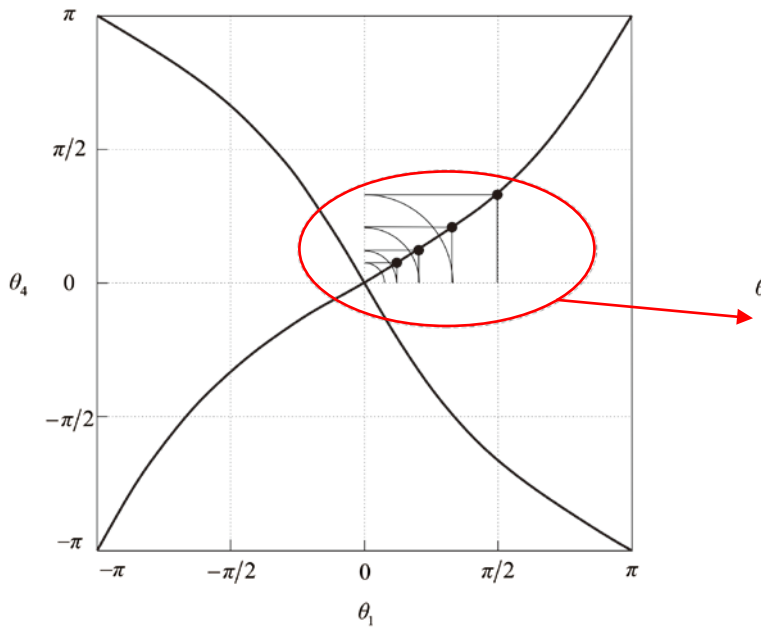
Type 1 Type 2 Type 3 Type 4

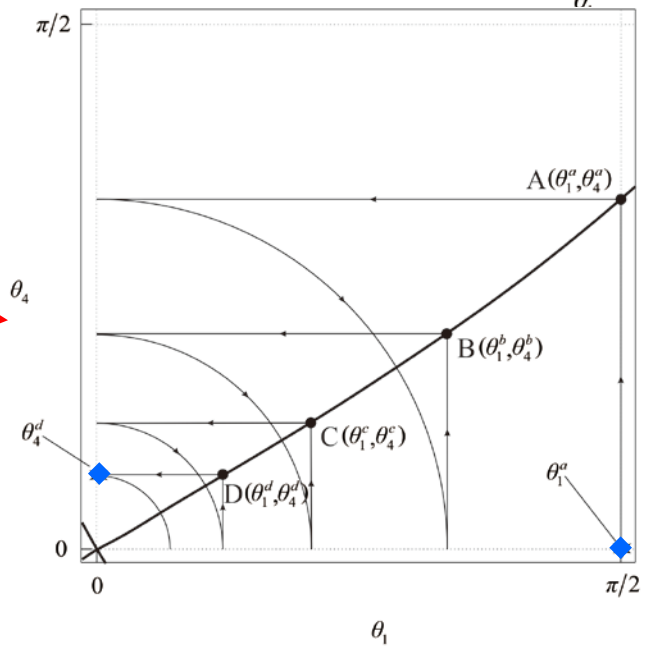
Square -twist Pattern: Type 1



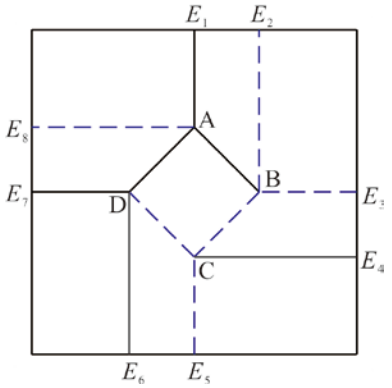


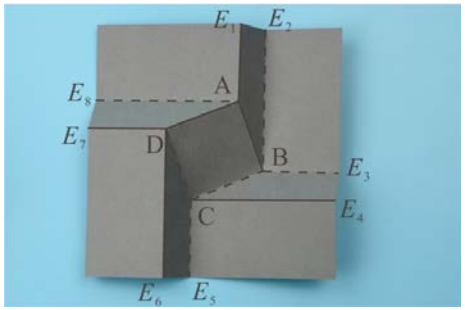


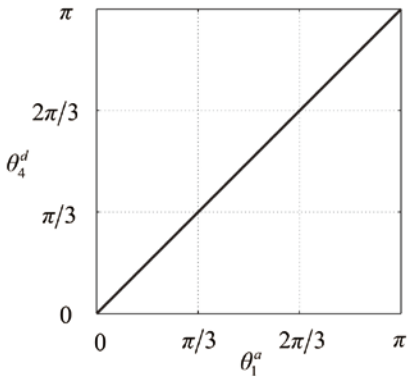


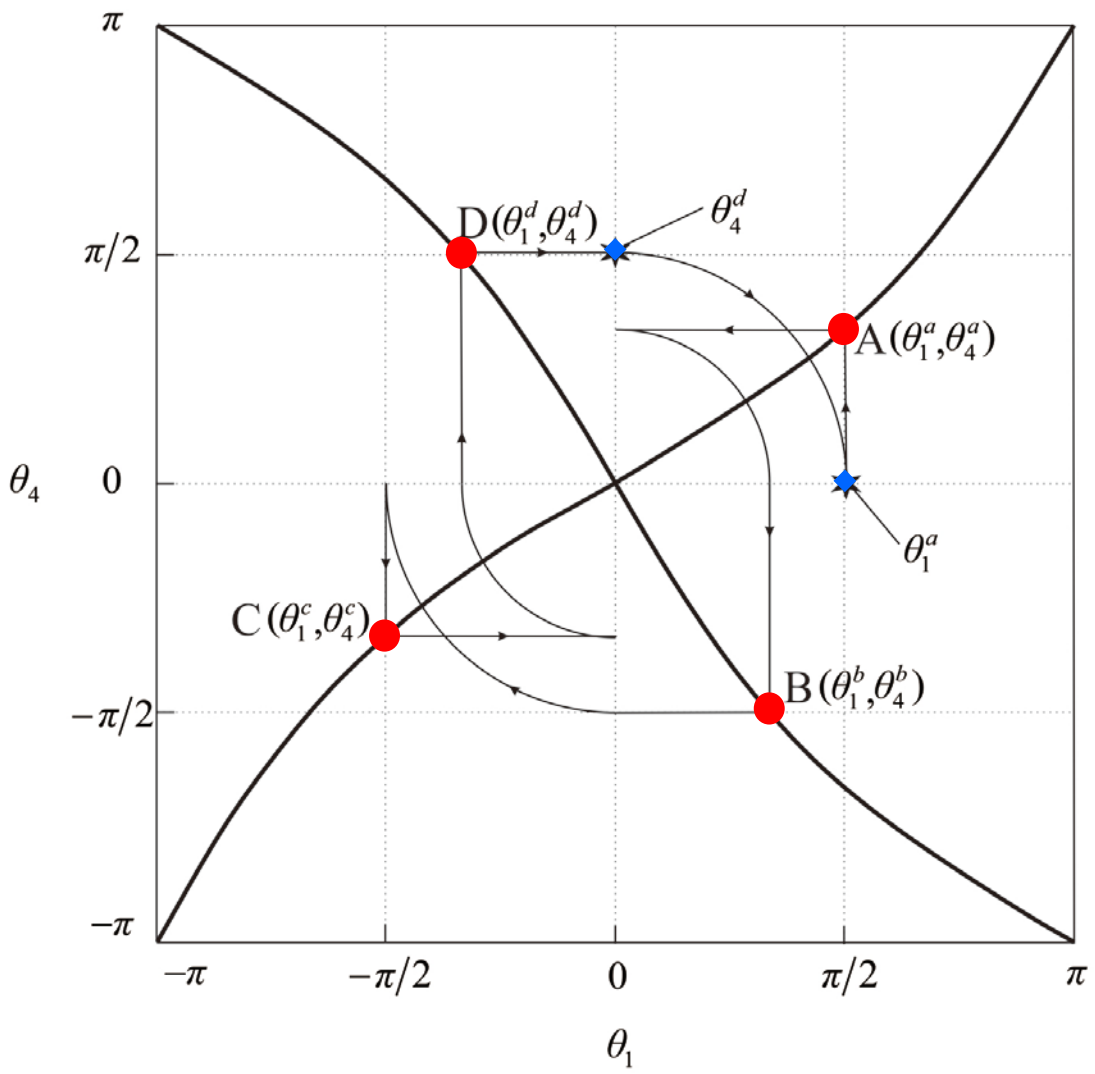


Square -twist Pattern: Type 3

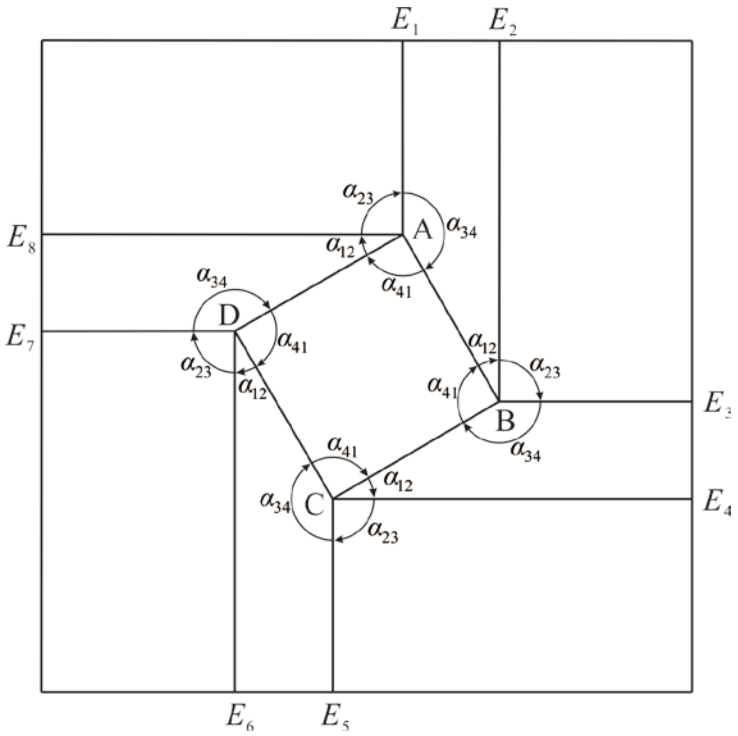


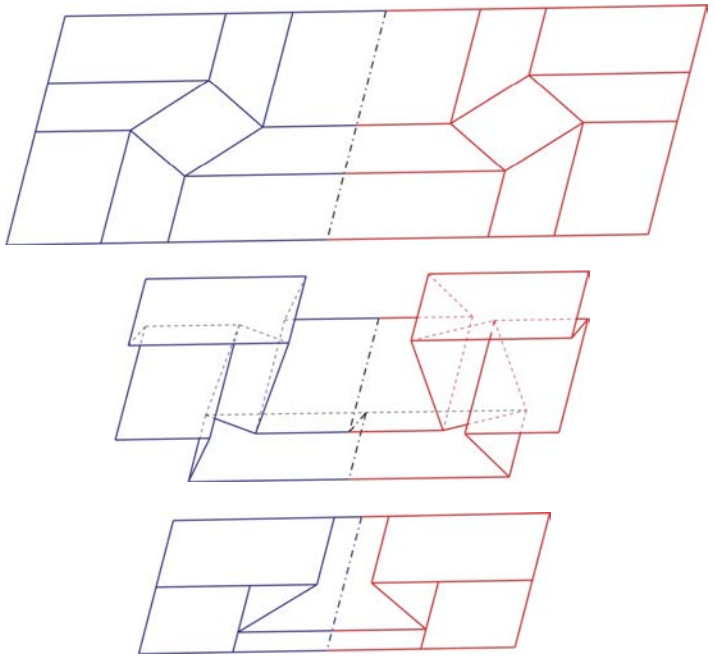


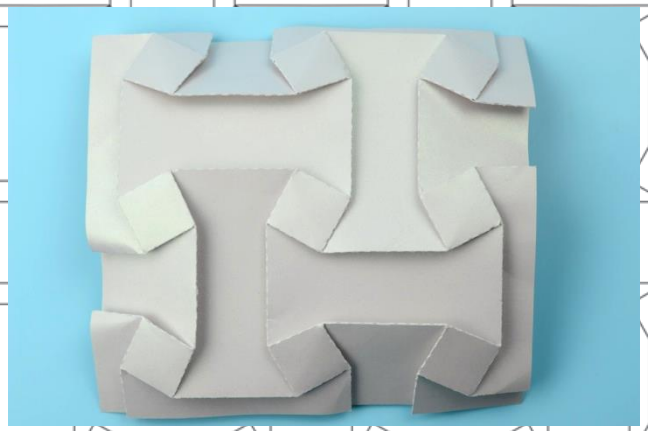




Square-twist Tessellation Crease Pattern

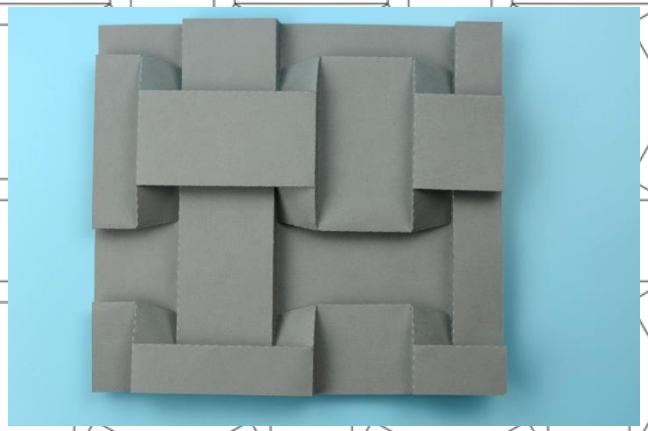






Type 1

Type 2



Type 3

Type 4

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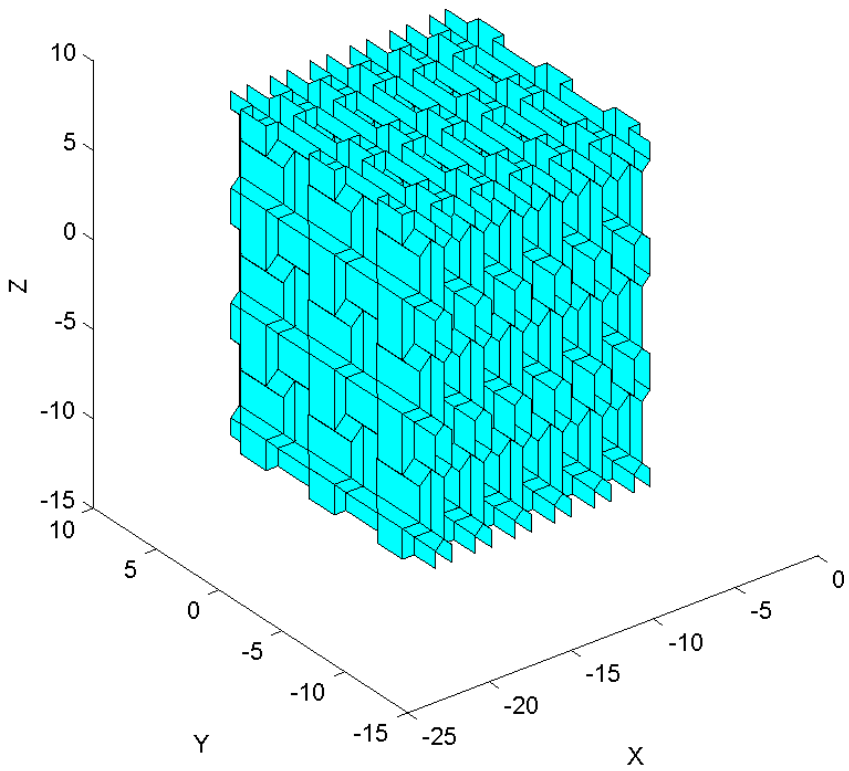
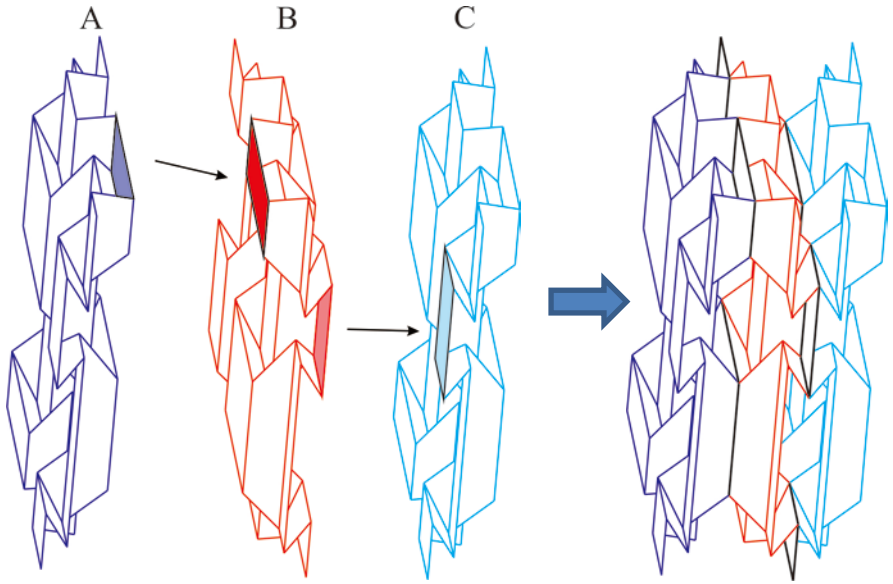
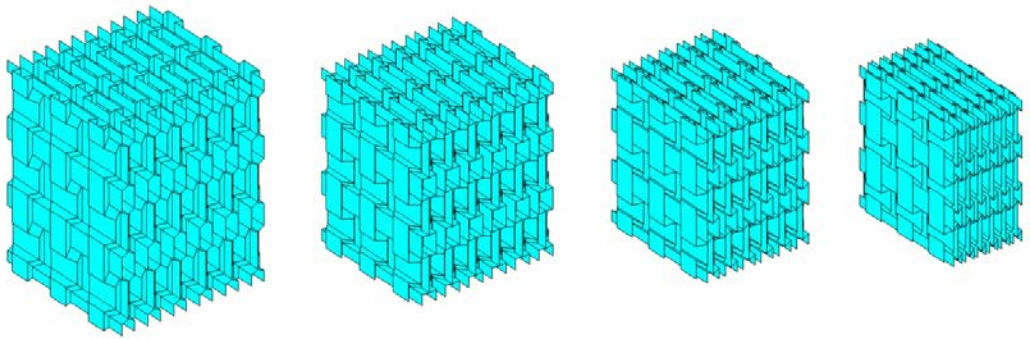
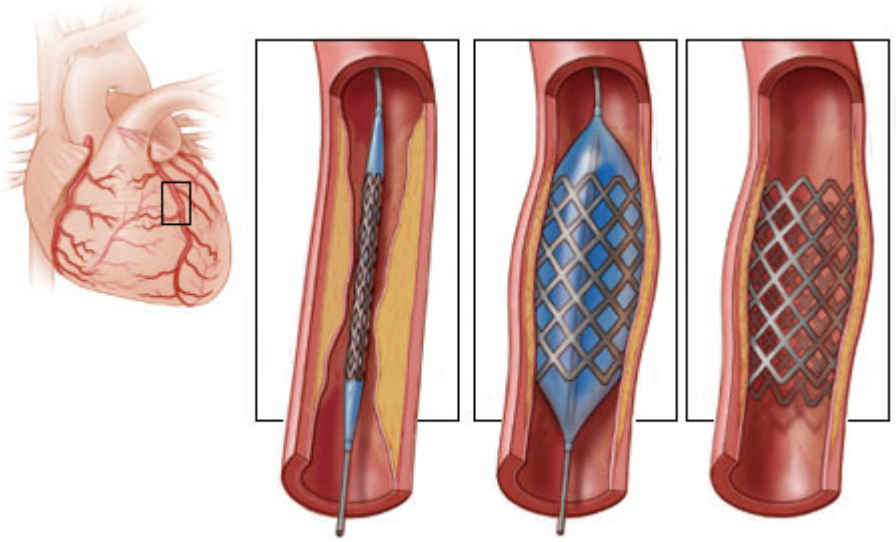
Metamaterial with negative Poisson's ratio







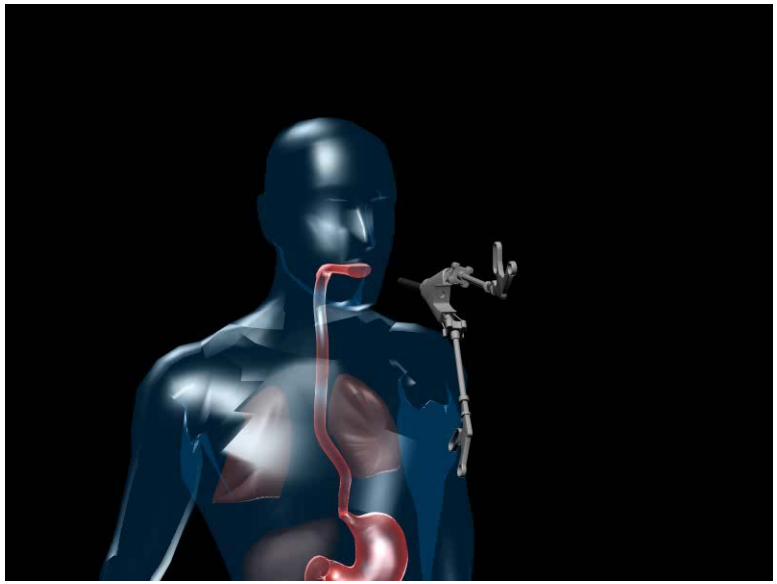
Medical devices based on origami structures

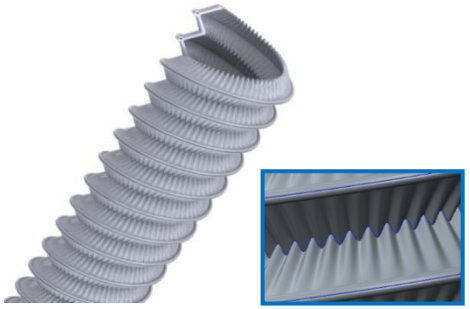


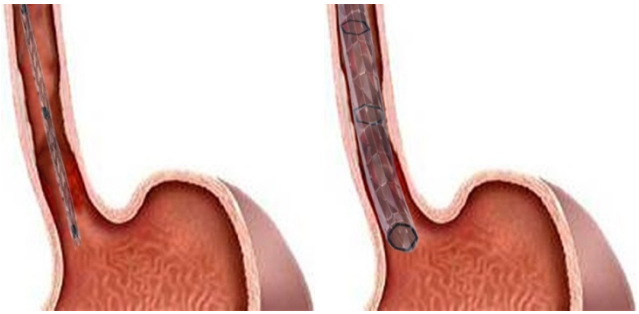
Kuribayashi, K., Tsuchiya, K., You, Z., Tomus, D., Umemoto, M., Ito, T., & Sasaki, M. (2006). Self-deployable origami stent grafts as a biomedical application of Ni-rich TiNi shape memory alloy foil. *Materials Science and Engineering: A*, *419*(1), 131-137.

Medical devices based on origami structures

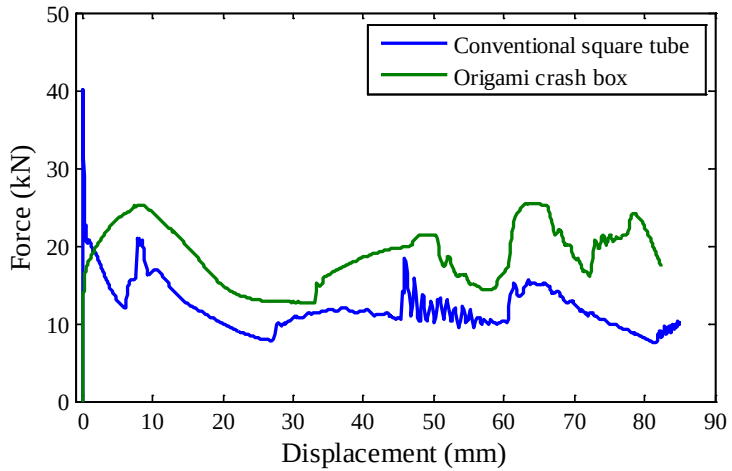
NOTES: Natural Orifice Translumenal Endoscopic Surgery

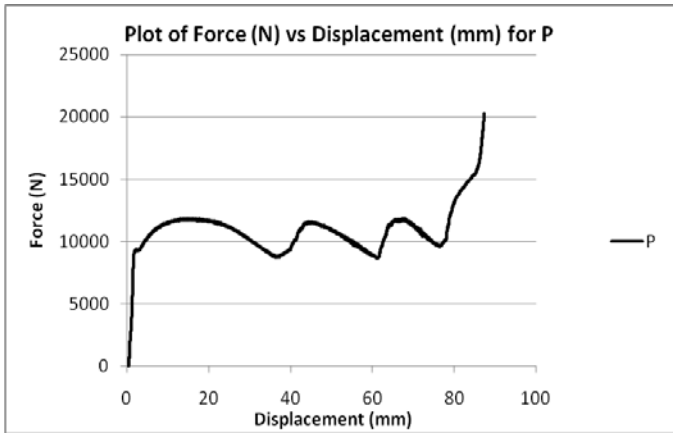


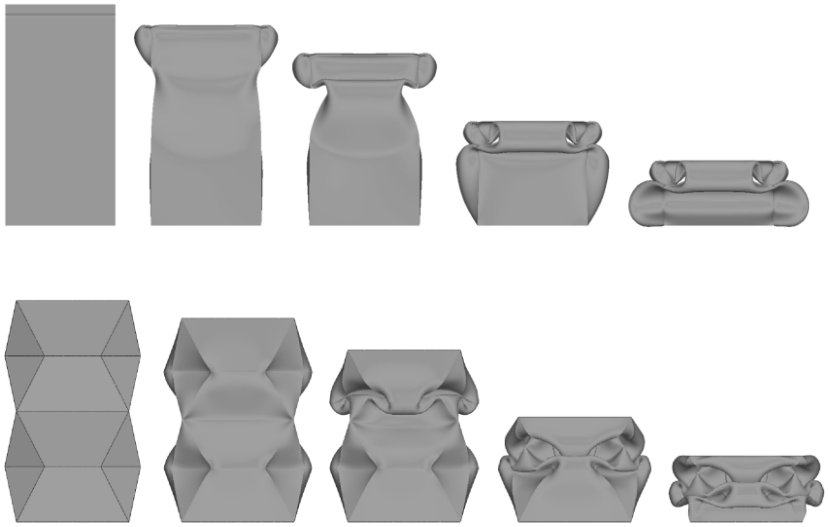




Origami structures for absorbing energy and carrying load







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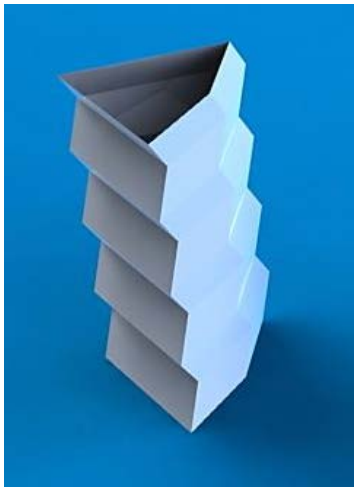
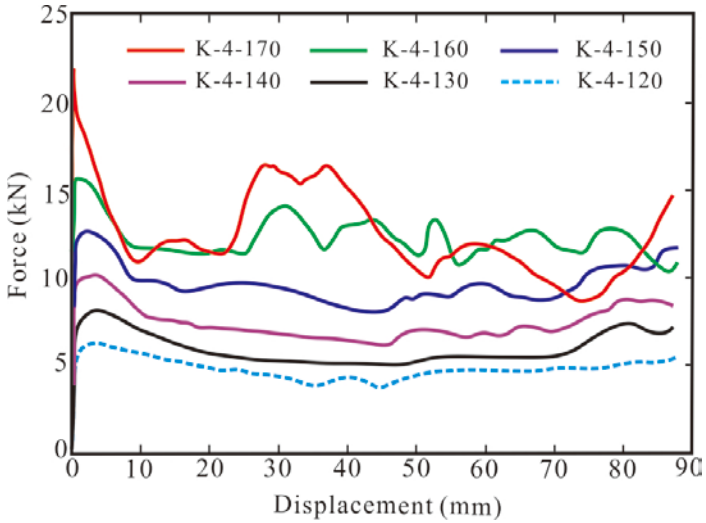
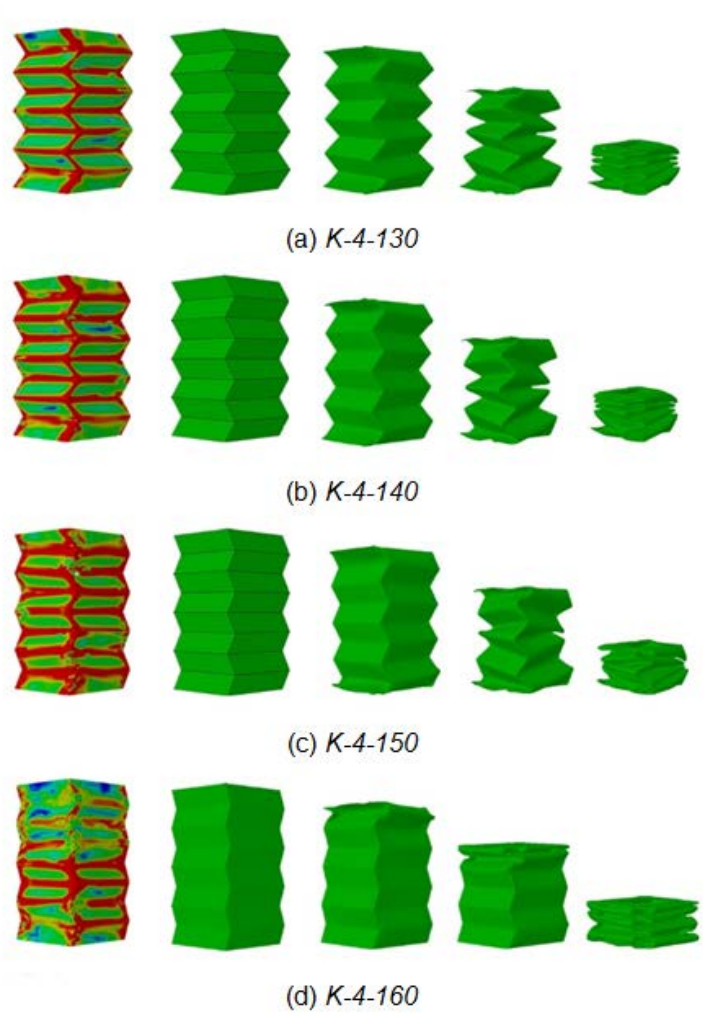
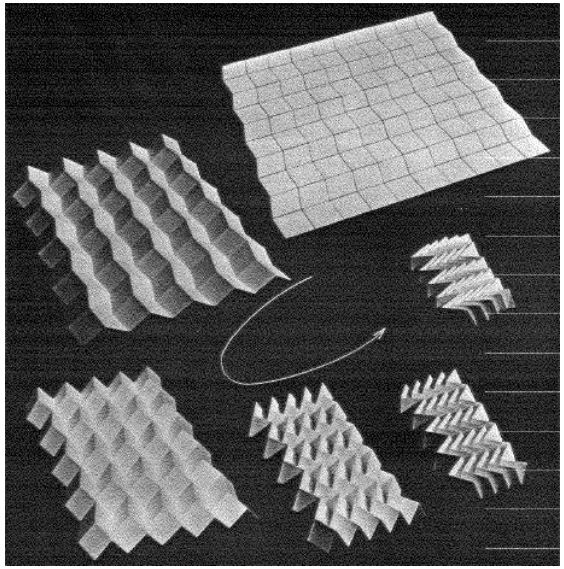
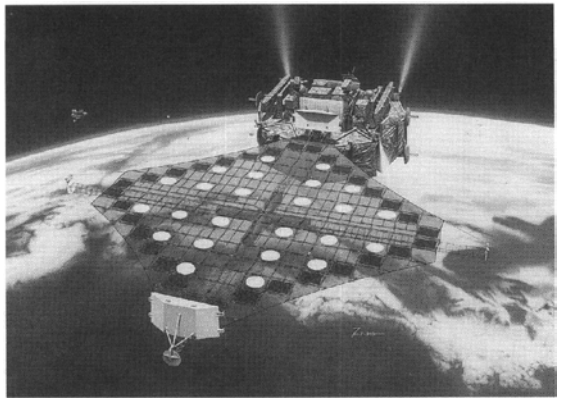


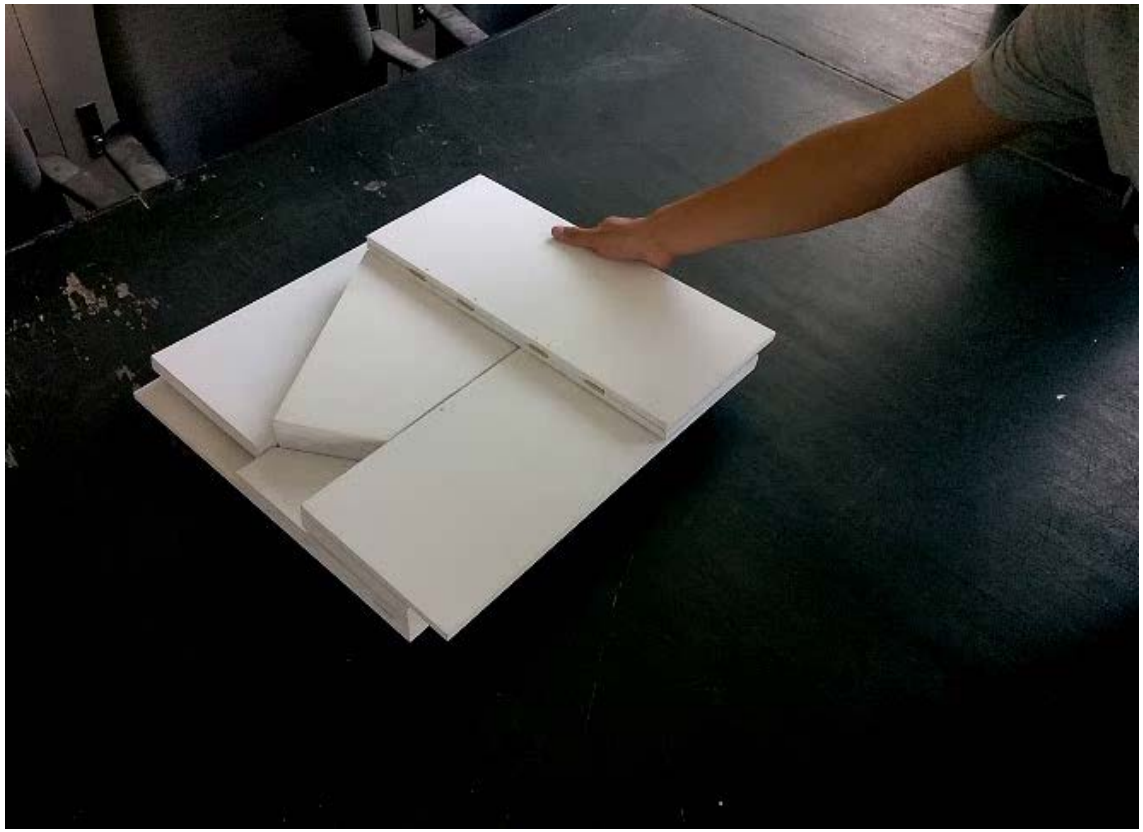




Large-scale deployable structures







Contents

- Origami: Art, Mathematics, Engineering
- Kinematics of rigid origami
- Engineering applications of origami structures
- Future development

Future development

Rigid origami:

- **Tessellation** is a powerful tool in synthesis;
- **Kinematics** of the linkages is the fundamental;
- To find more **new** rigid origami patterns, especially with **large deployable ratio**.

Engineering applications:

- **Compliant** structures are the bridge;
- To **widen** the application areas;
- To **enhance** the **advantages** of origami structures.

Collaboration in the interdisciplinary research!

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Thank you
谢谢