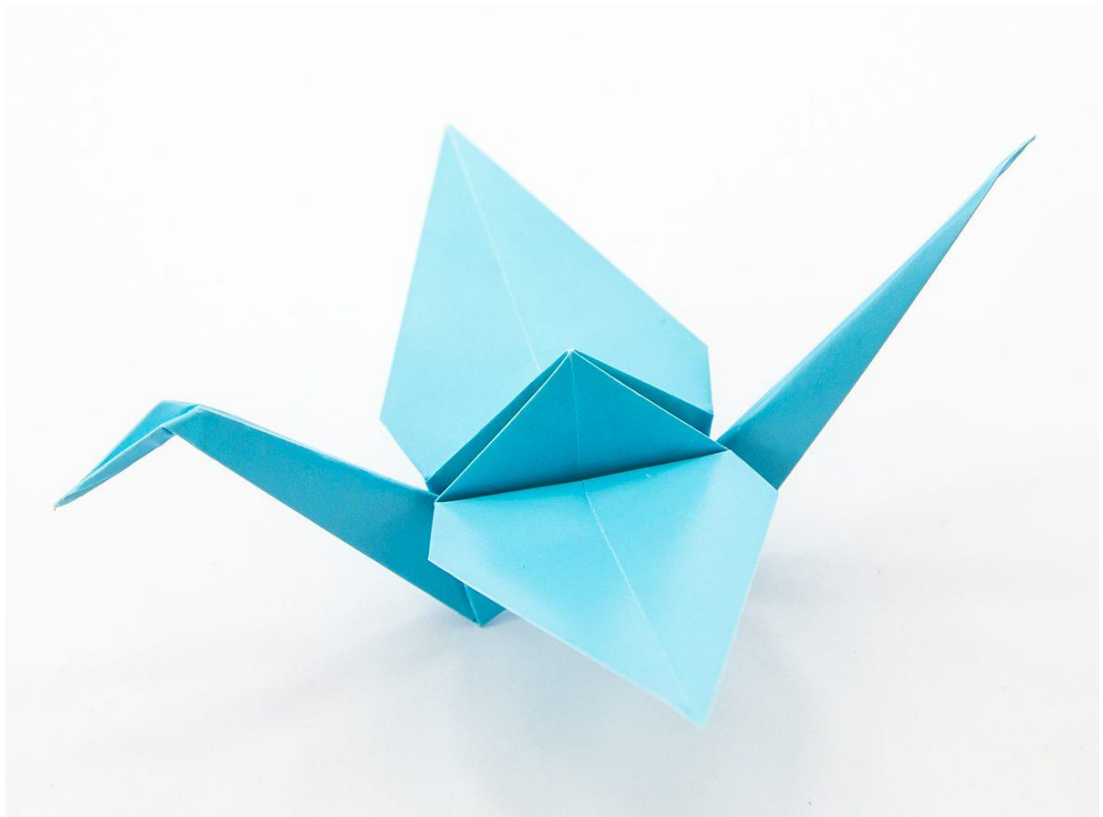
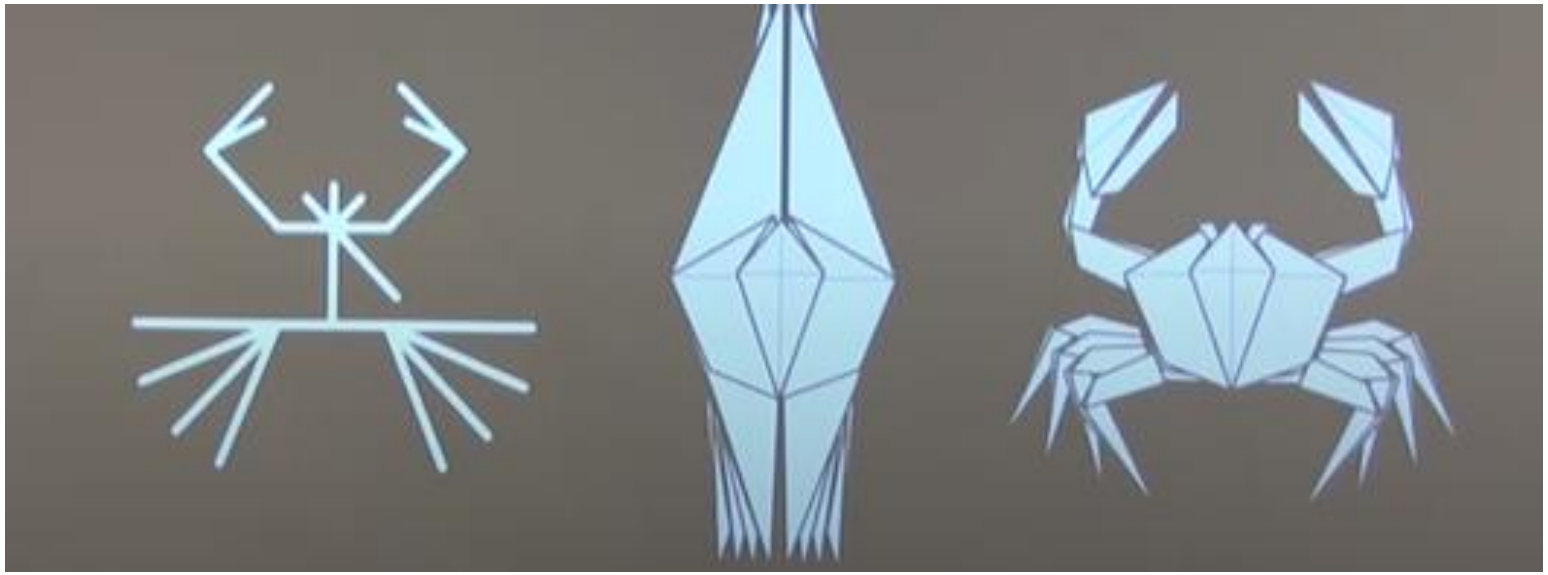
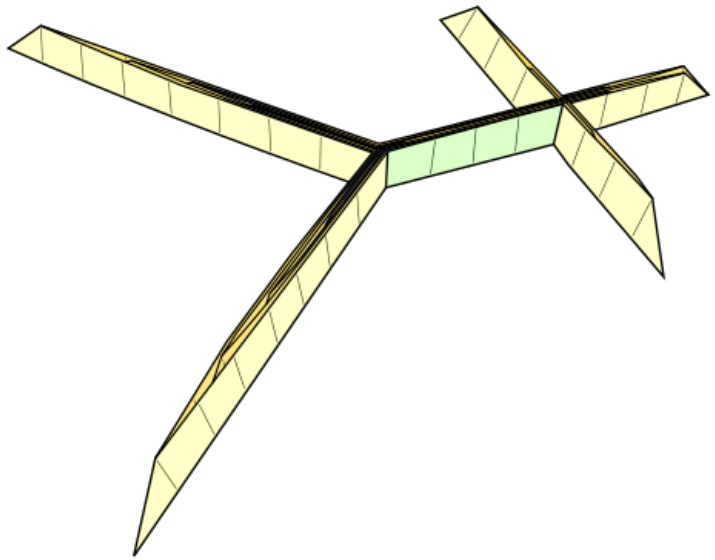
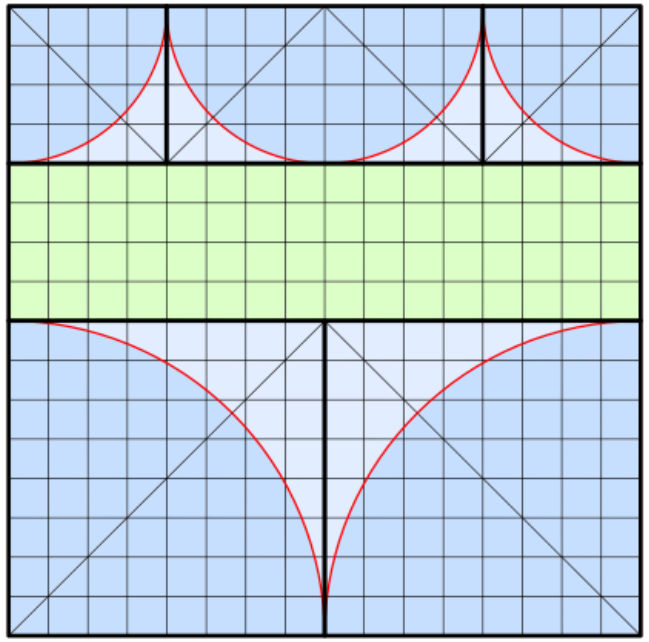
Računalni origami

Filip Barbarić

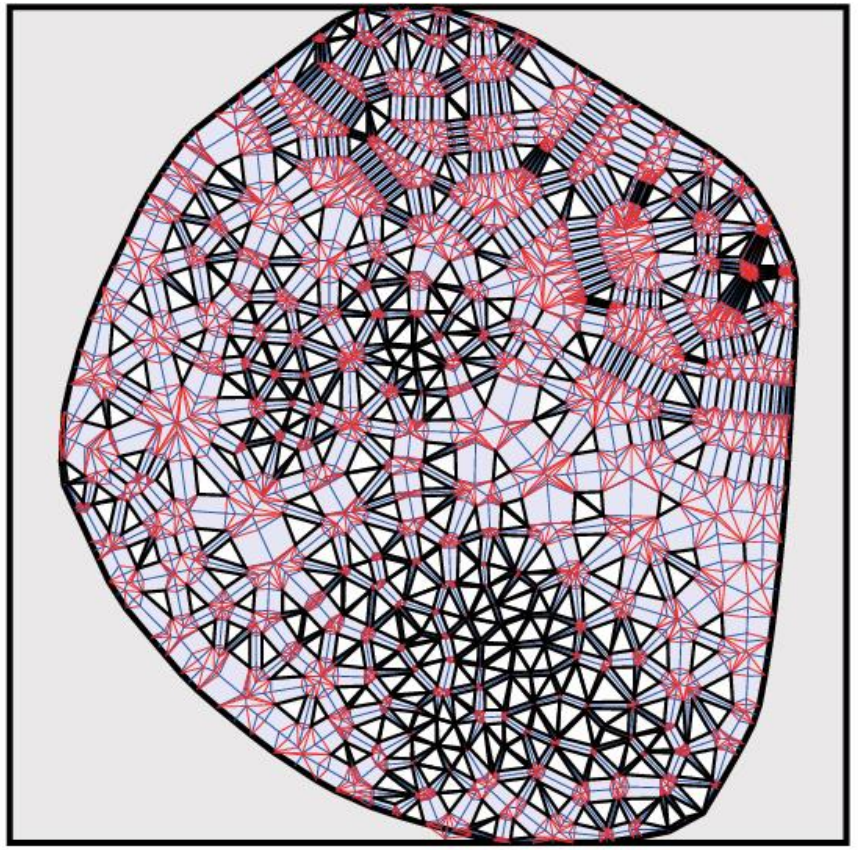


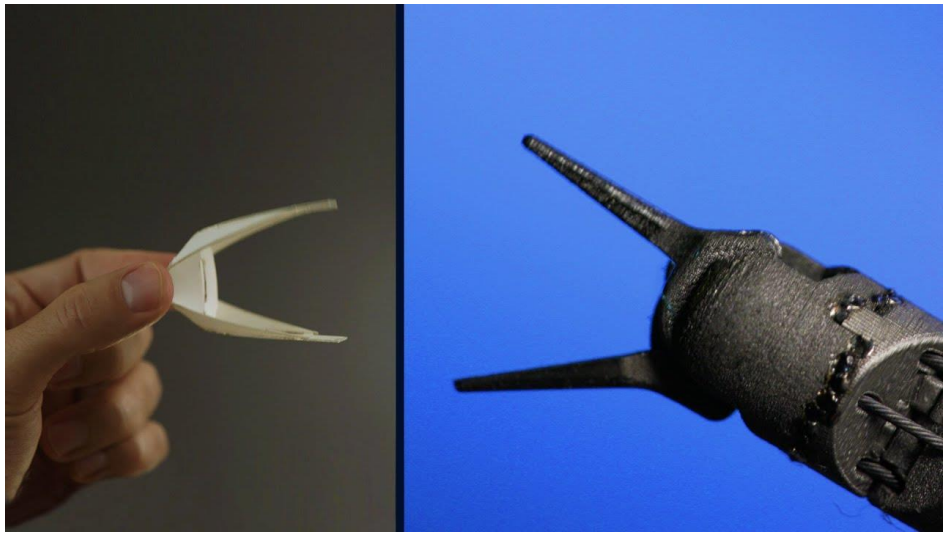


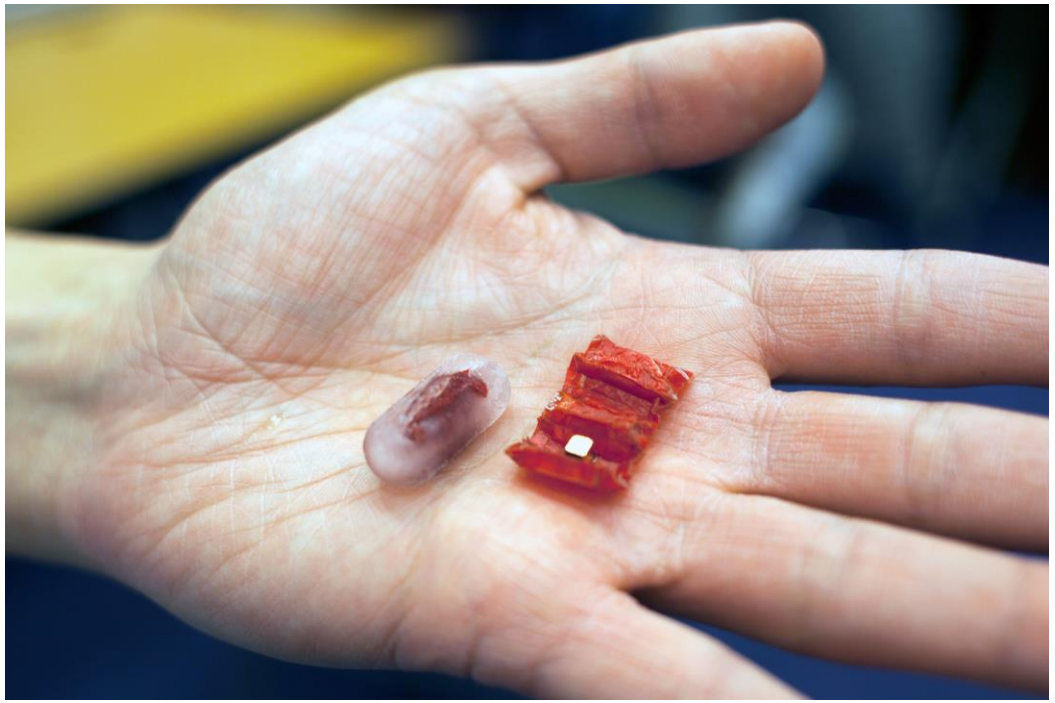


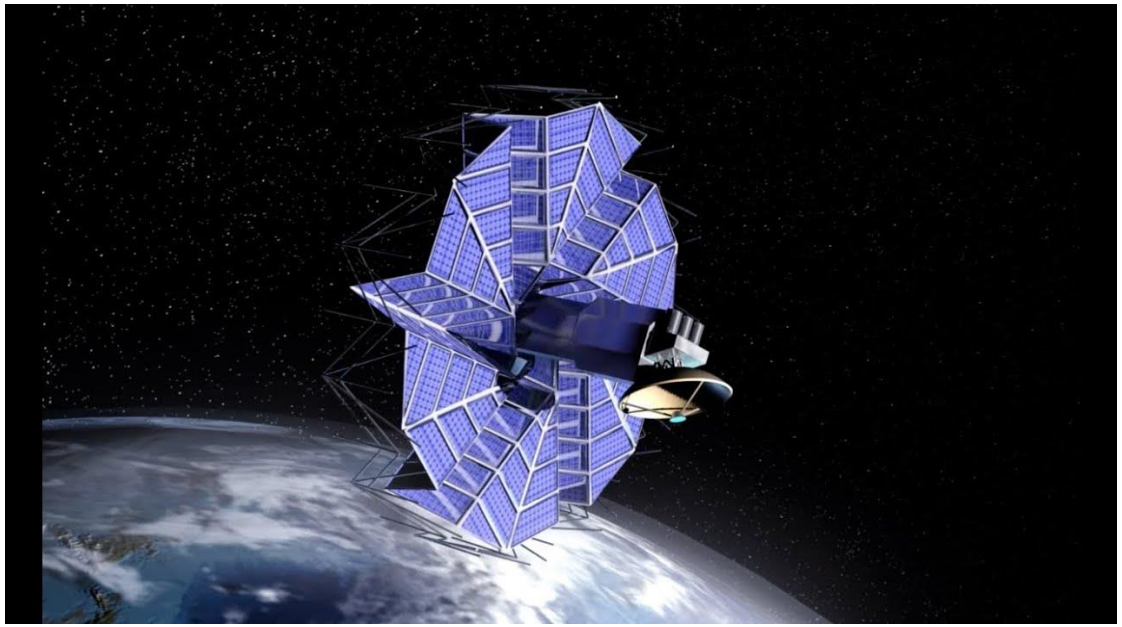


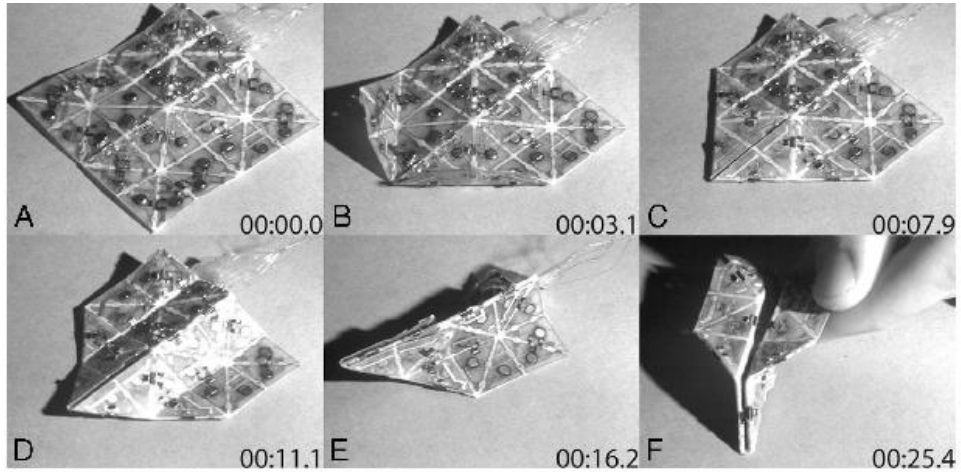
Origamizer, možemo napraviti sve







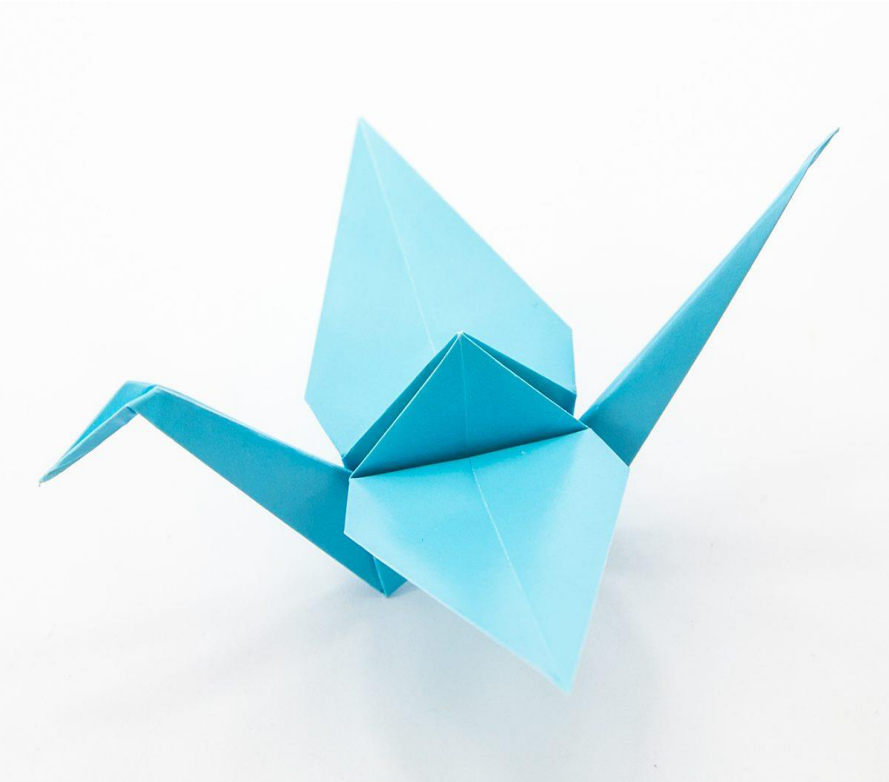


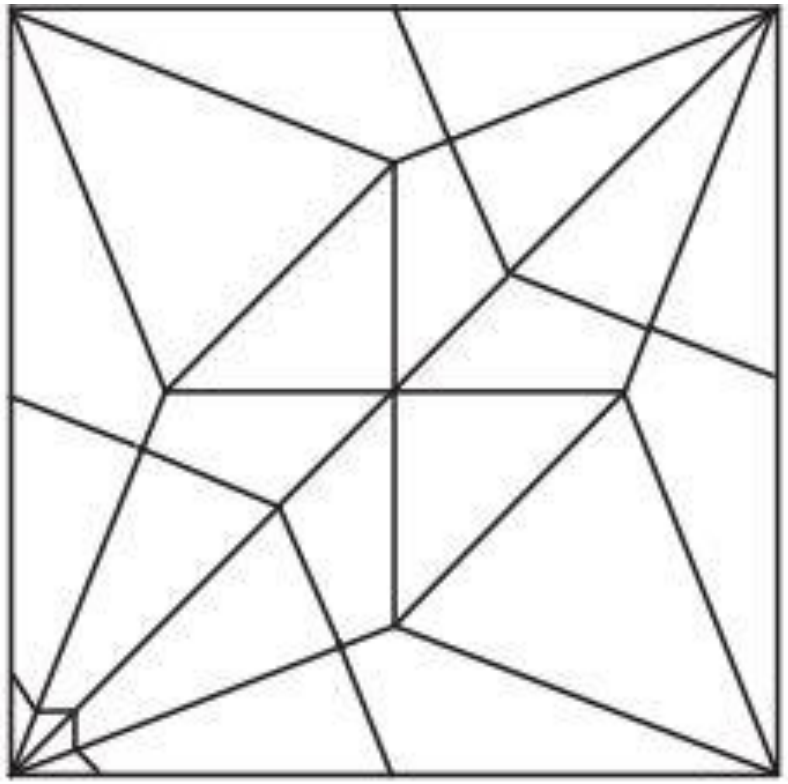

A
00:00.0
B
00:03.1
C
00:07.9
D
00:11.1
E
00:16.2
F
00:25.4

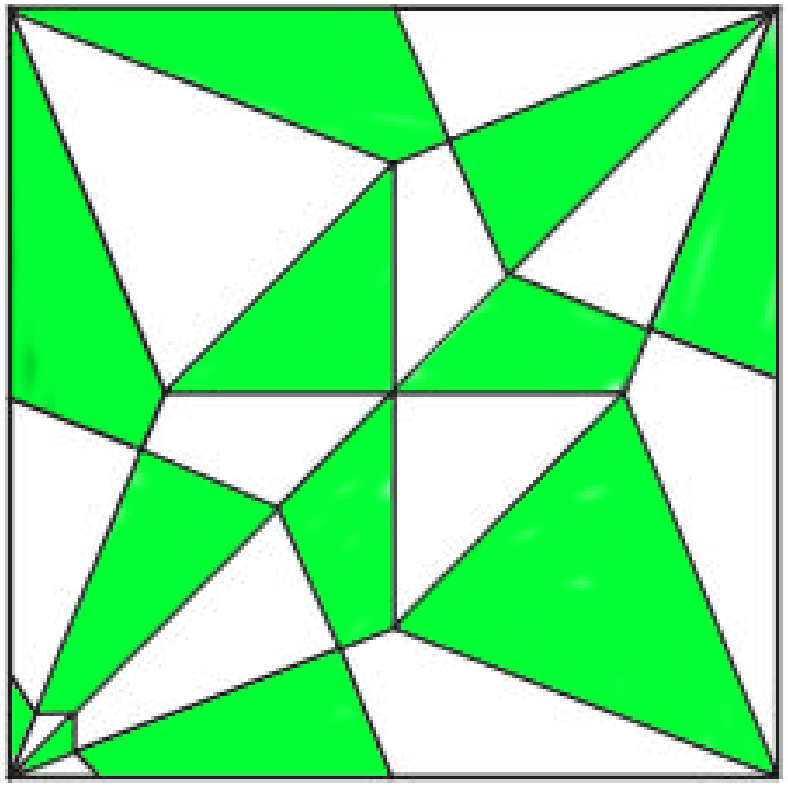
Dva svojstva

- Ravno savitljivost (eng. flat foldable)
- Rigidni origami (eng. Rigid origami)

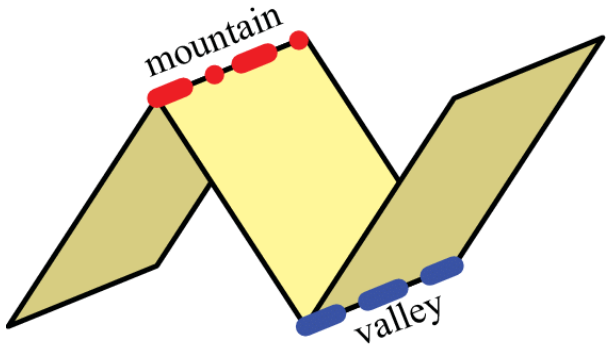
Matematika origamija







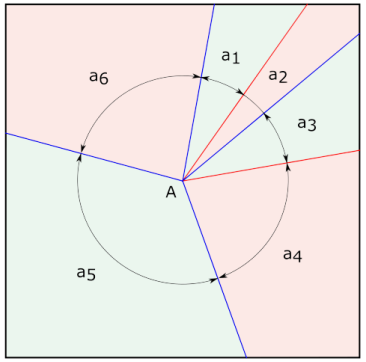
Maekawain teorem



M − V = ±2

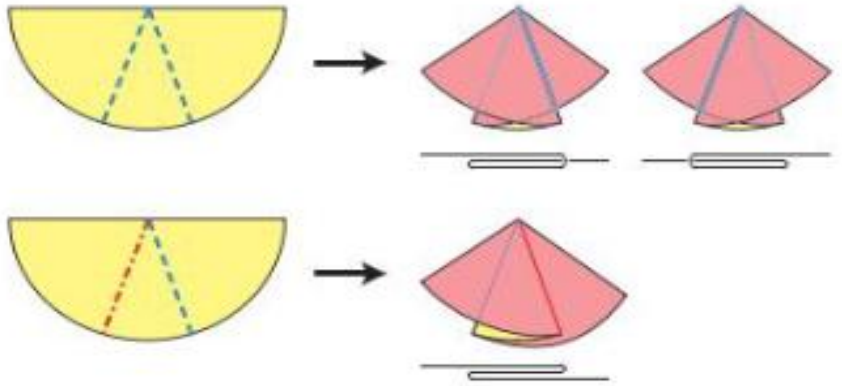
$$\sum_{i=1}^{2n} \mu(l_i) = \pm 2$$

Kawasakijev teorem

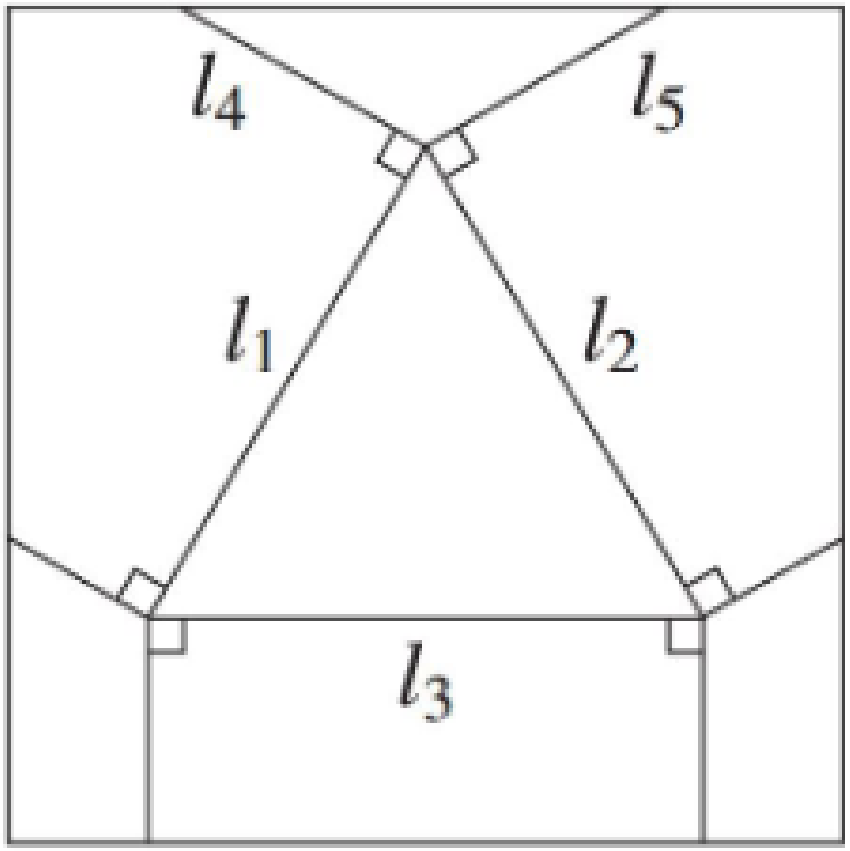


$$\alpha_0 - \alpha_1 + \alpha_2 - \ldots - \alpha_{2n-1} = 0$$

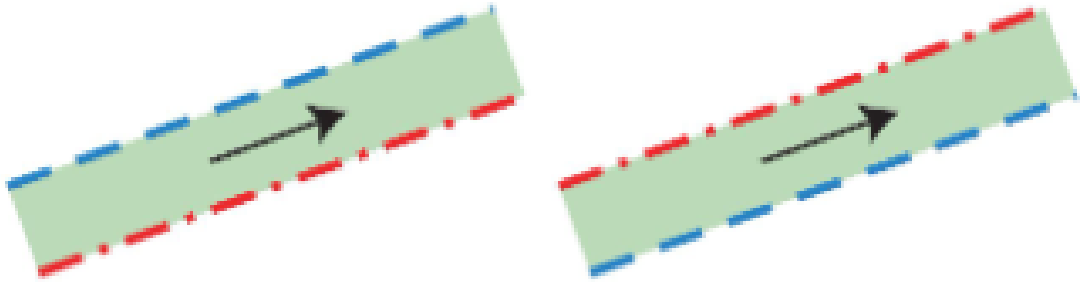
Lema Veliki-Mali-Veliki (Big-Little-Big)

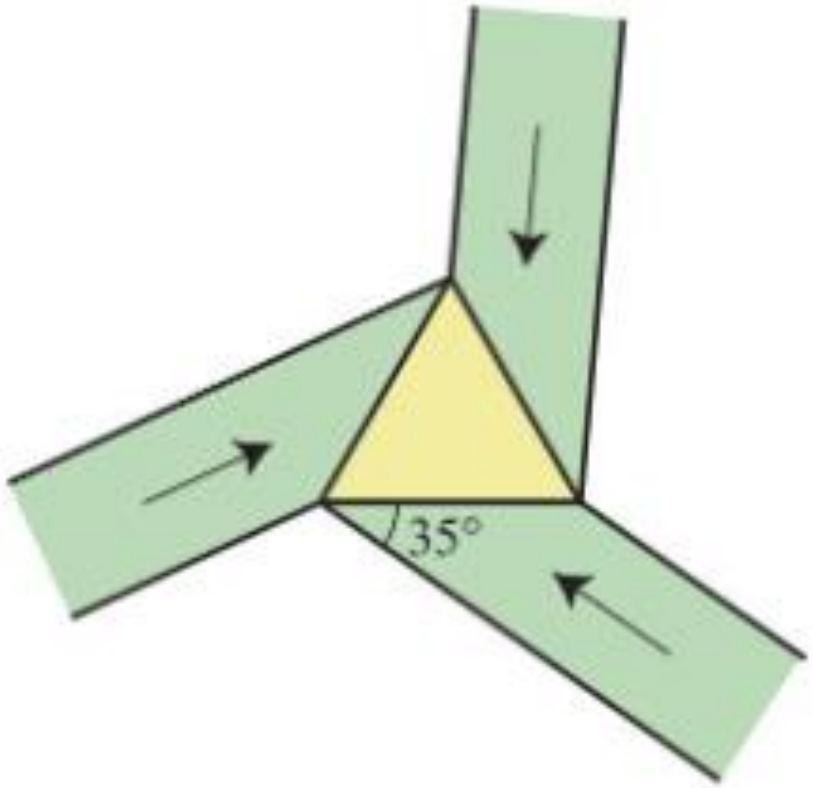


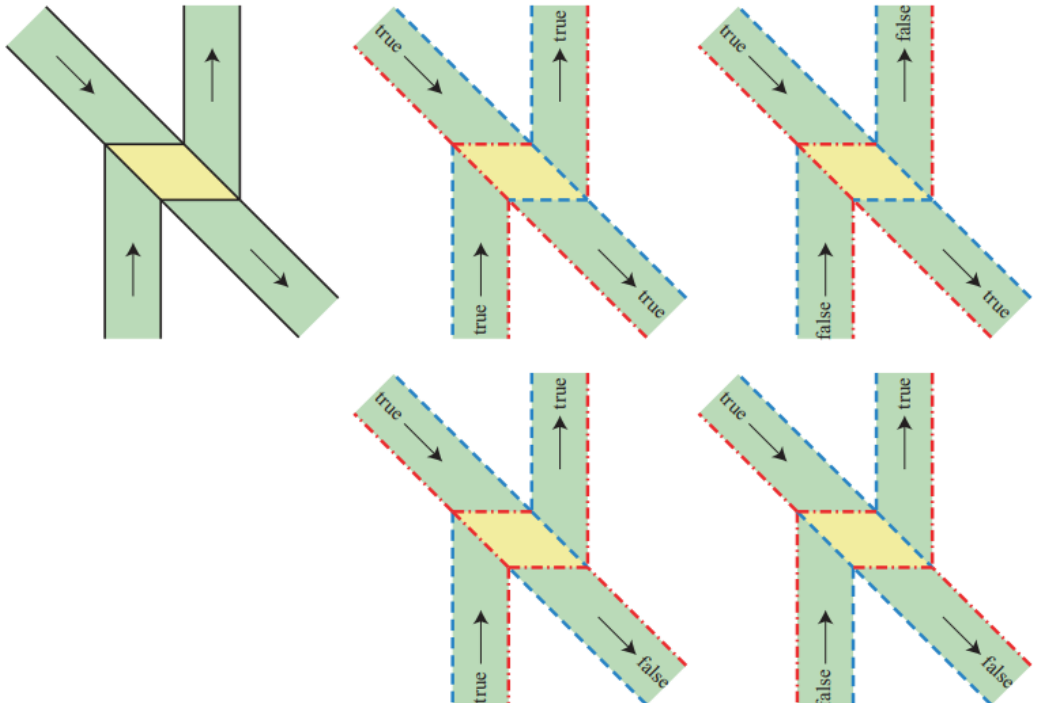
Origami je težak



Teorem: Ravno savitljivost je NP teško.






true
true
true
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false
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false
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true
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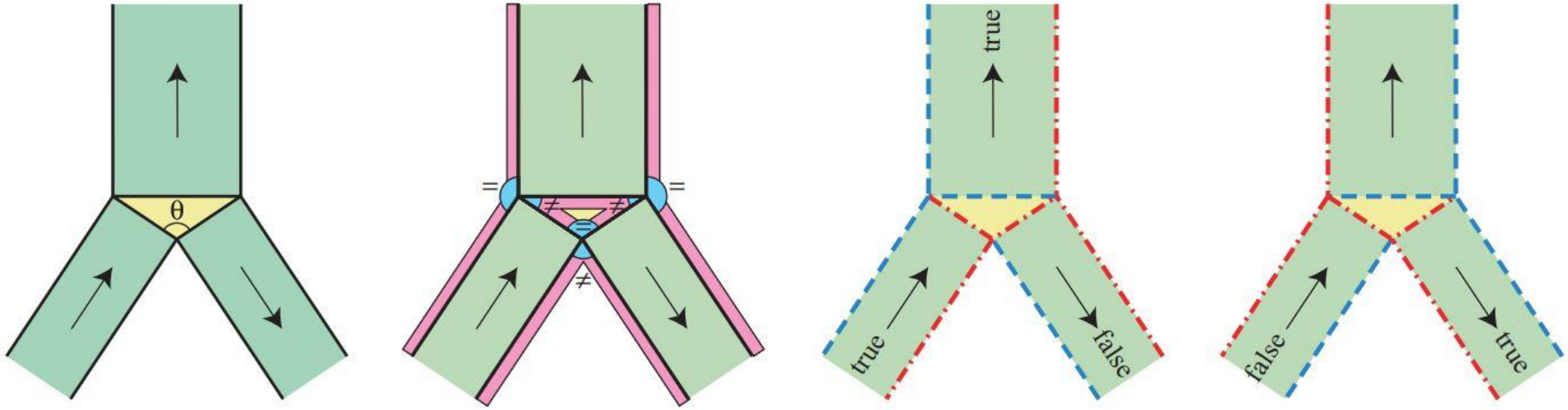
false


θ
=
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≠
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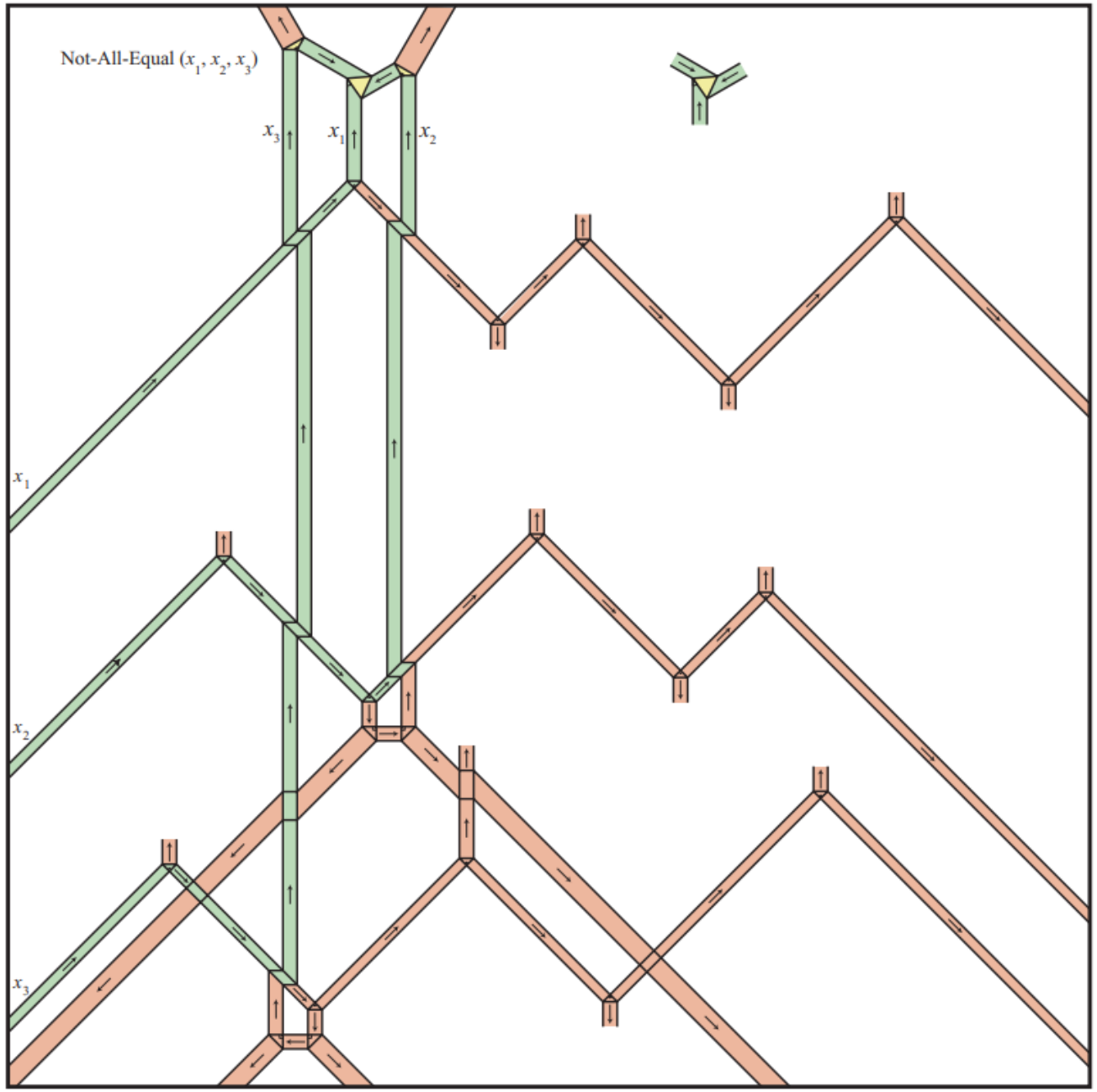
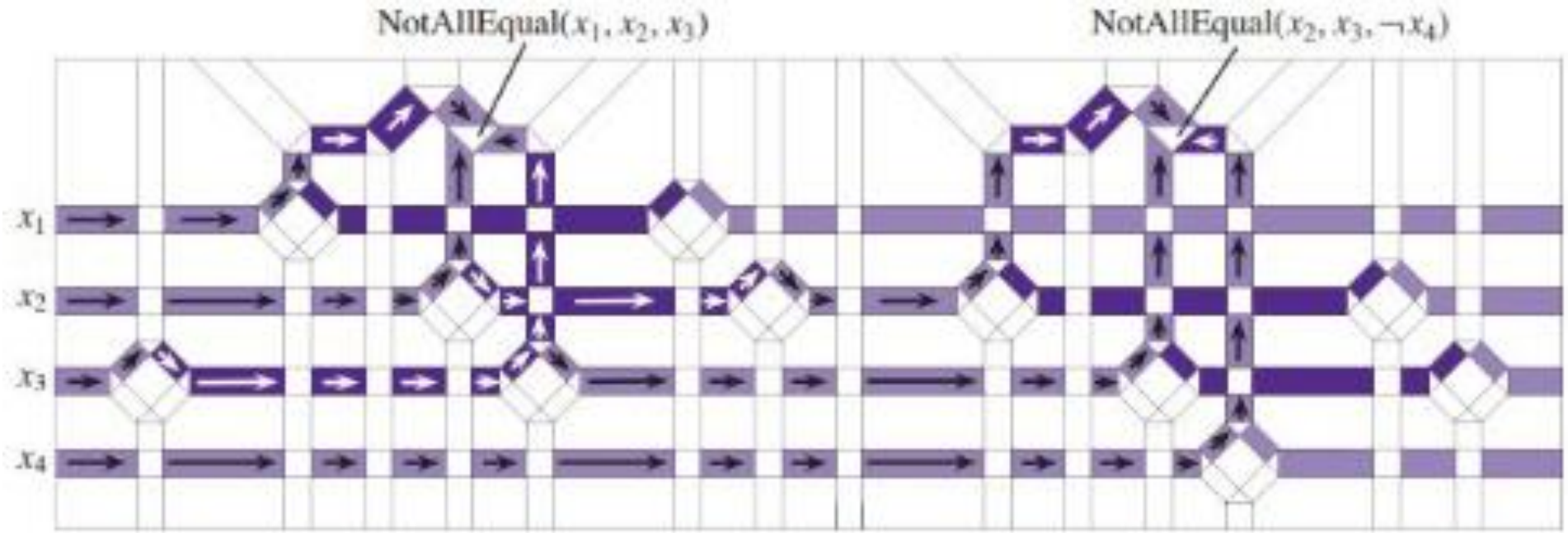
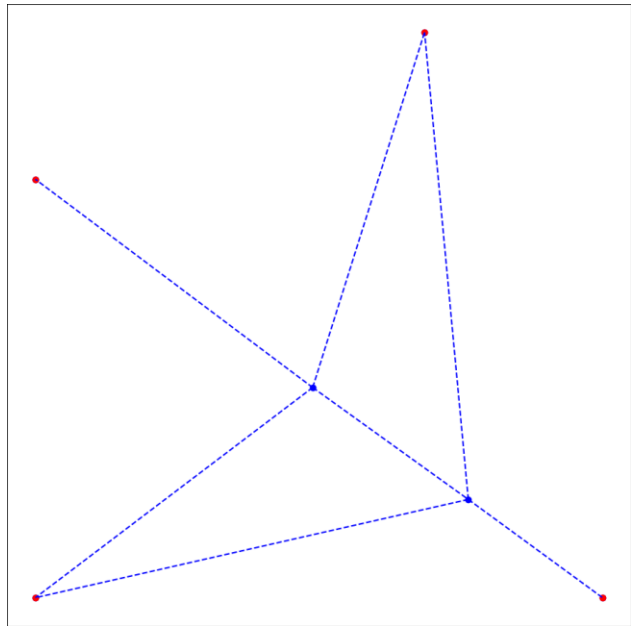
true
true
false
false
true

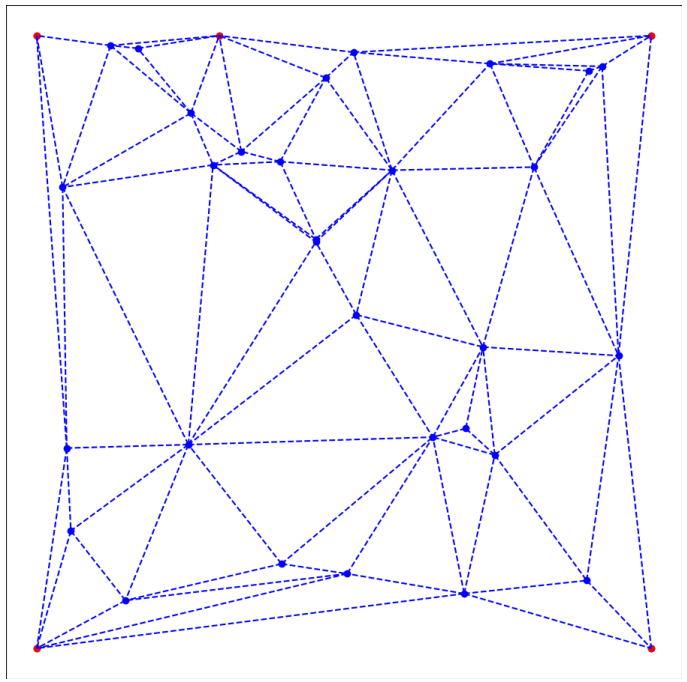

Not-All-Equal (x_1, x_2, x_3)
x_3
x_1
x_2
x_1
x_2
x_3

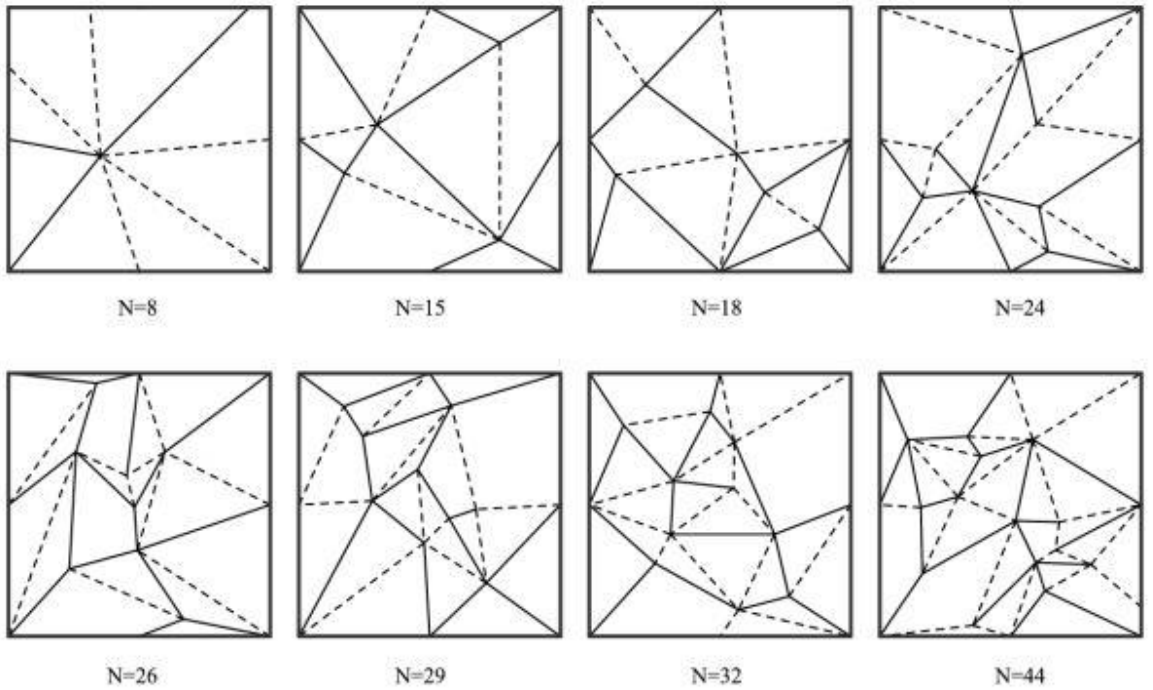

NotAllEqual(x_1, x_2, x_3)
NotAllEqual($x_2, x_3, \neg x_4$)
x_1
x_2
x_3
x_4

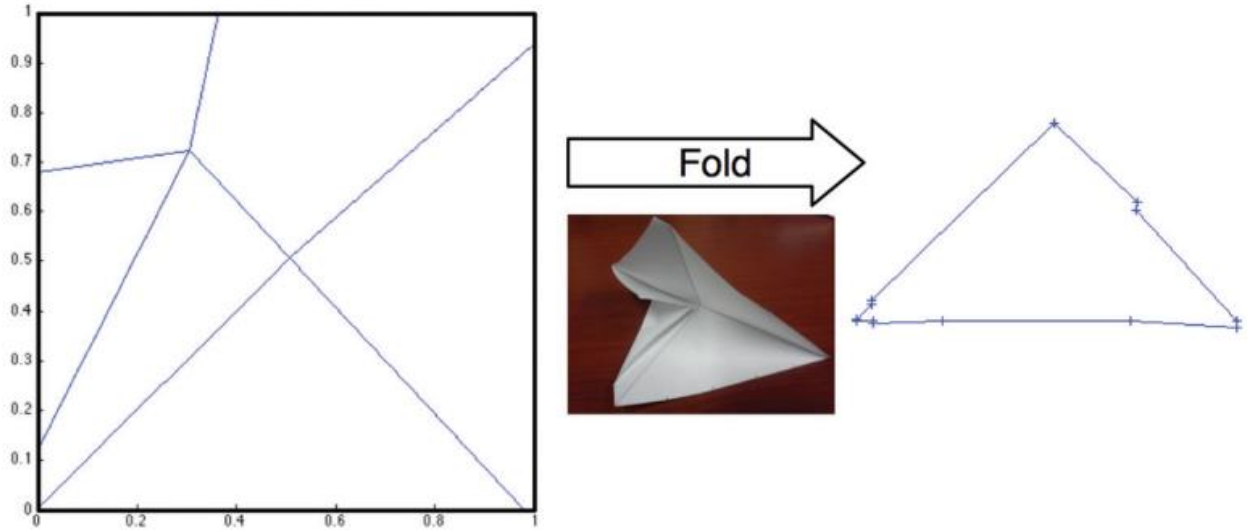
Metode kreiranja ravno savitljivih shema

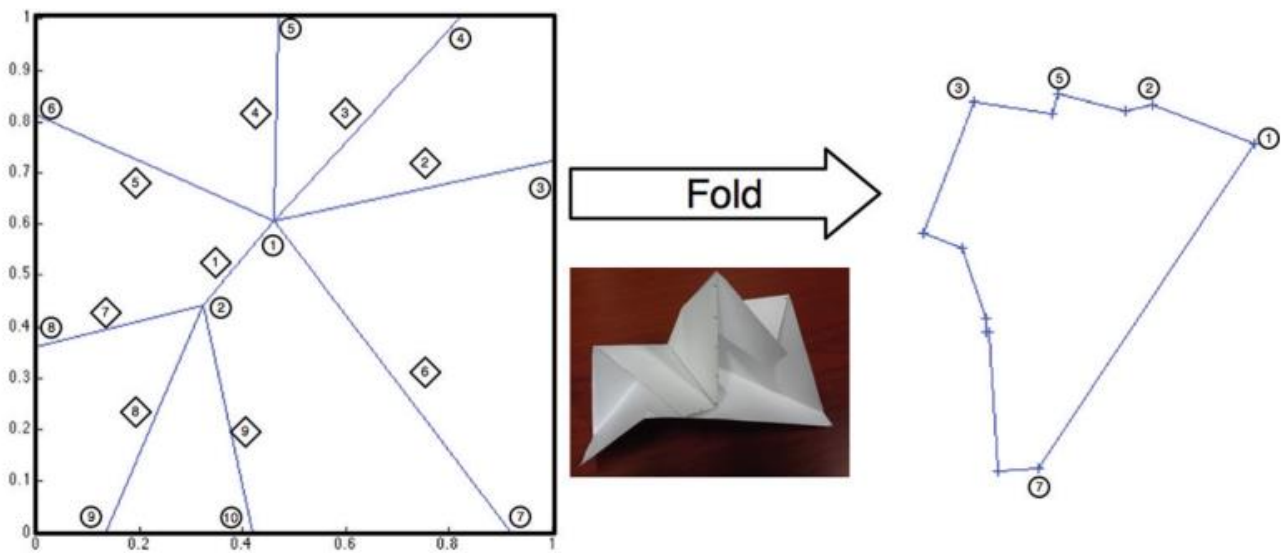
- Metode slučajno generiranih shema savijanja
  - Iz skupa točaka pokušava generirati rješenje koje zadovoljava sva ograničenja
  - Često ne radi, puno problema
- Metode heurističkim optimiziranjem
  - Metoda pucanja leda, na kreativan način se rješava problem ograničenja
  - Opet postoje problemi
  - Kako napraviti teselacijsku bazu
- Kreiranje iz postojećih modela
  - Neka dobro poznata baza se mijenja prema određenim ograničenjima
- Novije metode su vezane za rigidne origamije

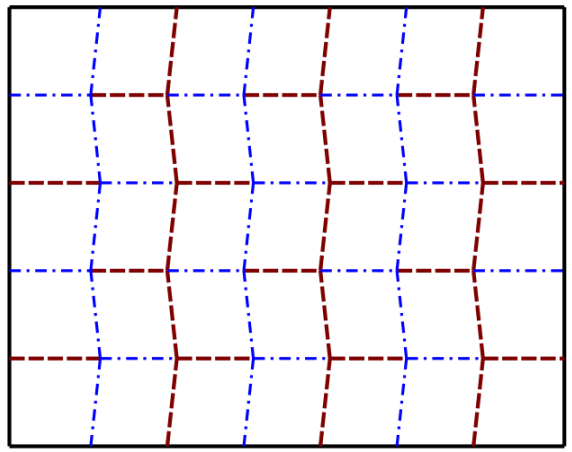


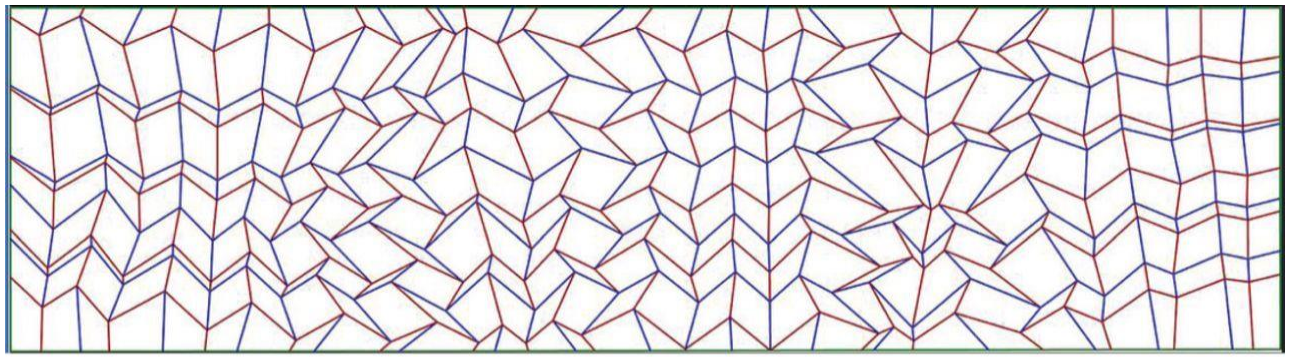



N=8
N=15
N=18
N=24
N=26
N=29
N=32
N=44


Fold

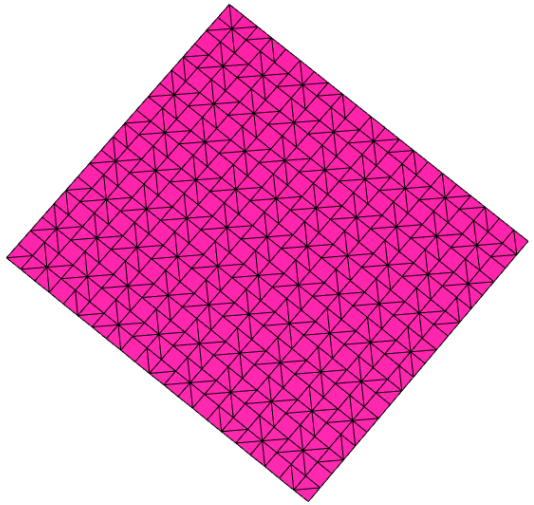

Fold

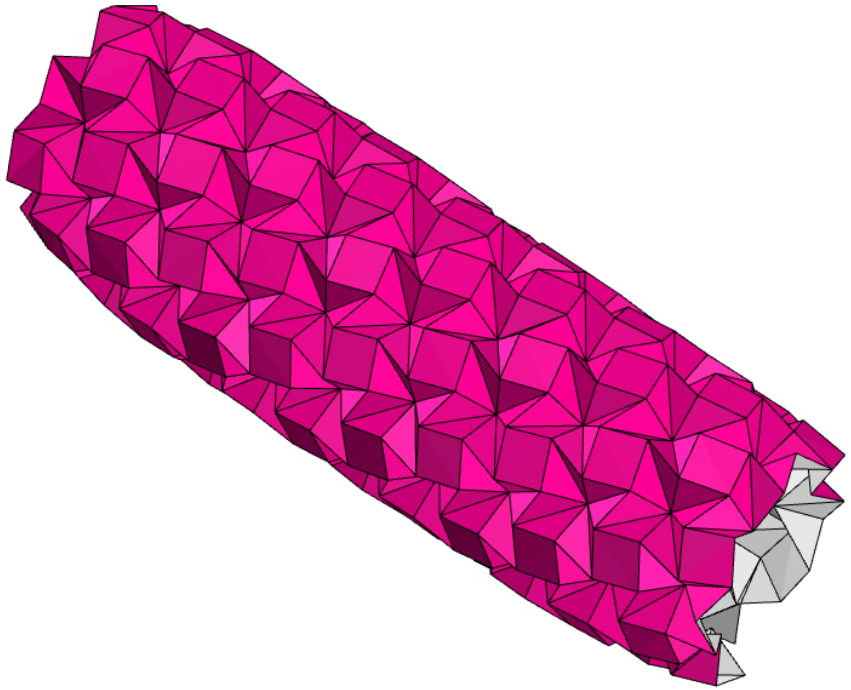


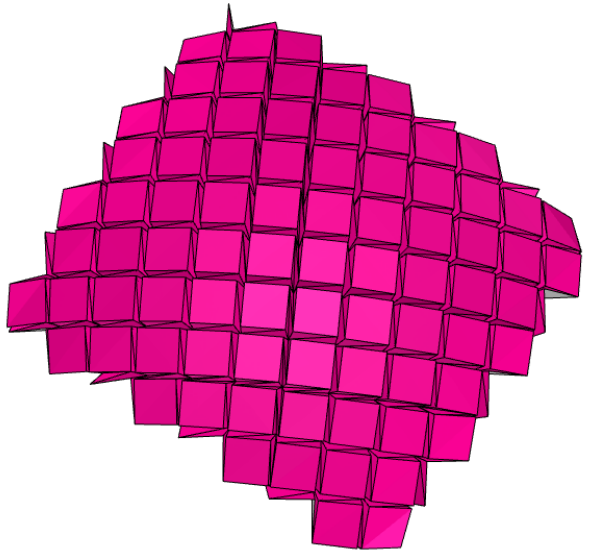


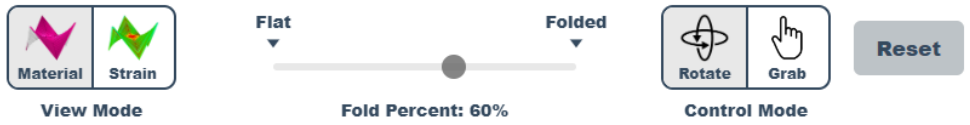
Simulacija origamija

- Više vrsta simulacija
- Zavisi o brzi i točnosti

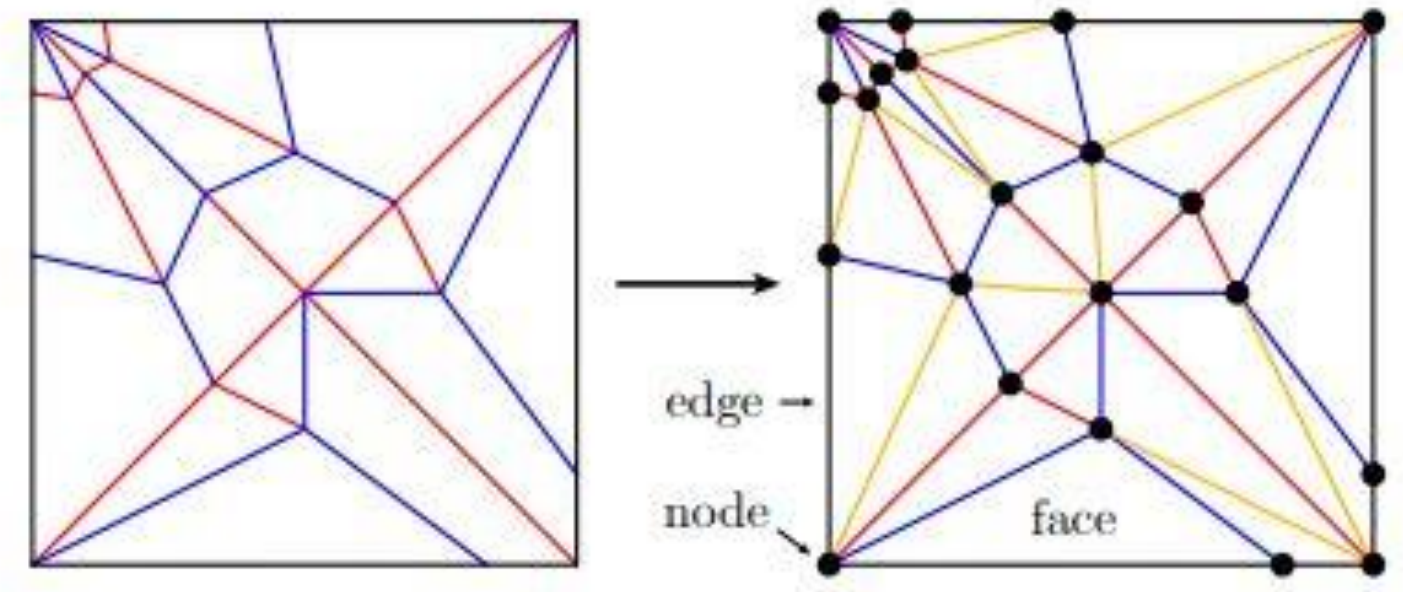






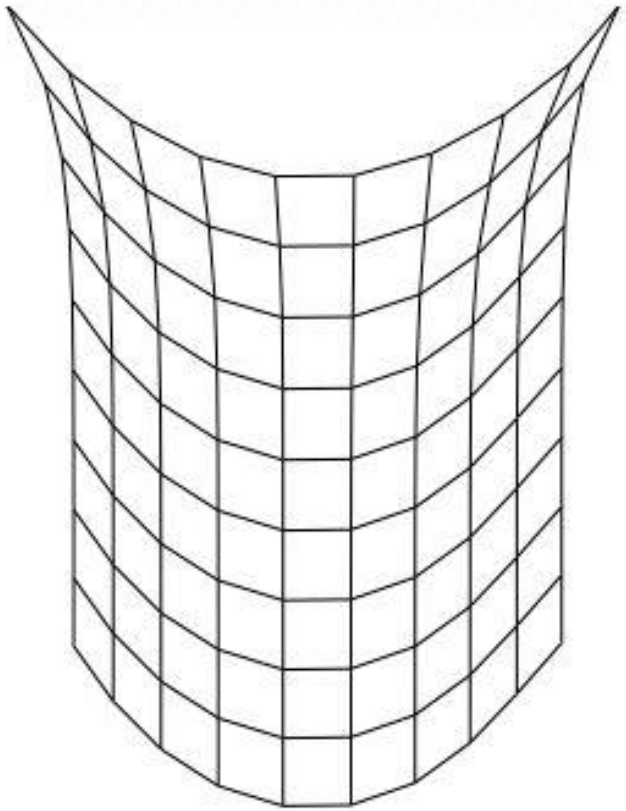


Triangulacija



$$\mathbf{F}_{\text{liniska}} = -k_{\text{liniska}}(l - l_0)\frac{\partial l}{\partial \mathbf{p}}$$

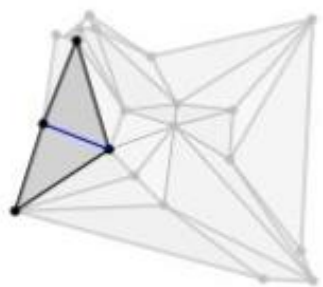
$$\frac{\partial l}{\partial p_1} = -\hat{I}_{12}, \qquad \frac{\partial l}{\partial p_2} = \hat{I}_{12}$$

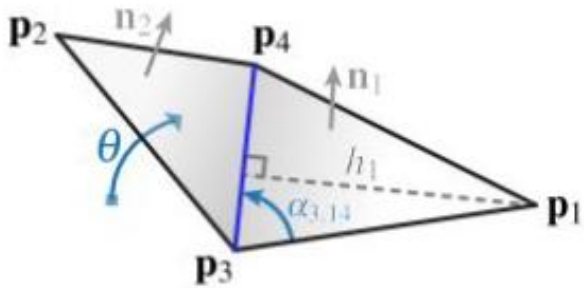


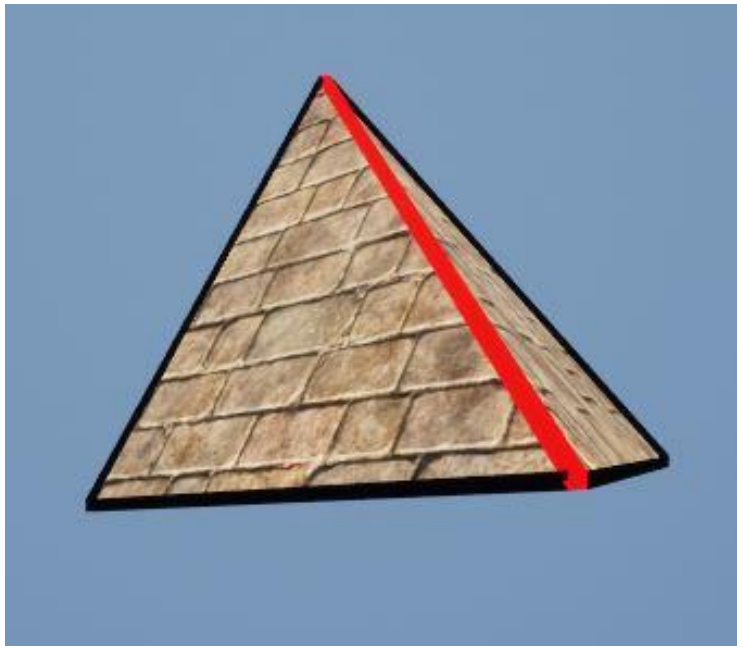
$$F_{\text{nabor}} = -k_{\text{nabor}}(\theta - \theta_{\text{ciljni}})\frac{\partial \theta}{\partial p}$$

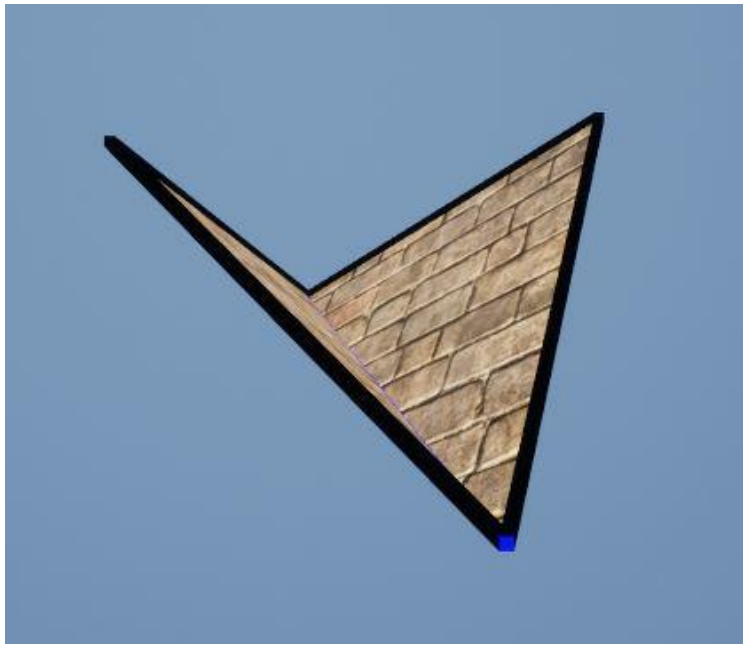
$$\theta_{\text{ciljni}} = \begin{cases} < 0 & \text{za ispupčenja,} \\ > 0 & \text{za udubljenja,} \\ 0 & \text{za novo dodane nabore pri triangulaciji.} \end{cases}$$

$$\begin{aligned}
\frac{\partial \theta}{\partial p_1} &= \frac{\mathbf{n}_1}{h_1} \\
\frac{\partial \theta}{\partial p_2} &= \frac{\mathbf{n}_2}{h_2} \\
\frac{\partial \theta}{\partial p_3} &= -\frac{\cot \alpha_{4,31}}{\cot \alpha_{3,14} + \cot \alpha_{4,31}}\frac{\mathbf{n}_1}{h_1} - \frac{\cot \alpha_{4,23}}{\cot \alpha_{3,42} + \cot \alpha_{4,23}}\frac{\mathbf{n}_2}{h_2} \\
\frac{\partial \theta}{\partial p_4} &= -\frac{\cot \alpha_{3,14}}{\cot \alpha_{3,14} + \cot \alpha_{4,31}}\frac{\mathbf{n}_1}{h_1} - \frac{\cot \alpha_{3,42}}{\cot \alpha_{3,42} + \cot \alpha_{4,23}}\frac{\mathbf{n}_2}{h_2}.
\end{aligned}$$







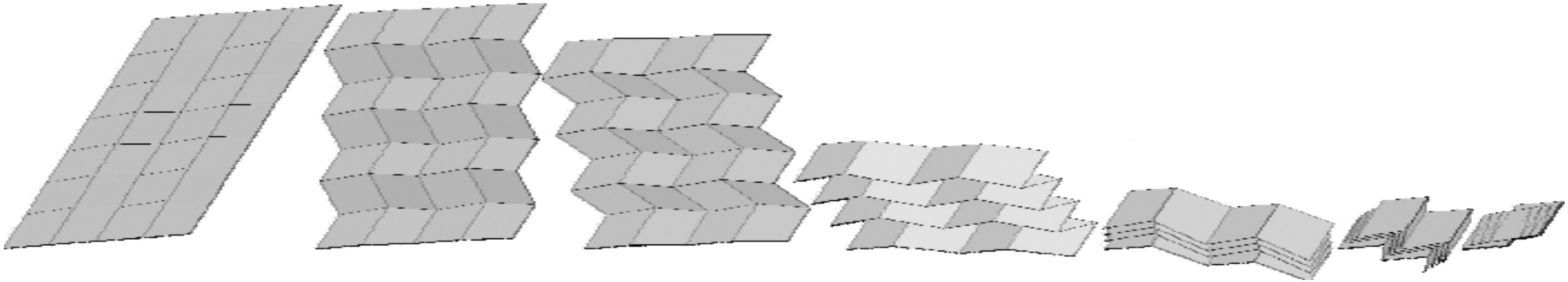


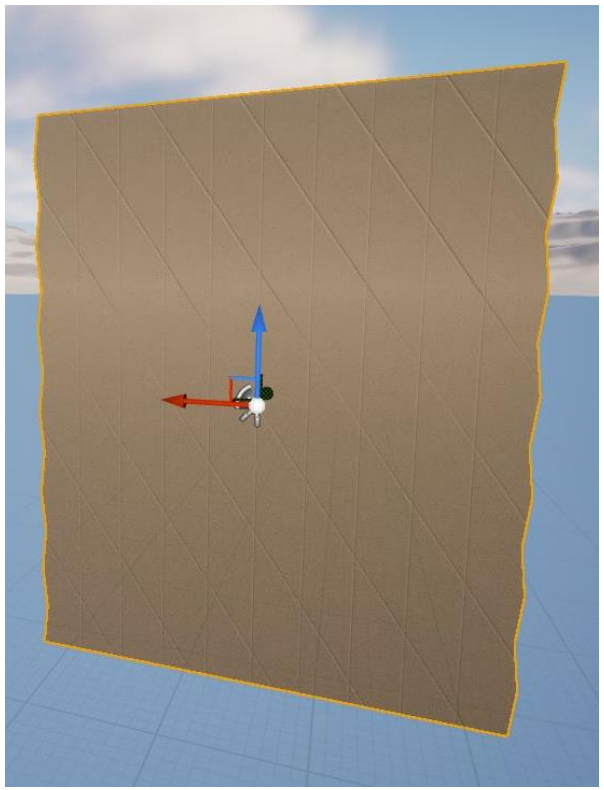
$$F_{\text{lice}} = -k_{\text{lice}}(\alpha - \alpha_0)\frac{\partial \alpha}{\partial \mathbf{p}}$$

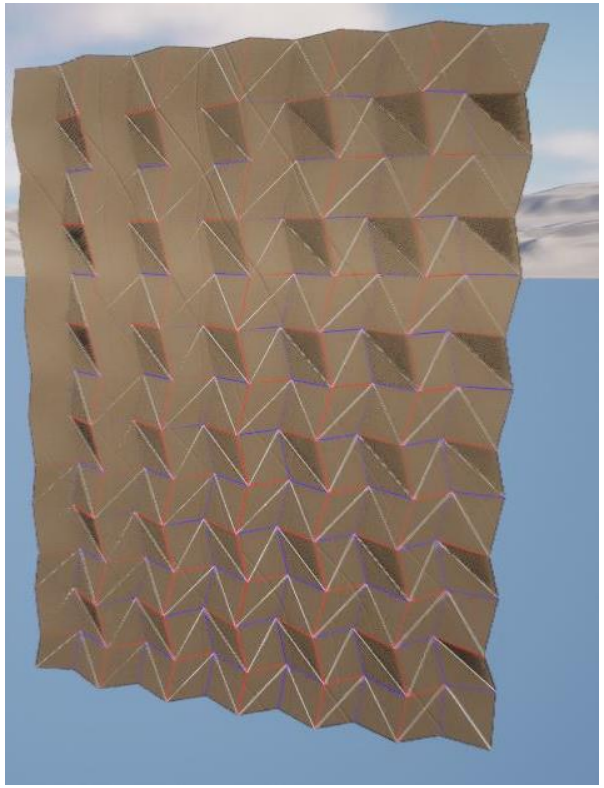
$$F_{\text{trenje}} = c(v_{\text{susjedi}} - v)$$

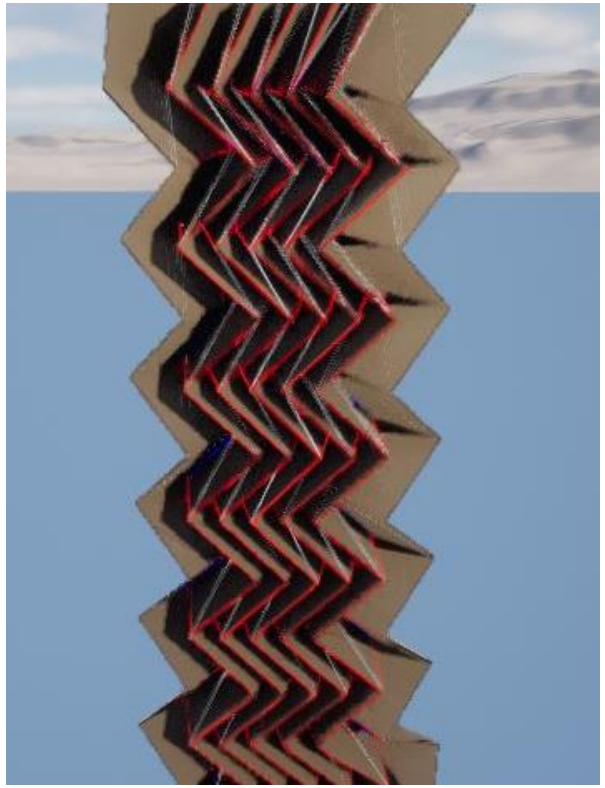
$$\begin{aligned}
\frac{\partial \alpha_{2,31}}{\partial p_1} &= \frac{\mathbf{n} \times (\mathbf{p}_1 - \mathbf{p}_2)}{\|\mathbf{p}_1 - \mathbf{p}_2\|^2}, \\
\frac{\partial \alpha_{2,31}}{\partial p_2} &= -\frac{\mathbf{n} \times (\mathbf{p}_1 - \mathbf{p}_2)}{\|\mathbf{p}_1 - \mathbf{p}_2\|^2} + \frac{\mathbf{n} \times (\mathbf{p}_3 - \mathbf{p}_2)}{\|\mathbf{p}_3 - \mathbf{p}_2\|^2}, \\
\frac{\partial \alpha_{2,31}}{\partial p_3} &= -\frac{\mathbf{n} \times (\mathbf{p}_3 - \mathbf{p}_2)}{\|\mathbf{p}_3 - \mathbf{p}_2\|^2}.
\end{aligned}$$

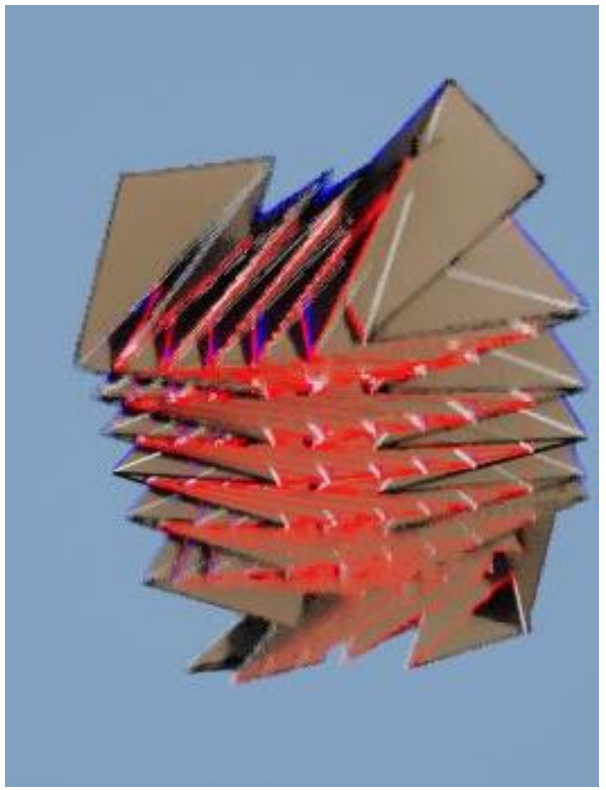
$$F_{\text{total}} = \sum_{\text{liniski}} F_{\text{liniski}} + \sum_{\text{nabora}} F_{\text{nabora}} + \sum_{\text{lica}} F_{\text{lica}}$$

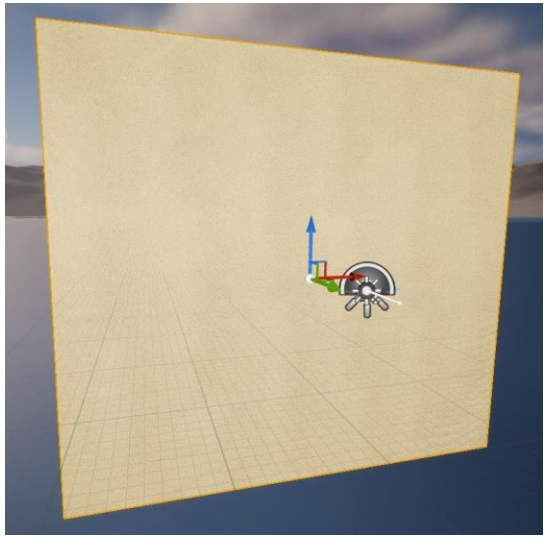


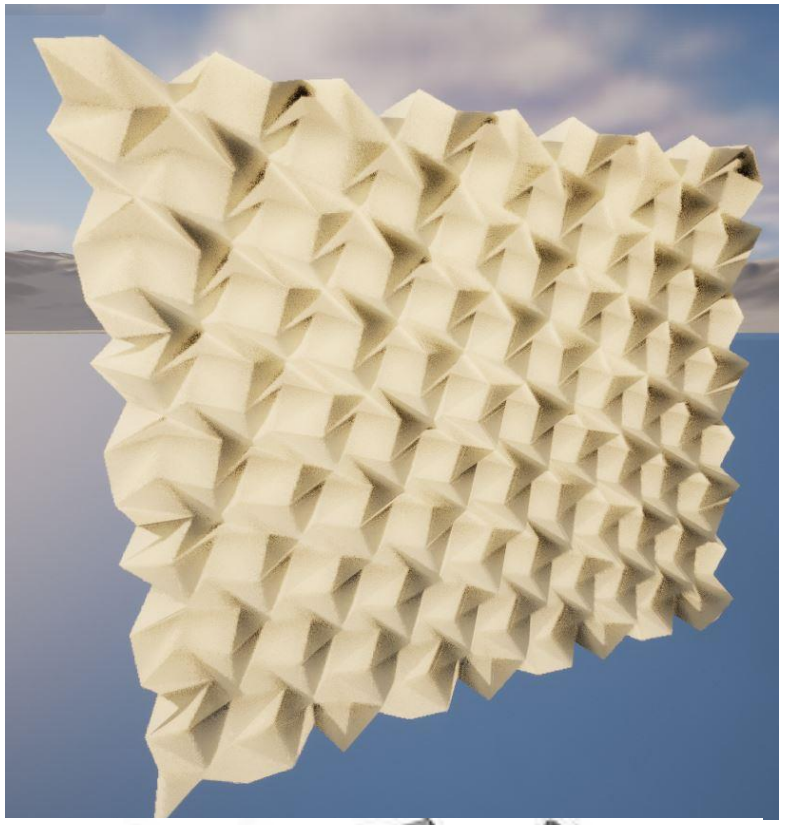


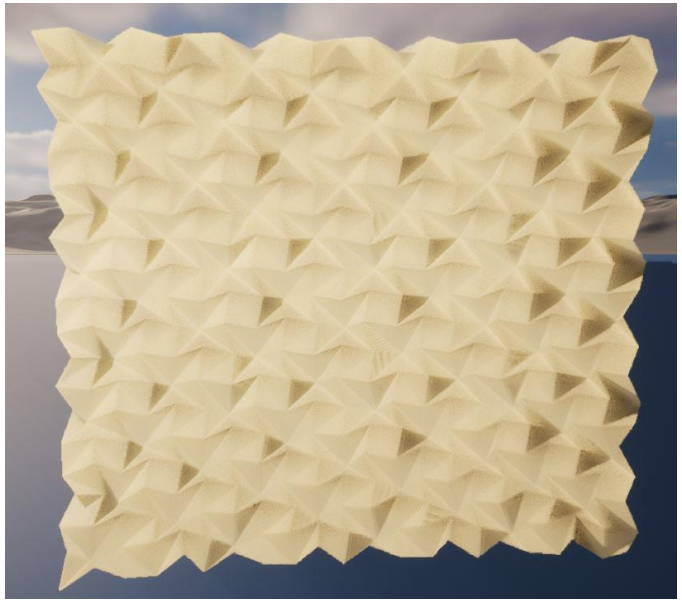


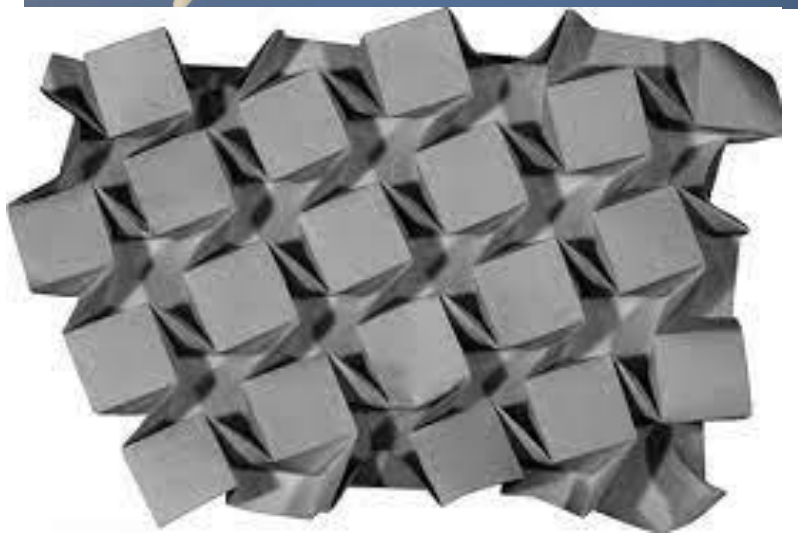


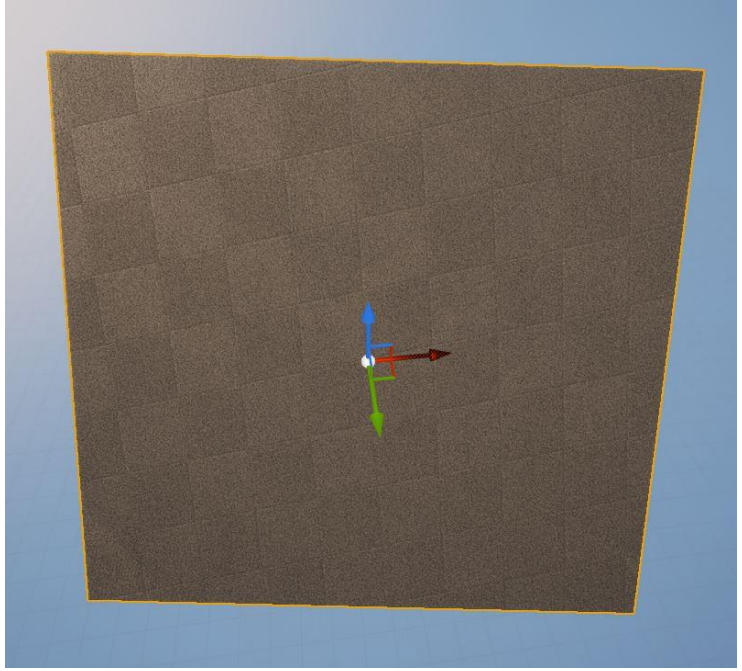


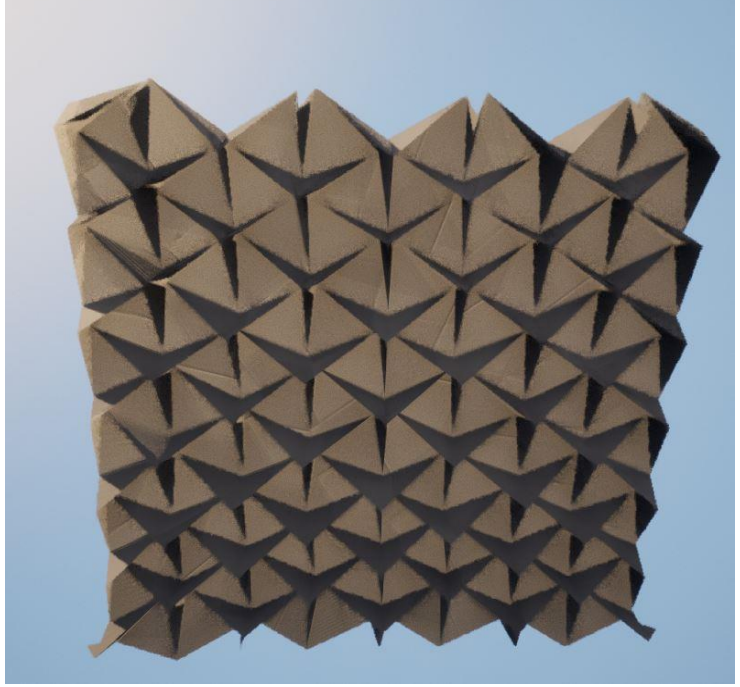


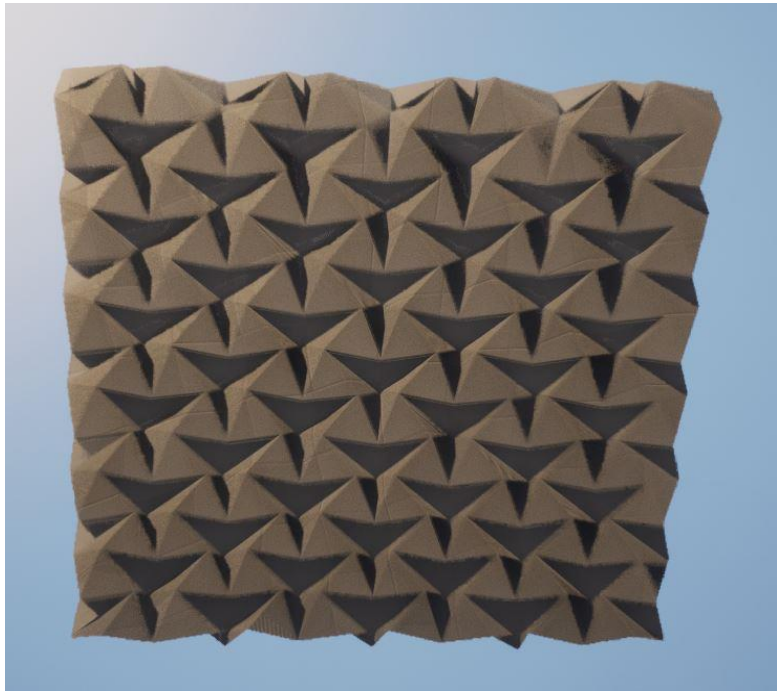


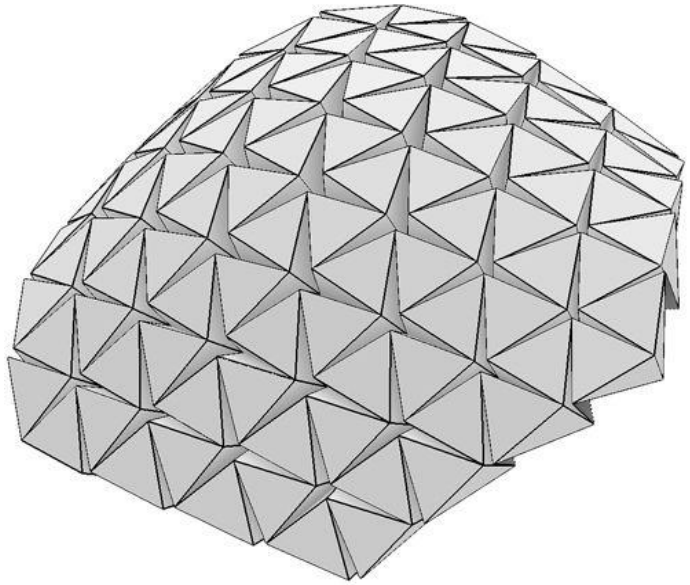












Zaključak

- Dizajniranje je teško
  - Teselacije su nužne
- Simulacije bi se mogle koristiti kao specijalan efekt
  - Radi se prijenosu u popularne programe kao Blender ili UE5