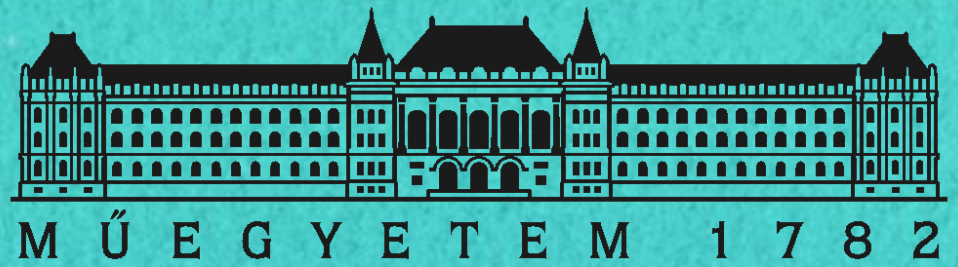
Szabadformájú alakzatok tervezése poliéderek segítségével

Szörfi Jázmin
Konzulens: Várady Tamás

3D számítógépes geometria 2 - 2020

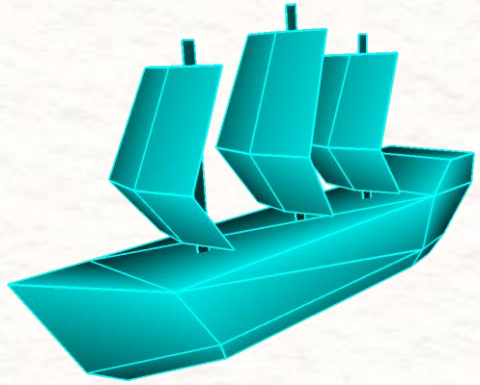


Tartalom

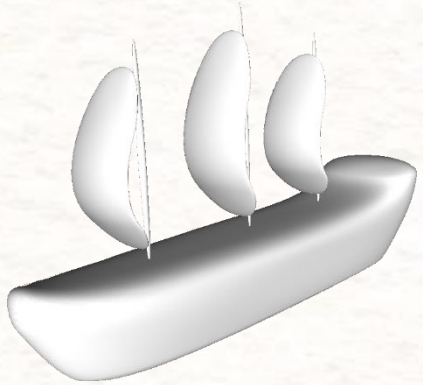
- Kontrollpoliéder alapú tervezés
- GB-patch
- Kétfajta reprezentáció bemutatása
- Algoritmus
  - Görbeháló struktúrák
  - Sima kapcsolódás
- Tesztprogram

Kontrollpoliéder alapú tervezés

Hajó(x,y,z) = ?

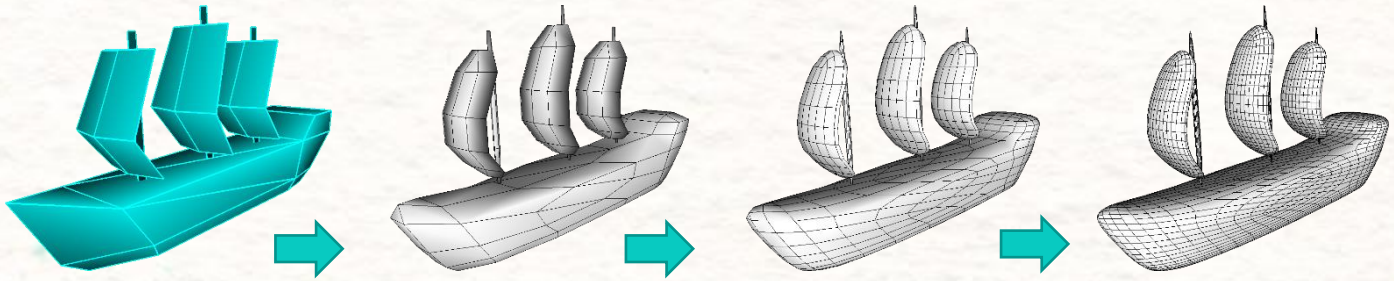


Kontrollpoliéder

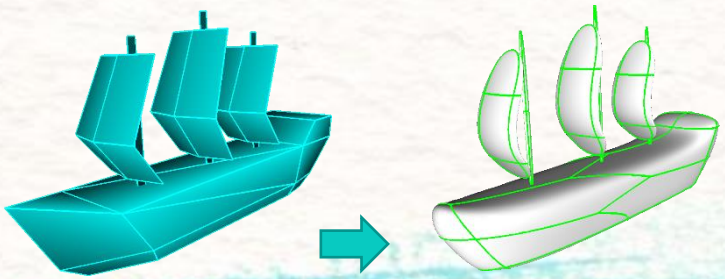


Felület

Rekurzív felosztás



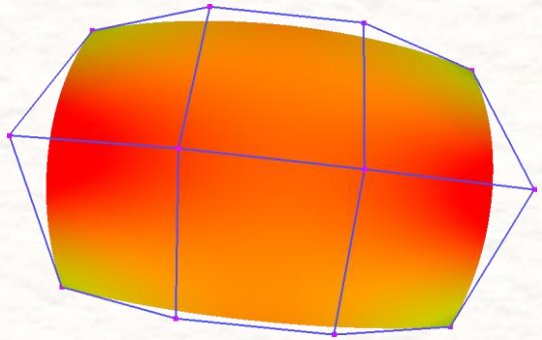
Görbeháló interpoláció

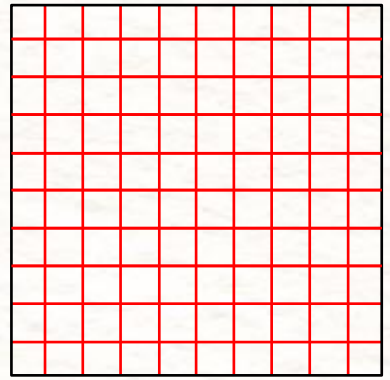


N-oldalú Bézier-felületek

Hagyományos reprezentáció

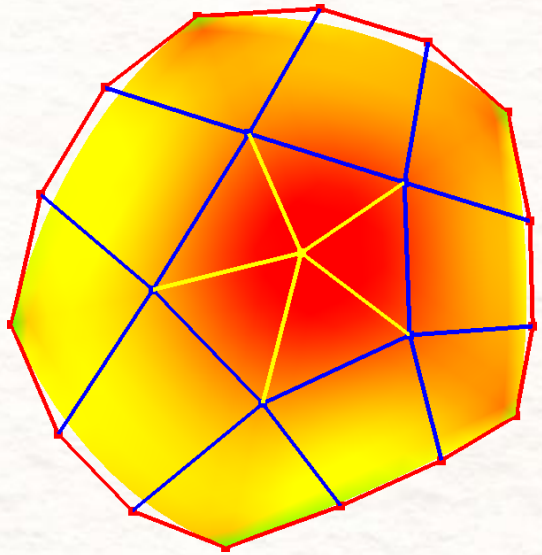
- Négy oldalú domén
- Szabályos kontrollrács

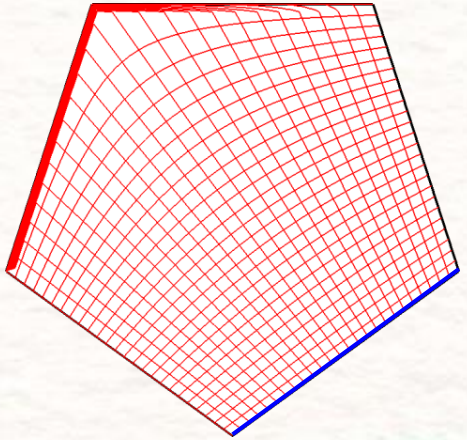




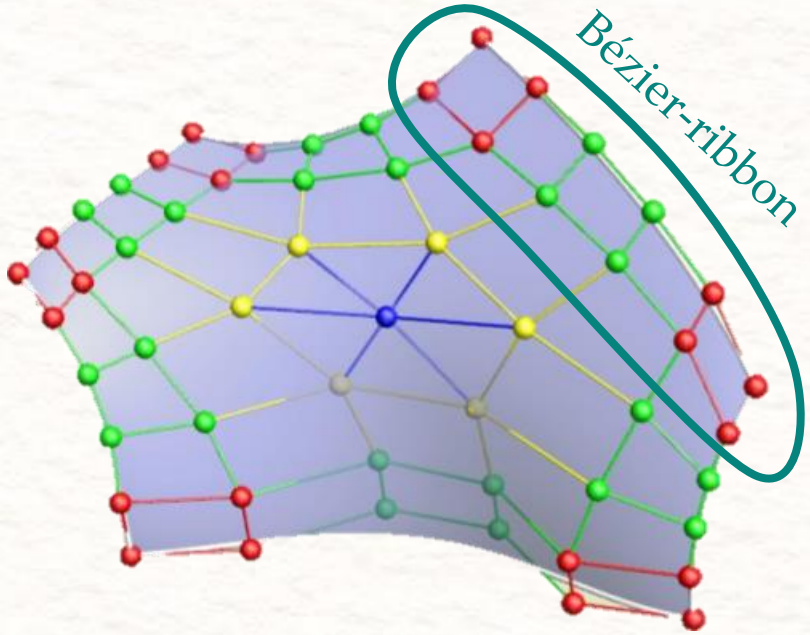
GB-patch reprezentáció

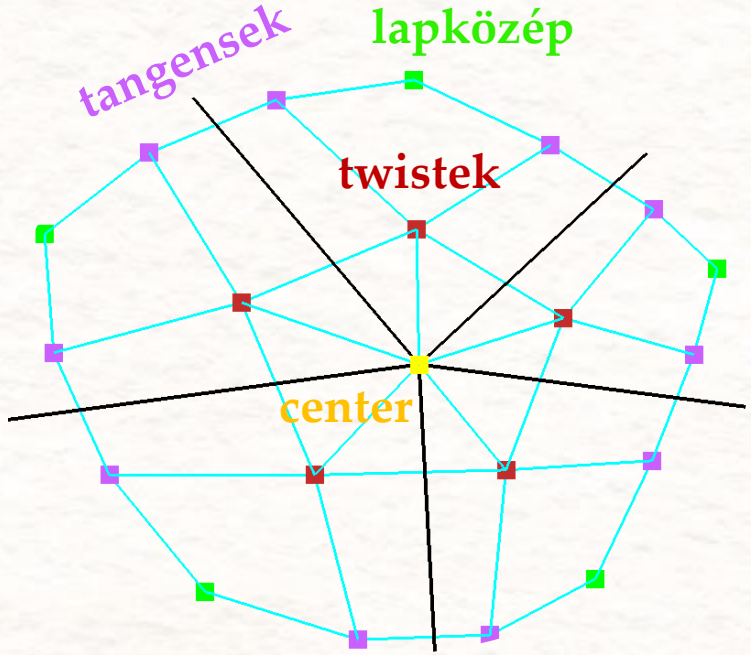
- N-oldalú domén
- Speciális paraméterezés
- Általános kontrollstruktúra





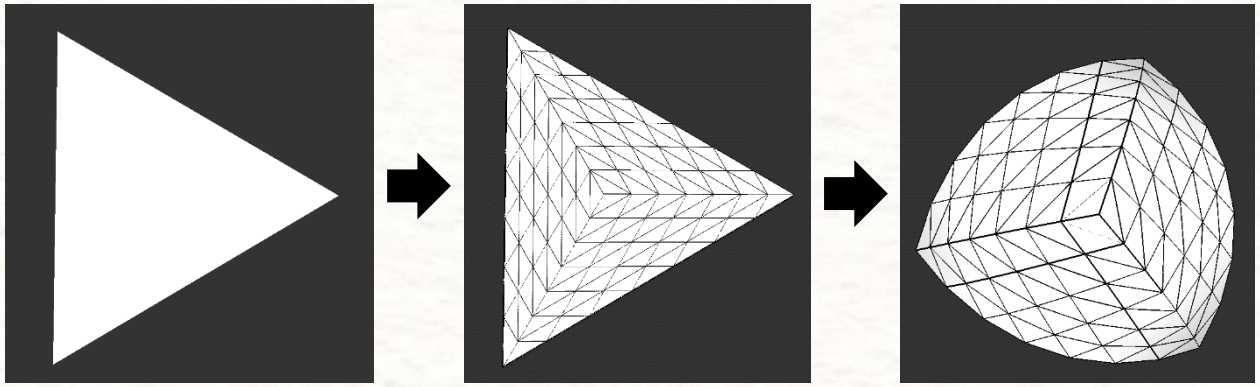
GB kontrollpont háló



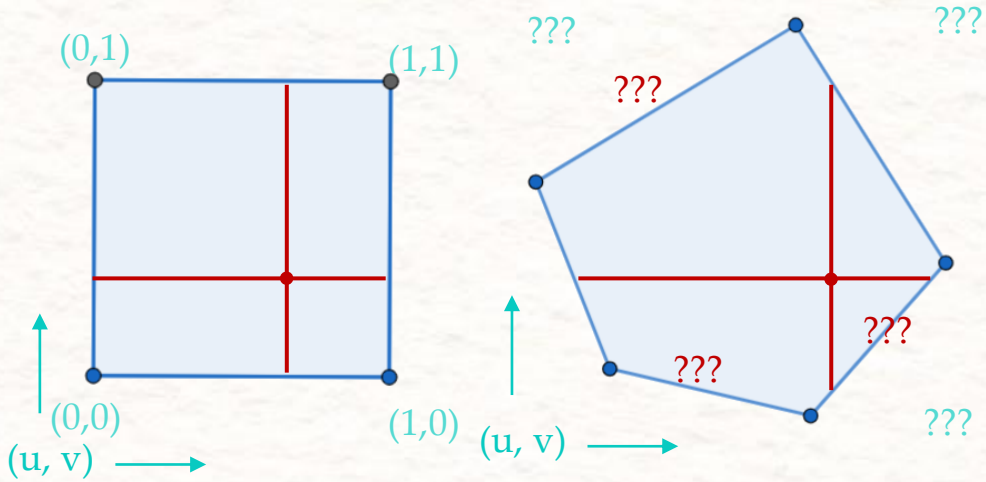


- **sarok kontrollpontok:** az i-edik és az (i+1)-edik oldalhoz is tartoznak
- **ribbon kontrollpontok:** csak az i-edik oldalhoz tartoznak
- **belső kontrollpontok:** fokszámemelés által keletkeznek
- **középső kontrollpont:** csak a felület belsejére hat

GB domén, általános baricentrikus koordináták



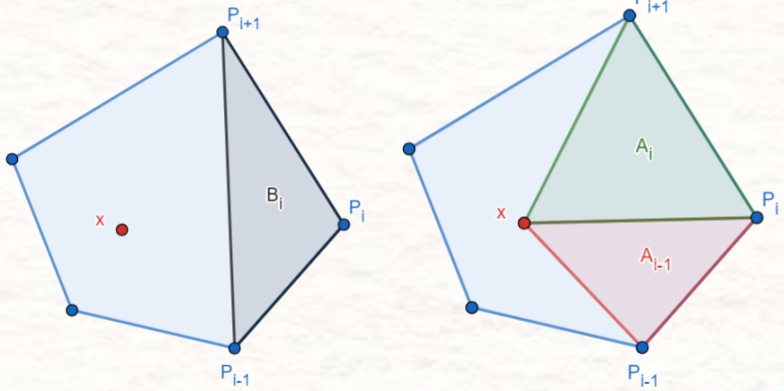
Domain Felosztás Felület



Általános baricentrikus koordináták

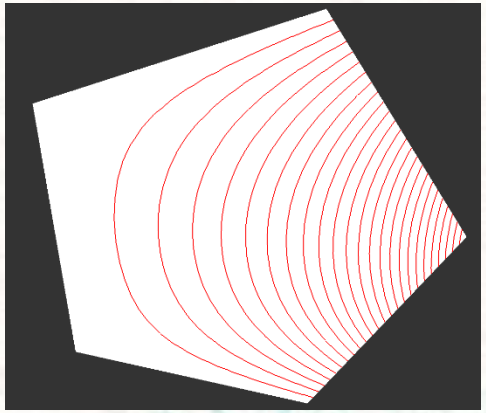
$$\boldsymbol{X} = \sum_{i=1}^{n} \lambda_i(\boldsymbol{X})\, \boldsymbol{P_i}$$

$$\sum_{i=1}^{n} \lambda_i(\boldsymbol{X}) = 1$$



$$w_i(\boldsymbol{X}) = \frac{B_i}{A_{i-1}A_i}$$

$$\lambda_i(\boldsymbol{X}) = \frac{w_i(\boldsymbol{X})}{\sum_{j=1}^{n} w_j(\boldsymbol{X})}$$



λ_i szintvonalak

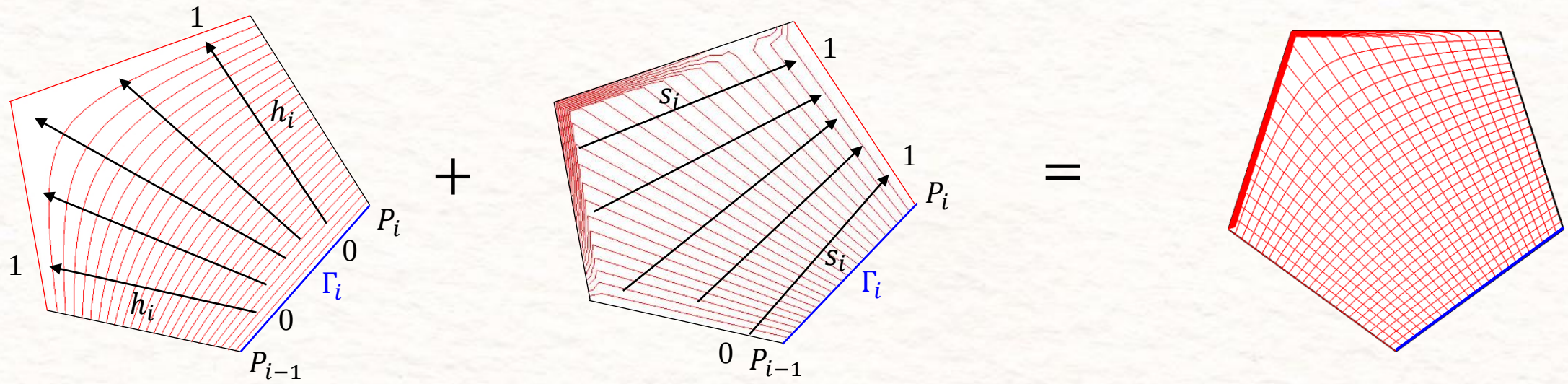
Lokális paraméterek és felület

Távolságparaméter

$$h_i = 1 - \lambda_{i-1} - \lambda_i$$

Oldalparaméter

$$s_i = \frac{\lambda_i}{\lambda_{i-1} + \lambda_i}$$



Lokális paraméterek + kontroll pontok → felület egyenlete:

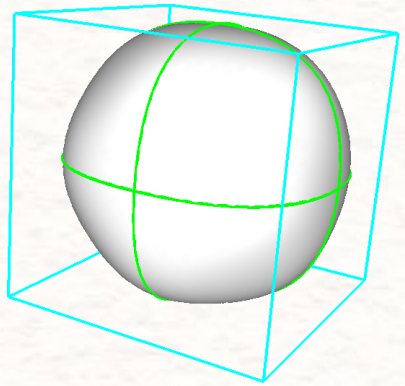
$$S(u,v) = \sum_{i=0}^{n-1} \sum_{j=0}^{d} \sum_{k=0}^{l-1} C_{j,k}^{d,i}\, \mu_{j,k}^{i}\, B_{j,k}^{d}(s_i(u,v), h_i(u,v)) + C_0 B_0(u,v)$$

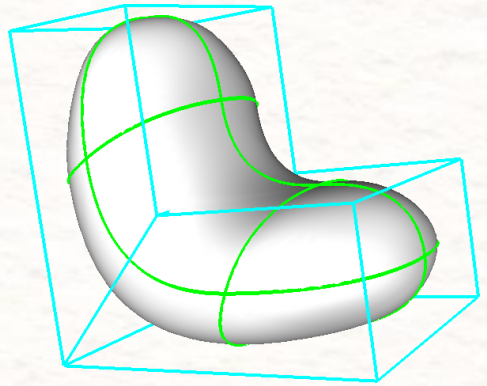
B_0: konvex kombináció biztosítása

Két görbeháló struktúra

Duális:

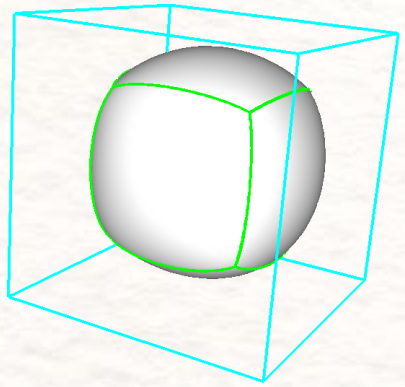
- Patch oldalszáma ~ csúcs fokszáma
- Csak konvex lapok
- Generalised Bézier (GB) patch reprezentáció
- Állítható görbültségi paraméter: induló tangens

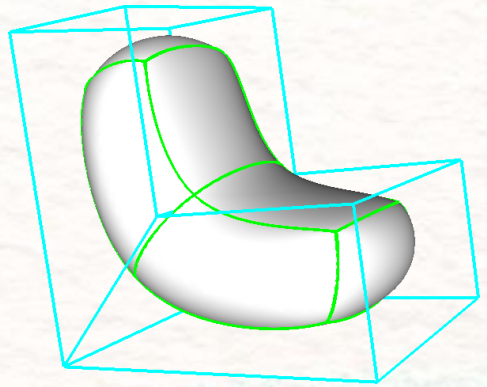




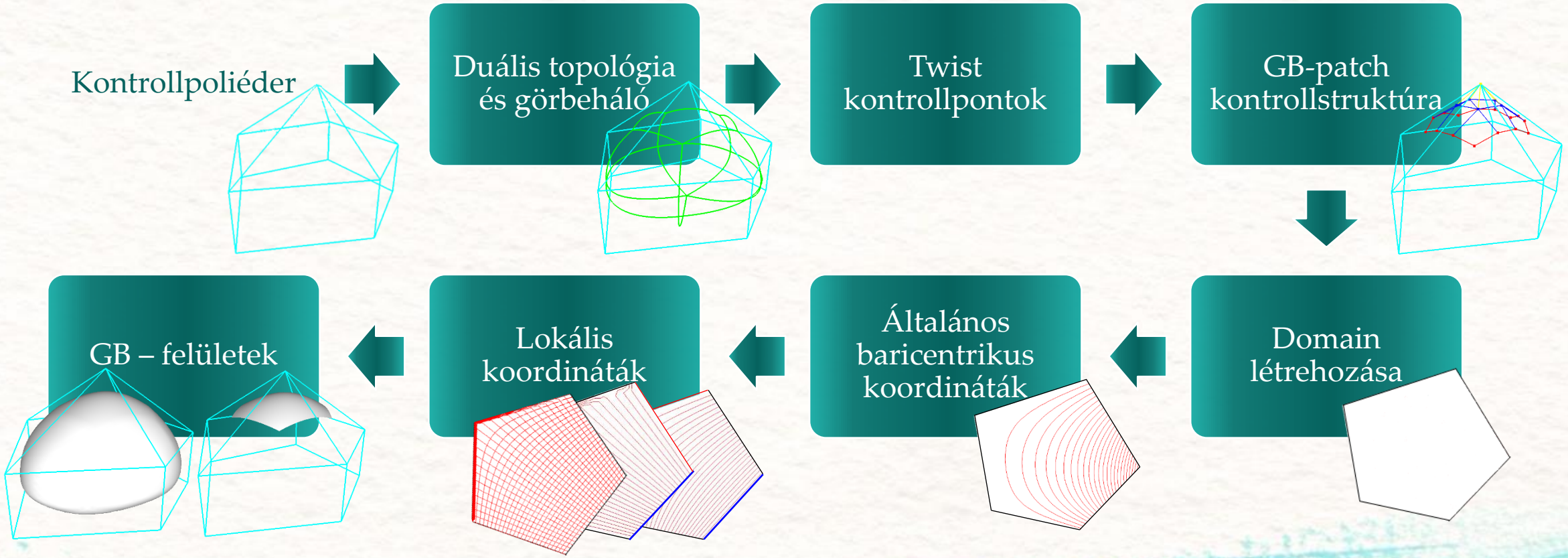
Topológia tartó:

- Patch oldalszáma ~ lap oldalszáma
- Konvex, konkáv és lyukas lapok (végső cél)
- Concave GB (CGB) patch reprezentáció
- Állítható görbültségi paraméter: lapkamélység

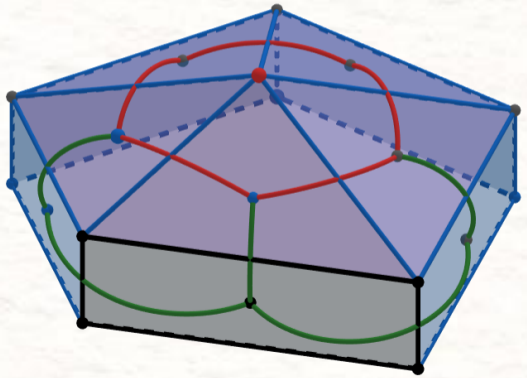




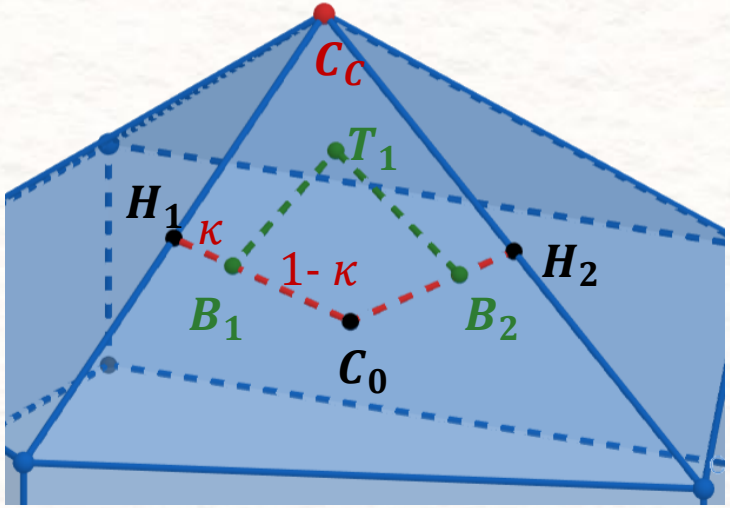
A duális algoritmus blokkdiagramja

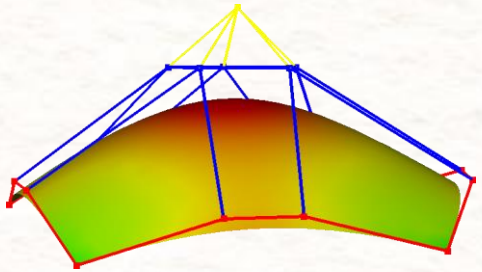


Duális topológia, kontrollpontok

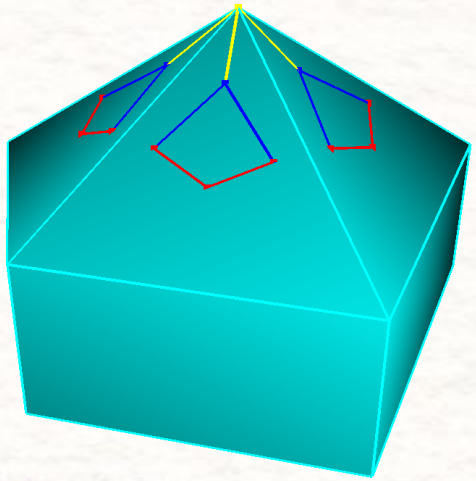


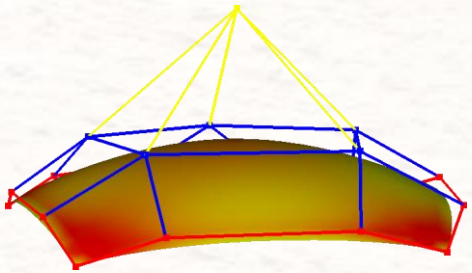
Duális topológia





Nagy induló tangens





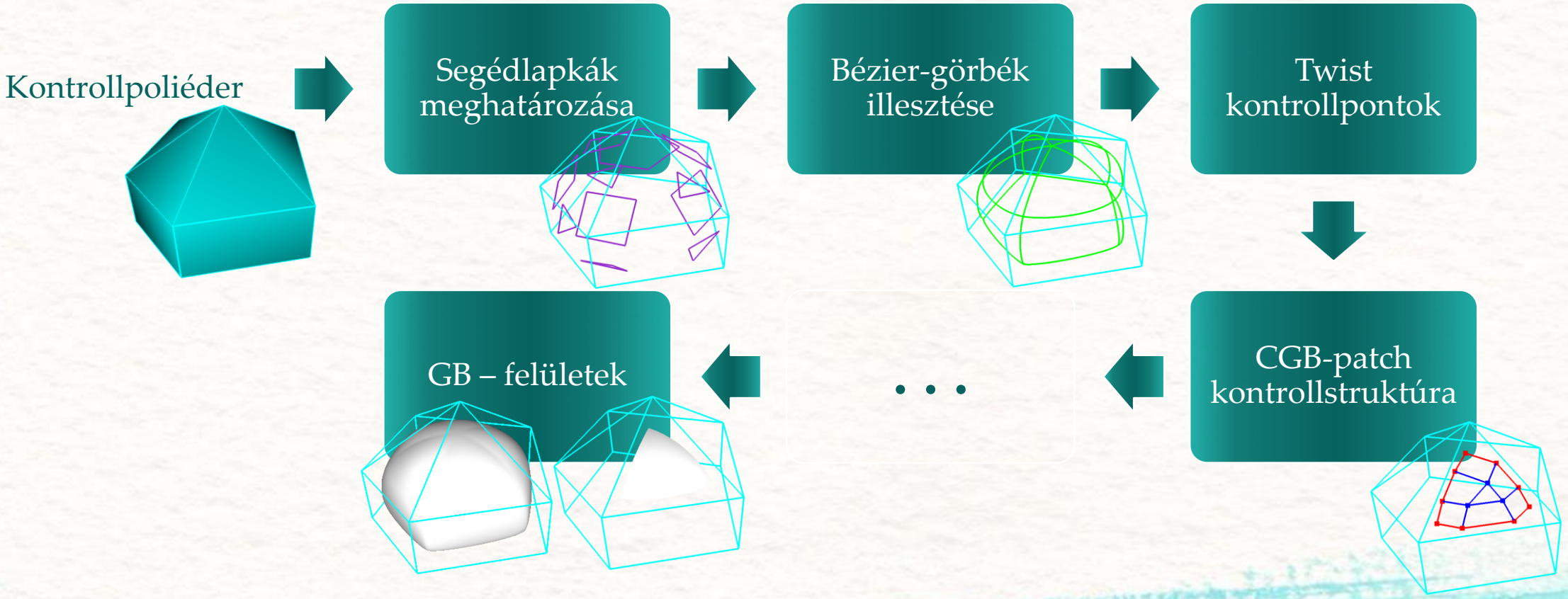
Kis induló tangens

$$B_1 = \kappa\, C_0 + (1-\kappa)\, H_1$$

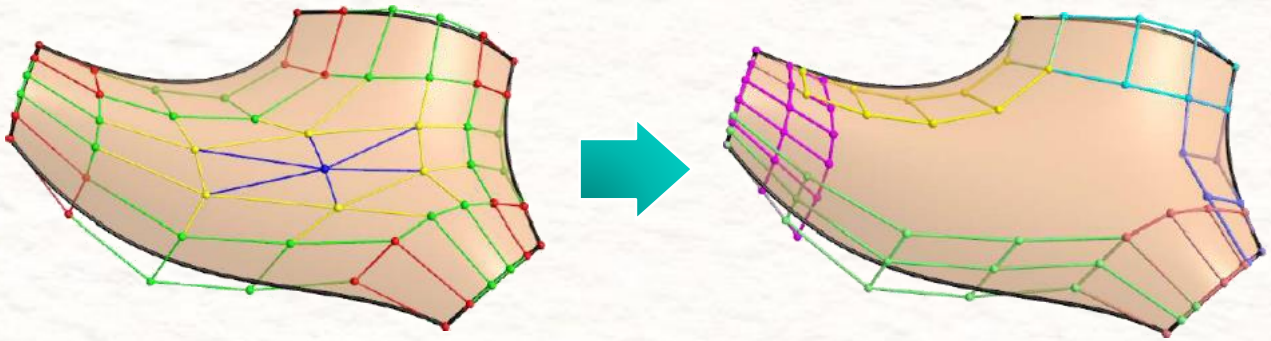
$$B_2 = \kappa\, C_0 + (1-\kappa)\, H_2$$

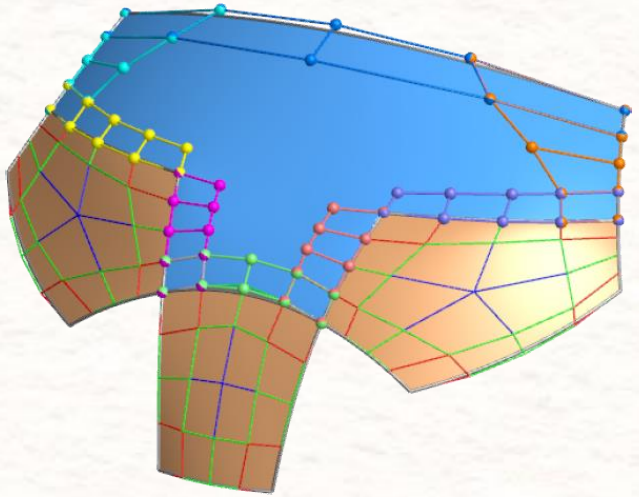
$$T_1 = \kappa^2 C_0 + \kappa(1-\kappa) H_1 + \kappa(1-\kappa) H_2 + (1-\kappa)^2\, C_C$$

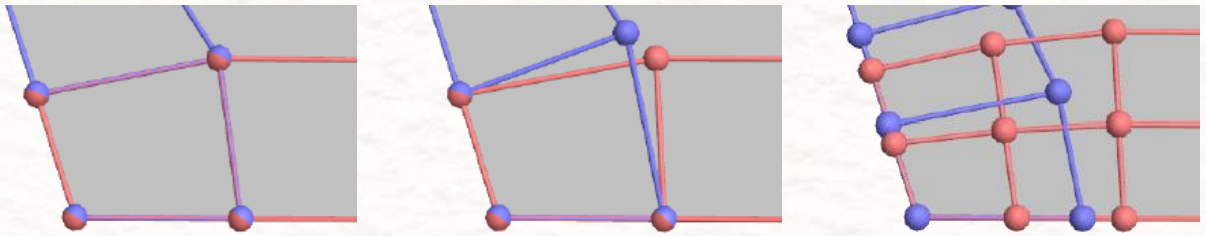
A topológiatartó algoritmus blokkdiagramja



Konkáv GB-patch reprezentáció



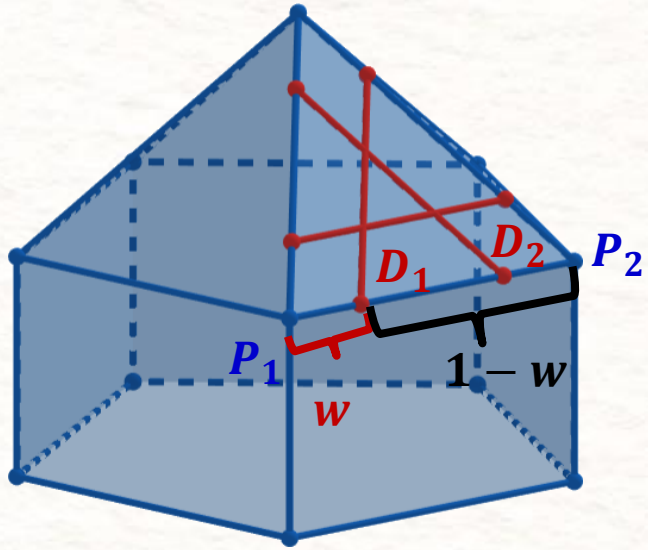




$$\boldsymbol{S}(u,v)) = \frac{1}{B_{sum}(u,v)} \sum_{i=0}^{n} \sum_{j=0}^{d_i} \sum_{k=0}^{l_i-1} \boldsymbol{C_{j,k}^{i}}\, \mu_{j,k}^{i}\, B_{j,k}^{d_i}(s_i(u,v)\,, h_i(u,v))$$

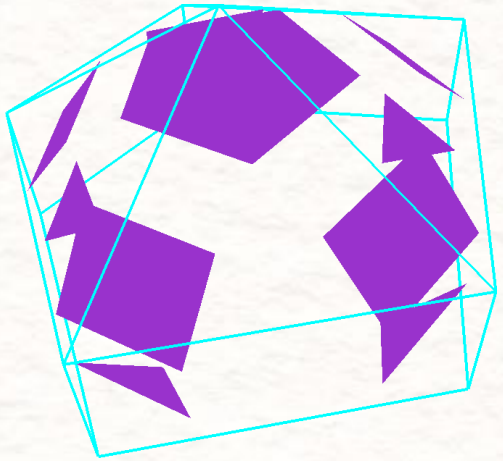
B_{sum}: konvex kombináció biztosítása

Segédlapkák létrehozása

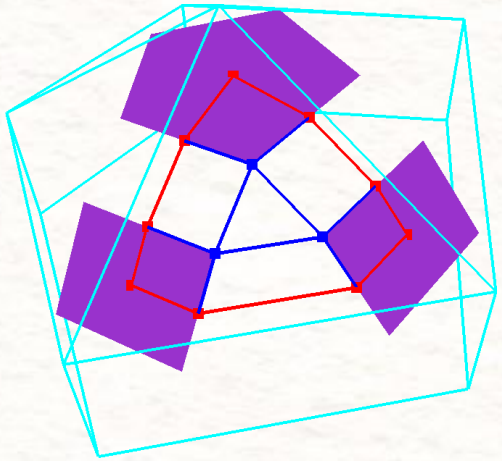


$$D_1 = w\,P_2 + (1-w)P_1$$

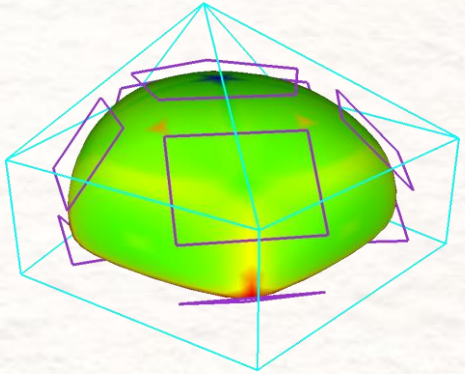
$$D_2 = w\,P_1 + (1-w)P_2$$



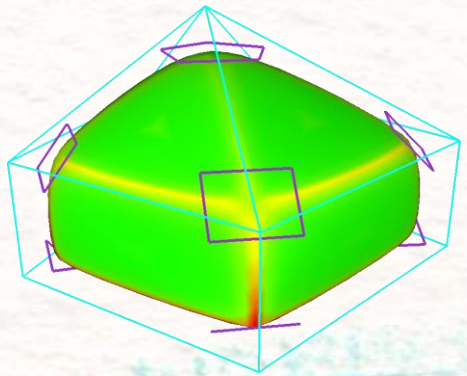
Segédlapkák



Kontrollpontok

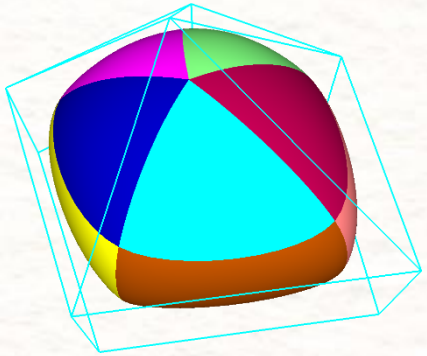


Nagy segédlapkák



Kis segédlapkák

Sima kapcsolódás - csúcsokban



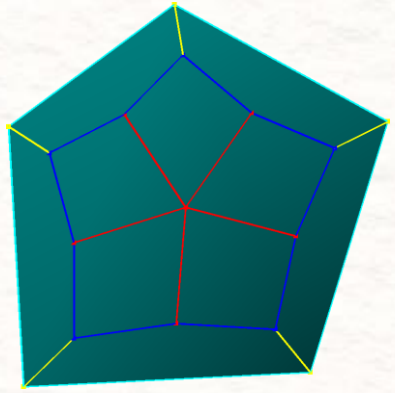
Közös érintősík a csúcsokban

Duális

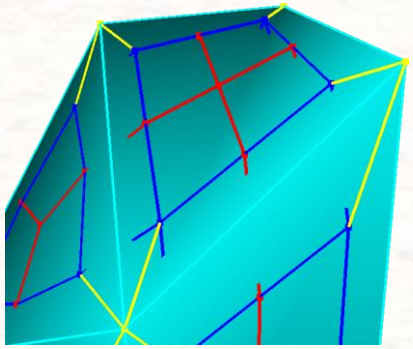
- Síklap ✓
- 3 (síklap) vagy 4 befutó él ✓

Topológiatartó

- 3 befutó él ✓



Síklap

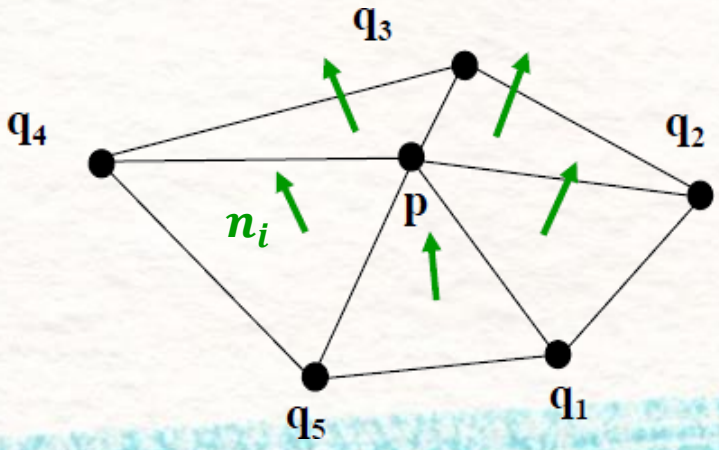


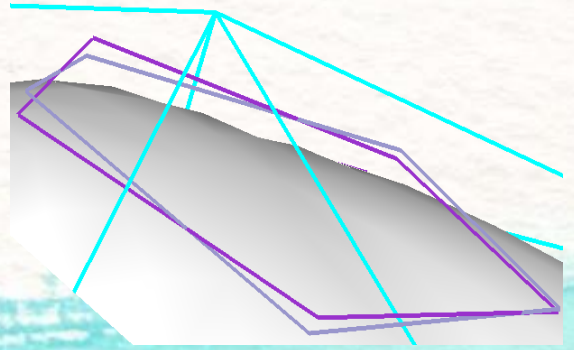
4 befutó él

Legjobb négyzetes sík

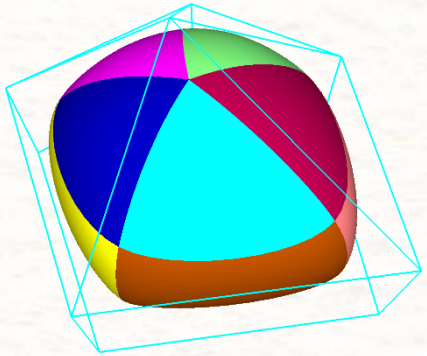
$$\boldsymbol{n_i} = (\boldsymbol{q_i} - \boldsymbol{p}) \times (\boldsymbol{q_{i+1}} - \boldsymbol{p})$$

$$A = \frac{1}{2}\sum_i |\boldsymbol{n_i}| \qquad \boldsymbol{n_p} = \frac{1}{2A}\sum_i \boldsymbol{n_i}$$

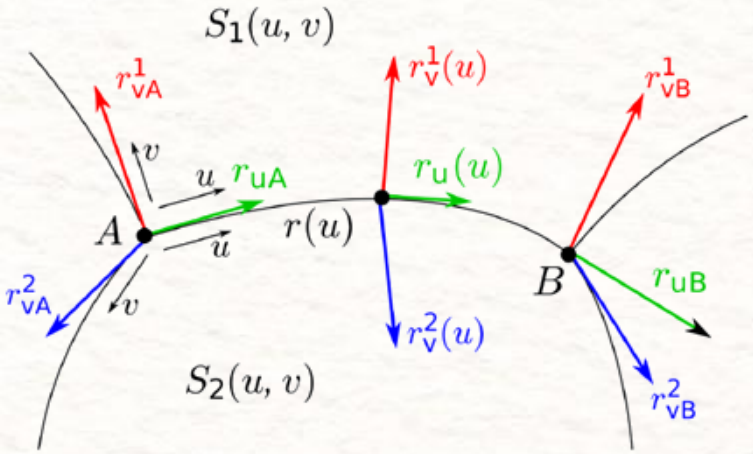




Sima kapcsolódás – élek mentén



Közös irányblend – közös érintő sík az él mentén



$$\boldsymbol{r_v^i}(u) = \alpha^i(u)\boldsymbol{D}(u) + \beta^i(u)\boldsymbol{r_u}(u)$$

$$\alpha(u) = (1-u)\alpha_A + u\alpha_B$$

$$\beta(u) = (1-u)\beta_A + u\beta_B$$

$$N_1(u) = \dot{\boldsymbol{r}}_{\boldsymbol{u}}(u) \times \dot{\boldsymbol{r}}^1_{\boldsymbol{v}}u$$

$$N_2(u) = \dot{\boldsymbol{r}}_{\boldsymbol{u}}(u) \times \dot{\boldsymbol{r}}^2_{\boldsymbol{v}}u$$

Széleken eredeti deriváltak:

$$\boldsymbol{r_v^i}(0) = \boldsymbol{r_{vA}^i}$$

$$\boldsymbol{r_v^i}(1) = \boldsymbol{r_{vB}^i}$$

Szélső blend értékek:

$$\boldsymbol{D}(0) = \boldsymbol{D_0} = \frac{\boldsymbol{r^1_{vA}} - \boldsymbol{r^2_{vA}}}{2}$$

$$\boldsymbol{D}(1) = \boldsymbol{D_1} = \frac{\boldsymbol{r^1_{vB}} - \boldsymbol{r^2_{vB}}}{2}$$

Approximáló irányblend

$\boldsymbol{D_0}$, $\boldsymbol{D_1}$ és $\boldsymbol{D_{0.5}}$

$\boldsymbol{D}(u)$ közelítse (approximálja) $\boldsymbol{D}_{0.5}$

u	$\boldsymbol{D_0}$	$\boldsymbol{D_{0.5}}$	$\boldsymbol{D_1}$
0	1	0	0
0.5	1/4	1/2	1/4
1	0	0	1

$$\boldsymbol{D}(u) = (1-u)^2\boldsymbol{D}_0 + 2u(1-u)\boldsymbol{D}_{0.5} + u^2\boldsymbol{D}_1$$

$$\boldsymbol{D}(u)\alpha(u) = \sum_{\boldsymbol{i=0}}^{\boldsymbol{3}} B_i^3(u)\, Q_i^{\alpha}$$

$$\boldsymbol{D}(u)\alpha(u) = (1-u)^3\alpha_A D_A + 3u(1-u)^2\frac{2\alpha_A D_{0.5} + \alpha_B D_A}{3} + 3u^2(1-u)\frac{\alpha_A D_B + 2\alpha_B D_{0.5}}{3} + u^3\,\alpha_B D_B$$

$$\boldsymbol{C_{i,1}} = \boldsymbol{C_{i,0}} + \frac{\boldsymbol{Q_i}}{3}$$

Interpoláló irányblend

$$\boldsymbol{D}(\mathbf{0.5}) = \boldsymbol{D}_{0.5}$$

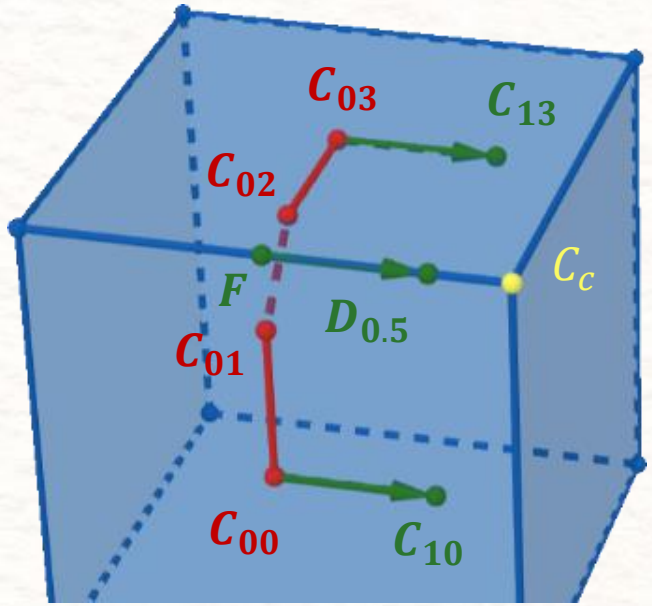
$$\boldsymbol{D}(u) = (2u^2 - 3u + 1)\boldsymbol{D_0} + 4u(1-u)\boldsymbol{D_{0.5}} + (2u^2 - u)\boldsymbol{D_1}$$

u	$\boldsymbol{D_0}$	$\boldsymbol{D_{0.5}}$	$\boldsymbol{D_1}$
0	1	0	0
0.5	0	1	0
1	0	0	1

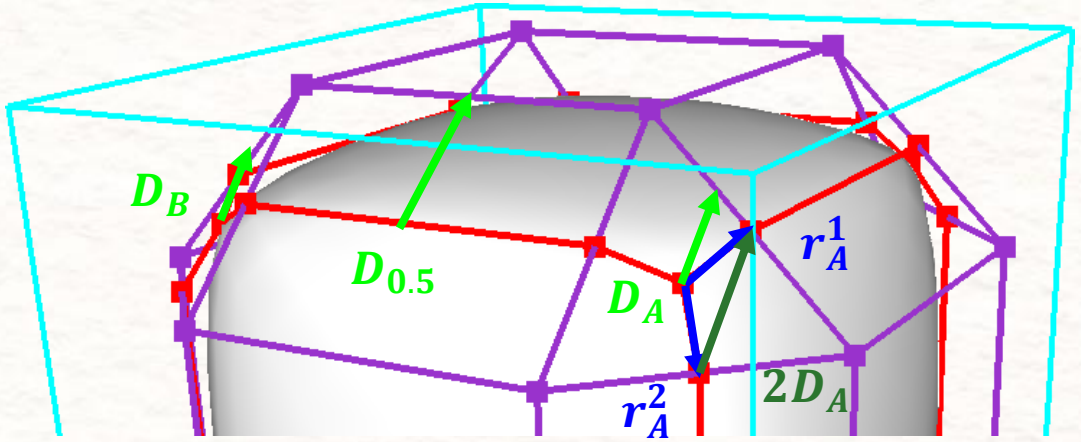
$\boldsymbol{D}_{0.5}$ választása

Duális

$$\boldsymbol{D_{0.5}} = 3(\,\kappa \boldsymbol{F} + (1-\kappa)\,\boldsymbol{C_c})$$

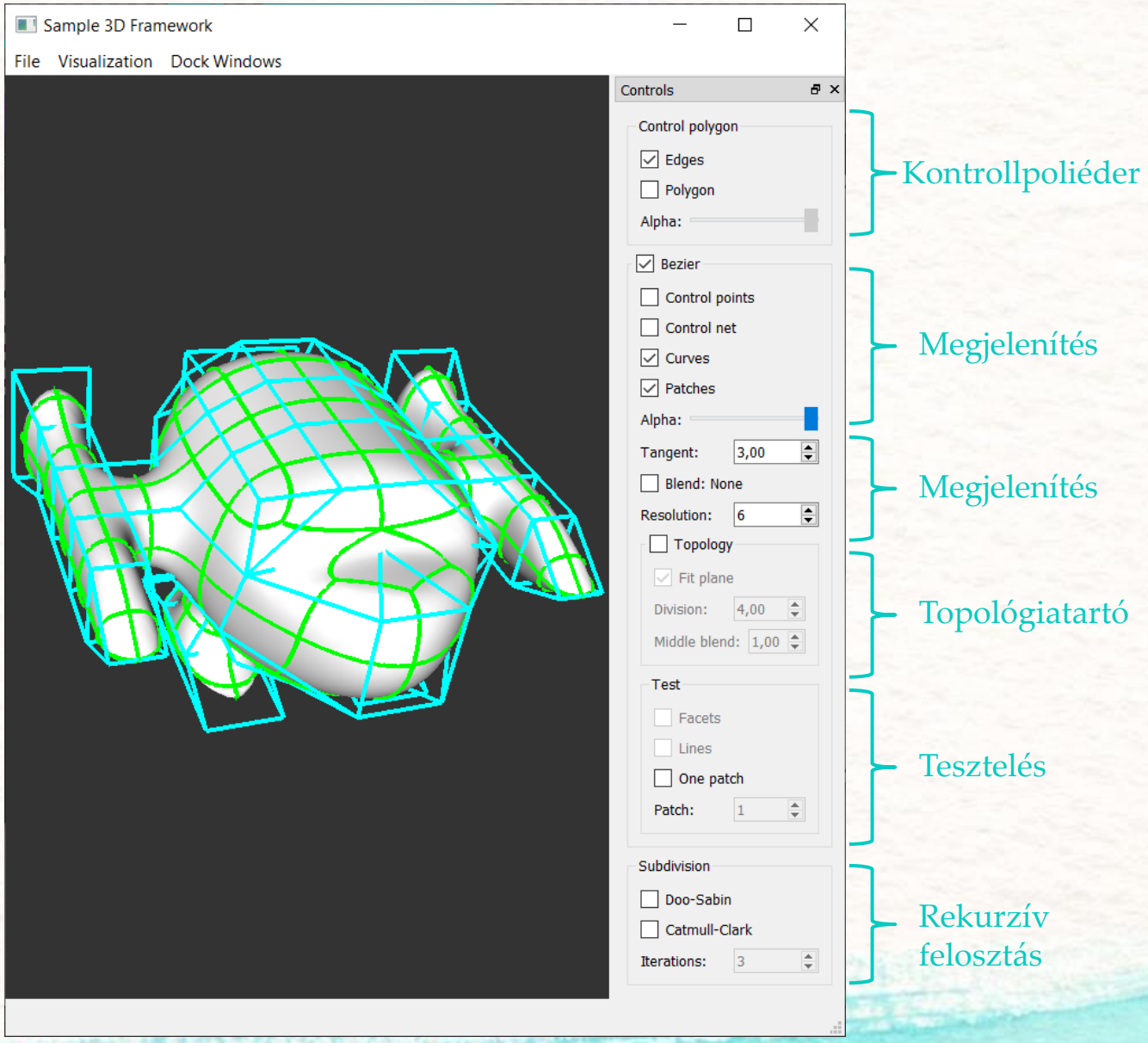


Topológiatartó



Tesztprogram

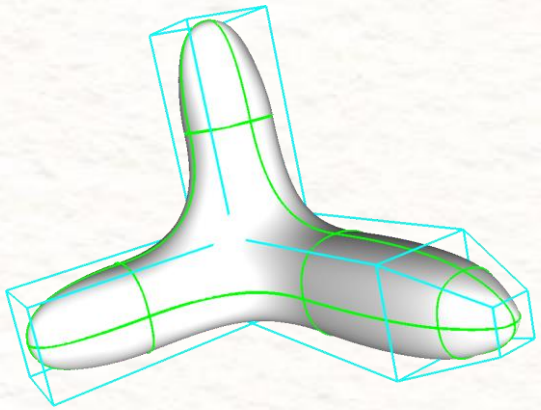
- Futtató környezet – Sample Framework*
  - OpenMesh
  - OpenGL
  - C++
- UI kiegészítés (Qt)
- Mesh kezelés
  - .obj beolvasás
  - Navigálás
  - Számítások



*https://github.com/salvipeter/sample-framework

Tesztpéldák

Duális



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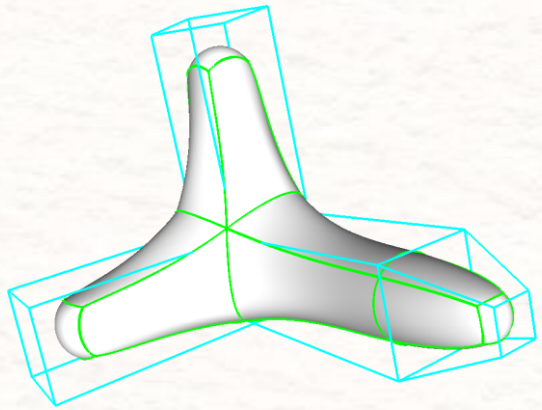
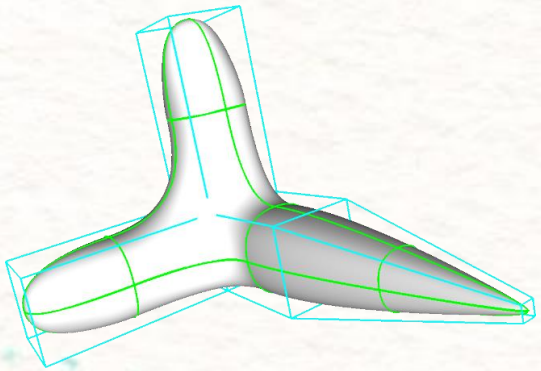
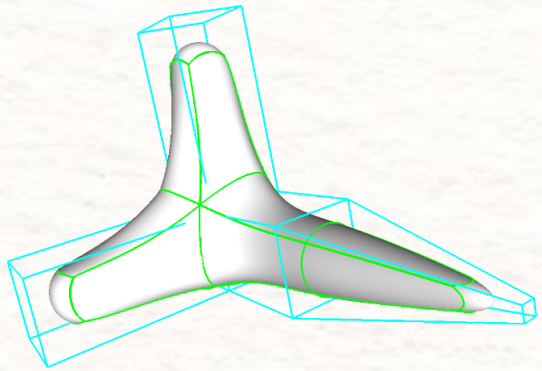
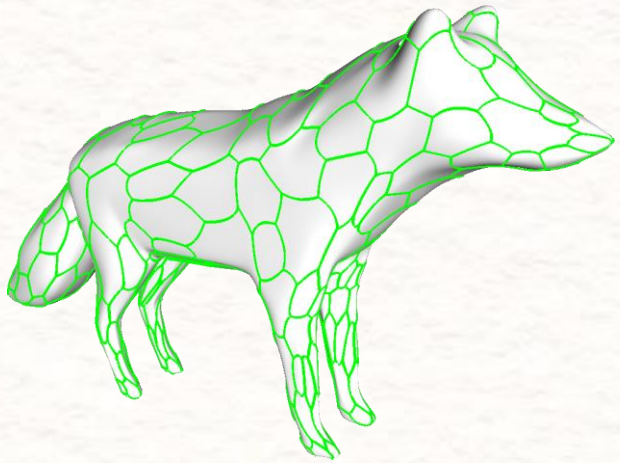






Lekerekítés

Duális



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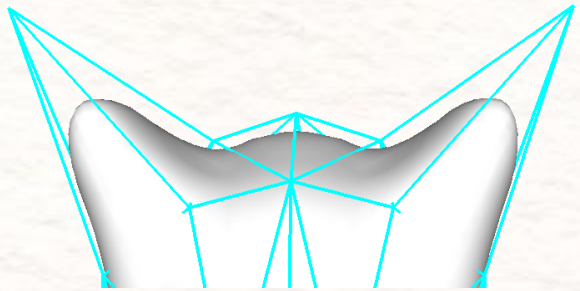

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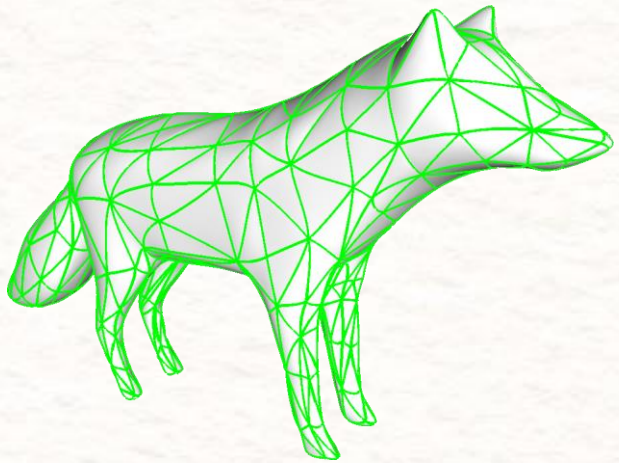

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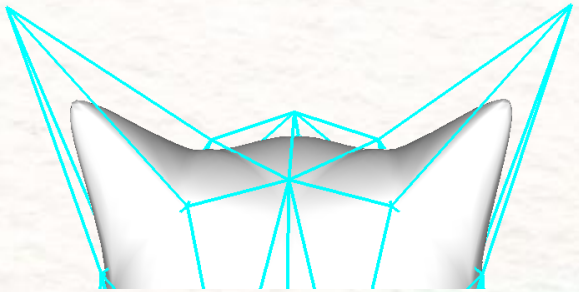
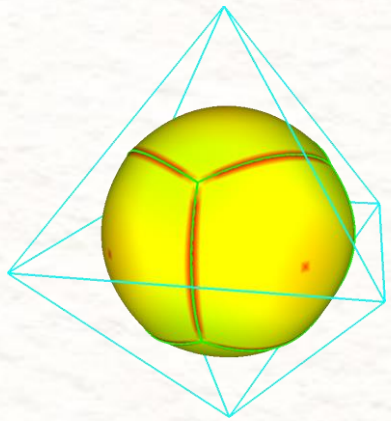
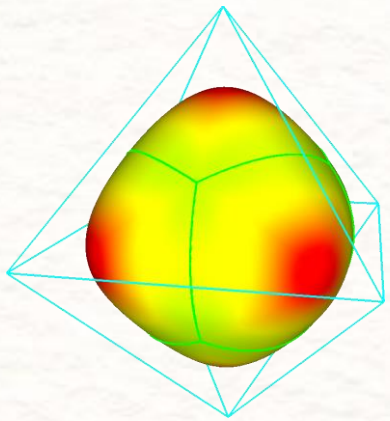


Csúcsosság megőrzése

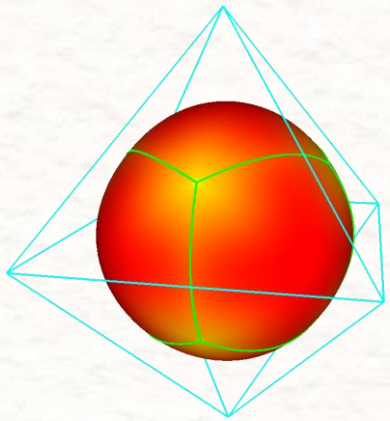
Tesztpéldák



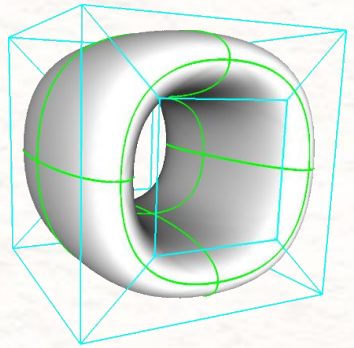
Blend nélkül



Interpoláló



Approximáló



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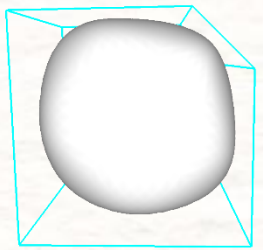
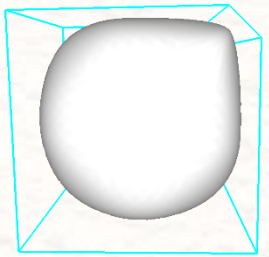
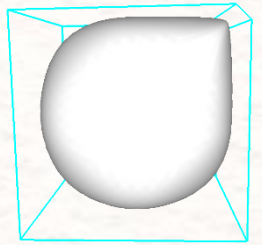
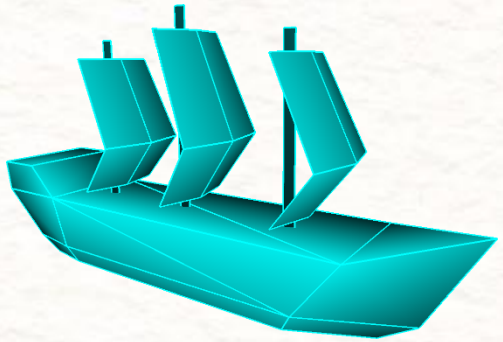
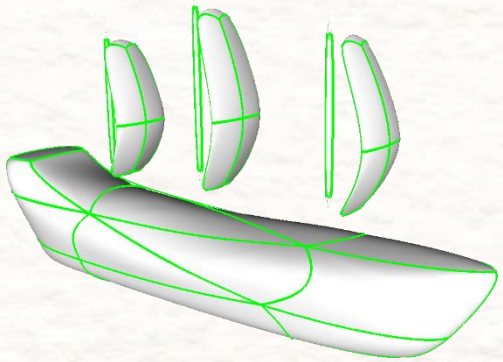








Kontrolpoliéder



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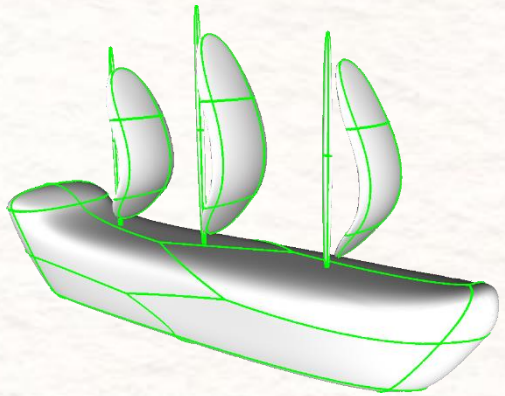
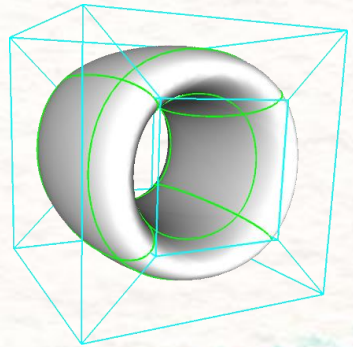


Topológia tartó



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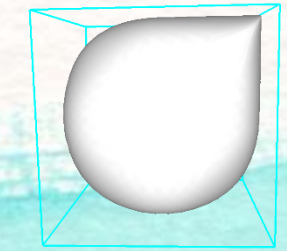

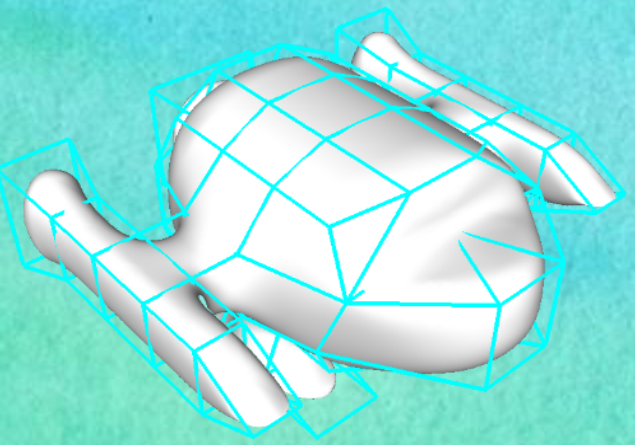
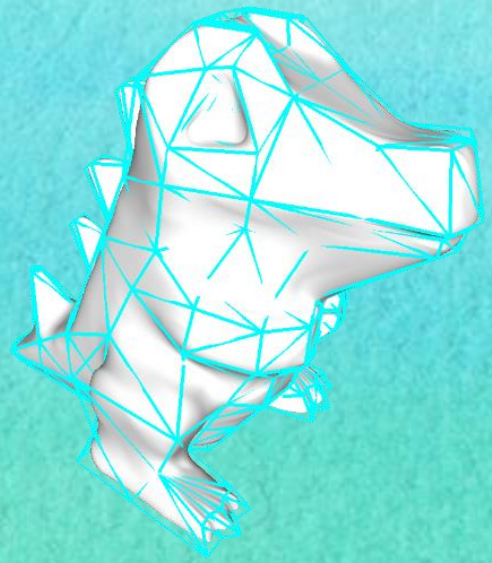


Köszönöm a figyelmet!