Put ka primjeni numeričkih metoda optimiranja i parametrizacije na složenije modele

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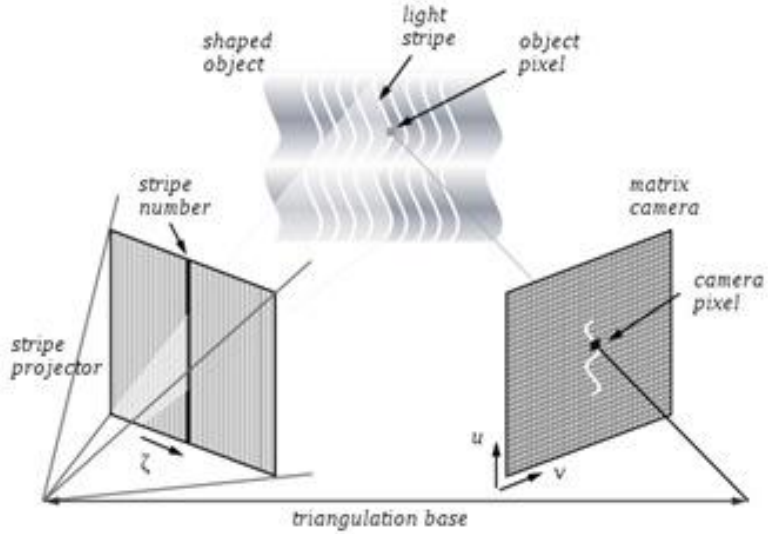
Pregled prezentacije

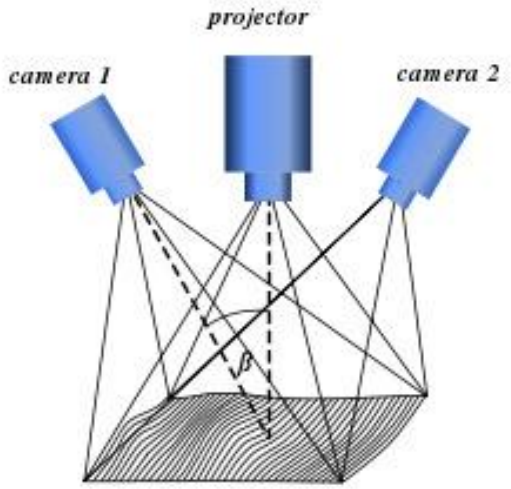
- Uvod
- 3D digitalizacija
- Parametrizacija
- Optimizacijske metode
- Genetski algoritam – operatori
- Cluster
- Primjer: lopatice, oštećenja, komfor
- Parametrizacija složenijih geometrija
- Topološko optimiranje
- Rezultati topološkog optimiranja
- Znanstveni doprinosi rada

Optimiranje u mehanici krutih i deformabilnih tijela

- 3D digitalizacija
- Parametrizacija
- Optimiranje
- Reverzno inženjerstvo

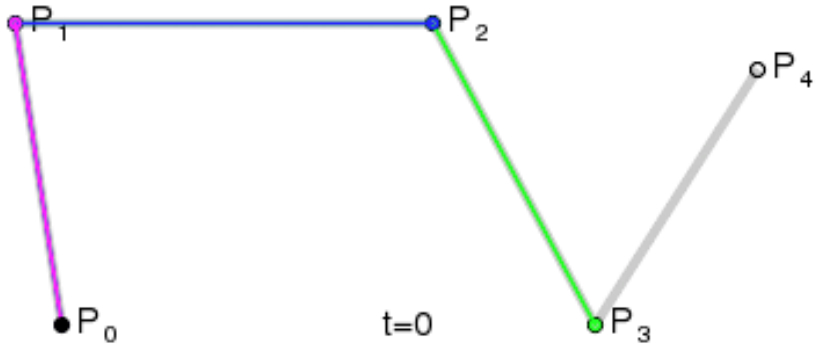
Princip rada 3D skenera





Parametrizacija

- Bezier krivulja i ploha



$$P(t) = \sum_{i=0}^{n} B_{i,n}(t) \cdot P_i = \sum_{i=0}^{n} \frac{n!}{i!(n-i)!} \cdot t^i \cdot (1-t)^{n-1} \cdot P_i$$

$$P(x,y) = \sum_{i=0}^{n} \sum_{j=0}^{m} B_i^n(x) \cdot B_j^m(y) \cdot P_i$$

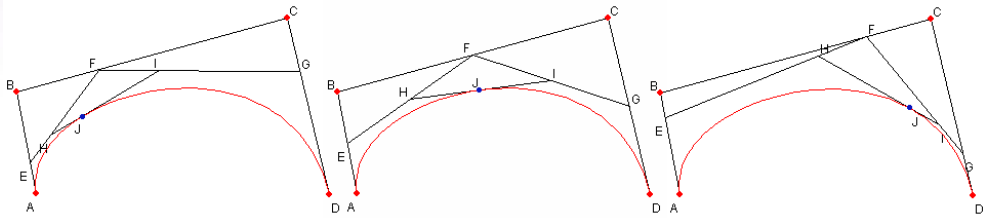
B - Bernsteinov polinom

P_i – kontrolne točke aproksimacije

n – broj točaka aproksimacije

t – interni parametar 0<t<1

Parametrizacija



- B – krivulje

$$P(t)=\sum_{i=0}^{n} N_{i,n}(t)\cdot P_i$$

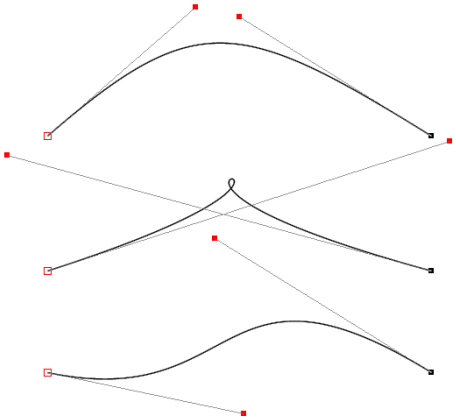
N – bazne funkcije $N_{i,0}(t)=\begin{cases}1, & t_i \le t < t_{i+1}\\ 0, & inače\end{cases}$

$$N_{i,j}(t)=\frac{t-t_i}{t_{i+j}-t_i}N_{i,j-1}(t)+\frac{t_{i+j+1}-t}{t_{i+j+1}-t_{i+1}}N_{i+1,j-1}(t)$$

t – krivolinijska varijabla pozicije

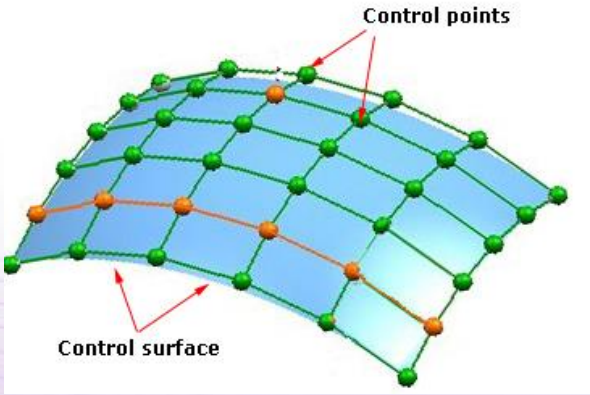
t_i – čvorovi

n – stupanj krivulje $1\le d\le n$ $t_i=\begin{cases}0, & 0\le i\le d\\ \frac{i-d}{n+1-d}, & d+1\le i\le n\\ 1 & n+1\le i\le n+d+1\end{cases}$



*P*i – kontrolne točke aproksimacije

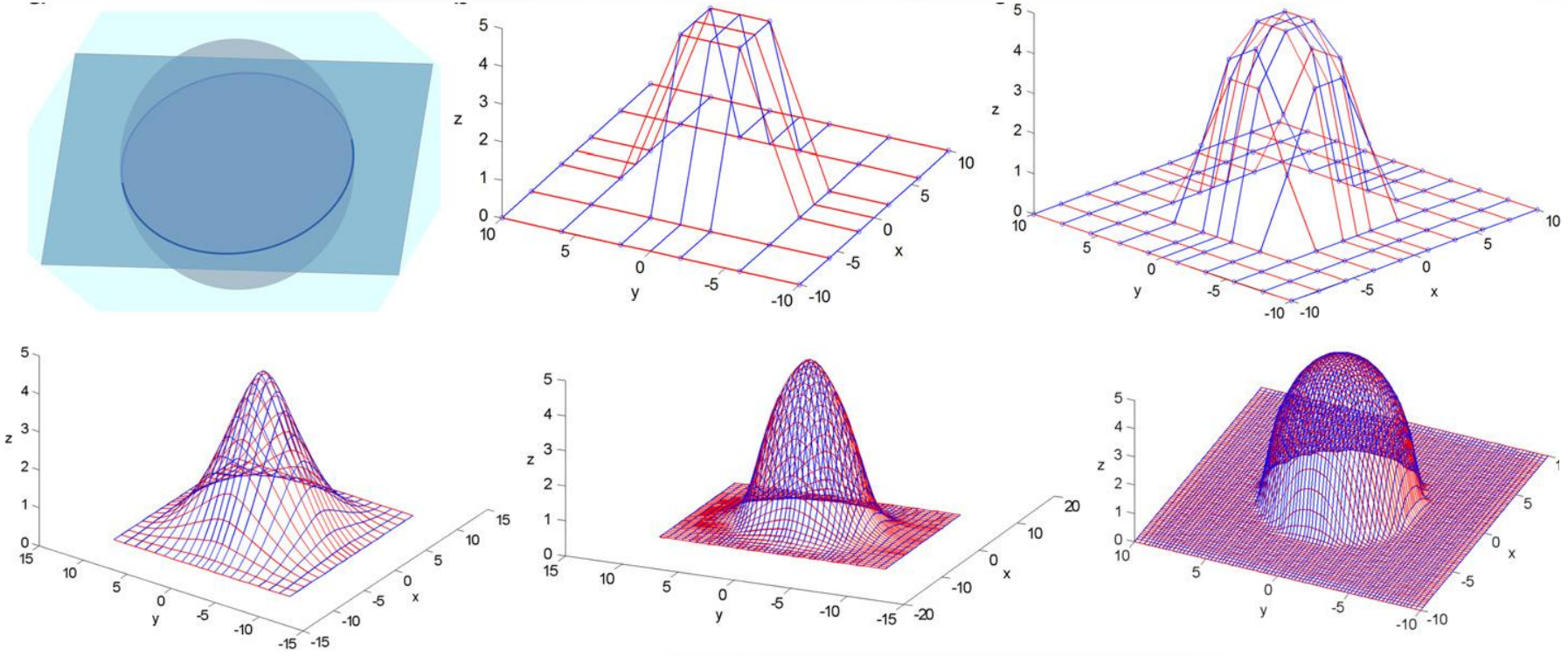
- lokalni utjecaj, poštujući zadani stupanj krivulje, glatkoću i točke koje opisuje.



- B – ploha

$$P(u,v)=\sum_{i=0}^{n}\sum_{j=0}^{m} N_{j,d_n}(u)\cdot N_{j,d_m}(v)\cdot p_{ij}$$

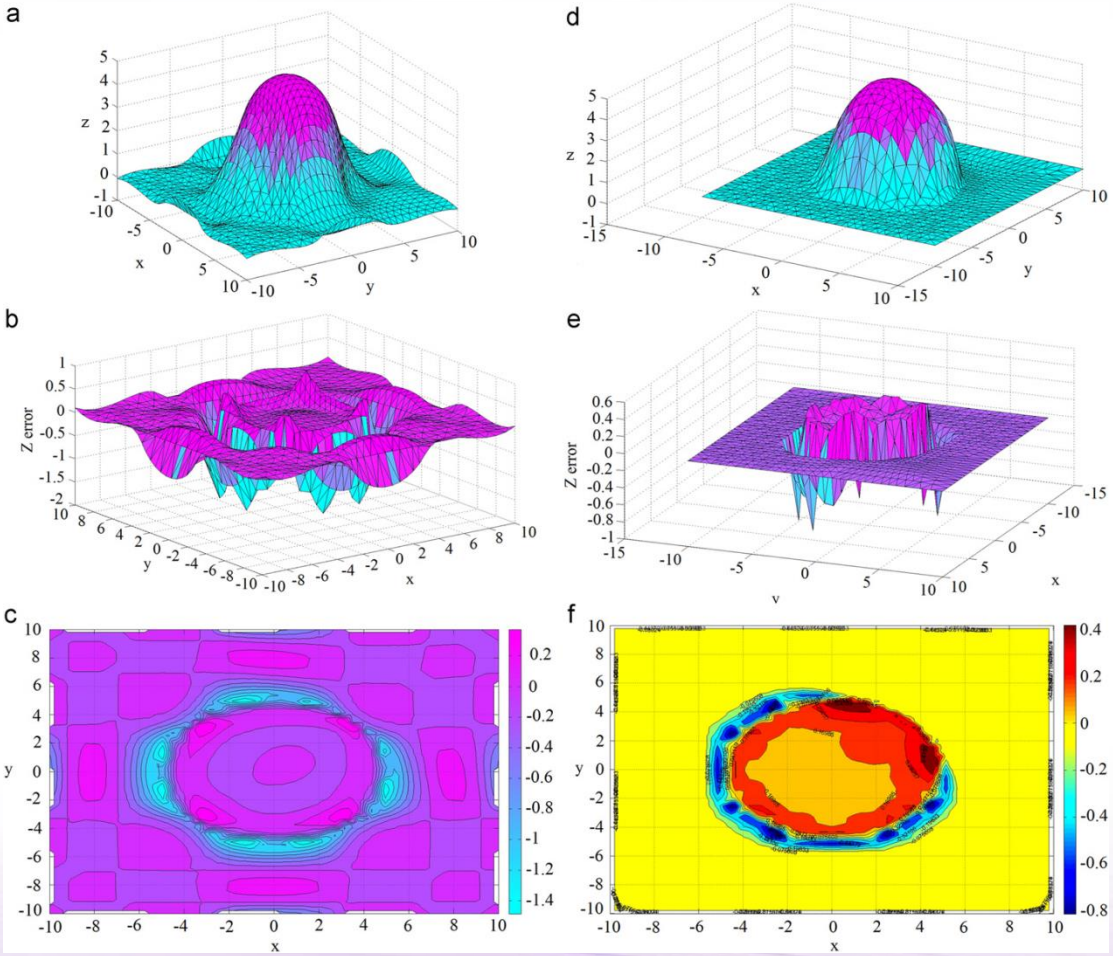
Parametrizacija rubova



Automatsko dodavanje točaka na spojevima krivulja osigurava kontinuitet.

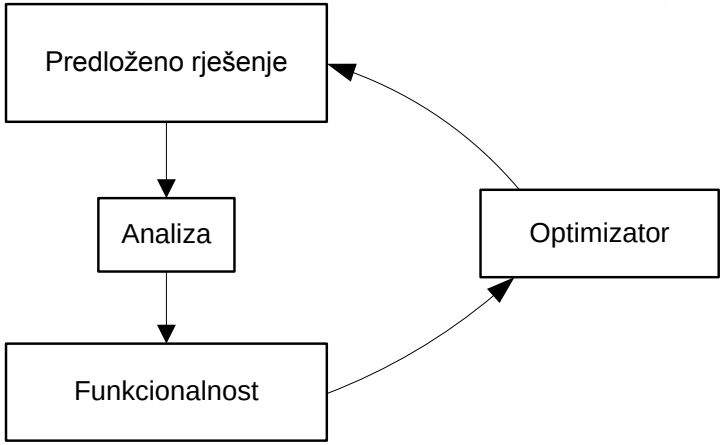
Adaptivan broj krivulja (ploha) u nizu, njihov stupanj i pozicije te položaj kontrolnih točaka.

Parametrizacija rubova



Optimizacijske metode

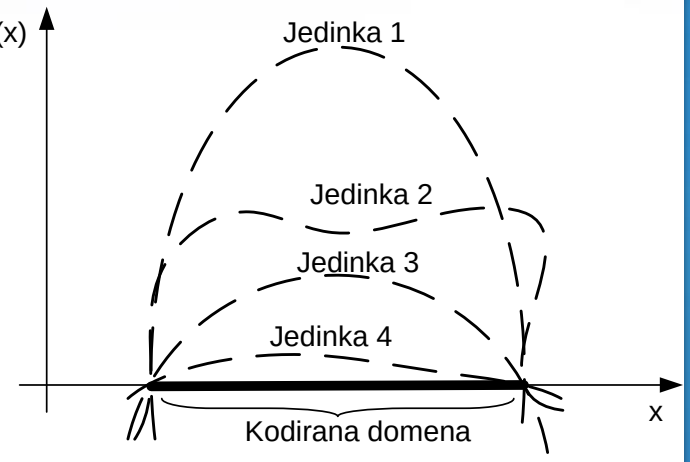
- Gradijentne
- Ne gradijentne
- Evolucijske



Genetski algoritam: populacija, generacije, mutacija, križanje…

Kazneni GA operator

- GA – prerana konvergencija
- Ekvivalentne jedinke kažnjavaju se određenim dodatkom na funkciju cilja:



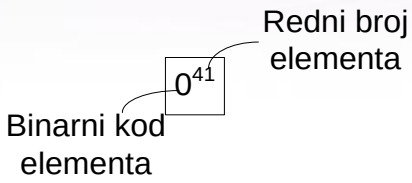
J1	J2	J3	J4	J5	J6	J7	J8	J9	….

Jedinke J2, J5 i J7 su ekvivalentne, a J1 i J3 daju najmanju funkciju cilja
Sljedeća generacija:

Je1	Je3	Jk4-8	Jk6-9	….	Jm2	Jm5	Jm7	….

Je – elitne jedinke
Jk – jedinke nastale križanjem
Jm – jedinke nastale mutacijom

Kazneni GA operator



Jedinka 1

0^{41}	0^{42}	0^{43}	0^{44}	0^{45}	0^{46}	0^{47}	0^{48}	0^{49}	0^{50}
0^{31}	0^{32}	0^{33}	0^{34}	0^{35}	0^{36}	0^{37}	0^{38}	0^{39}	0^{40}
0^{21}	0^{22}	0^{23}	0^{24}	0^{25}	0^{26}	0^{27}	0^{28}	0^{29}	0^{30}
1^{11}	1^{12}	1^{13}	1^{14}	1^{15}	1^{16}	1^{17}	1^{18}	1^{19}	1^{20}
0^{1}	0^{2}	0^{3}	0^{4}	0^{5}	0^{6}	0^{7}	0^{8}	0^{9}	0^{10}

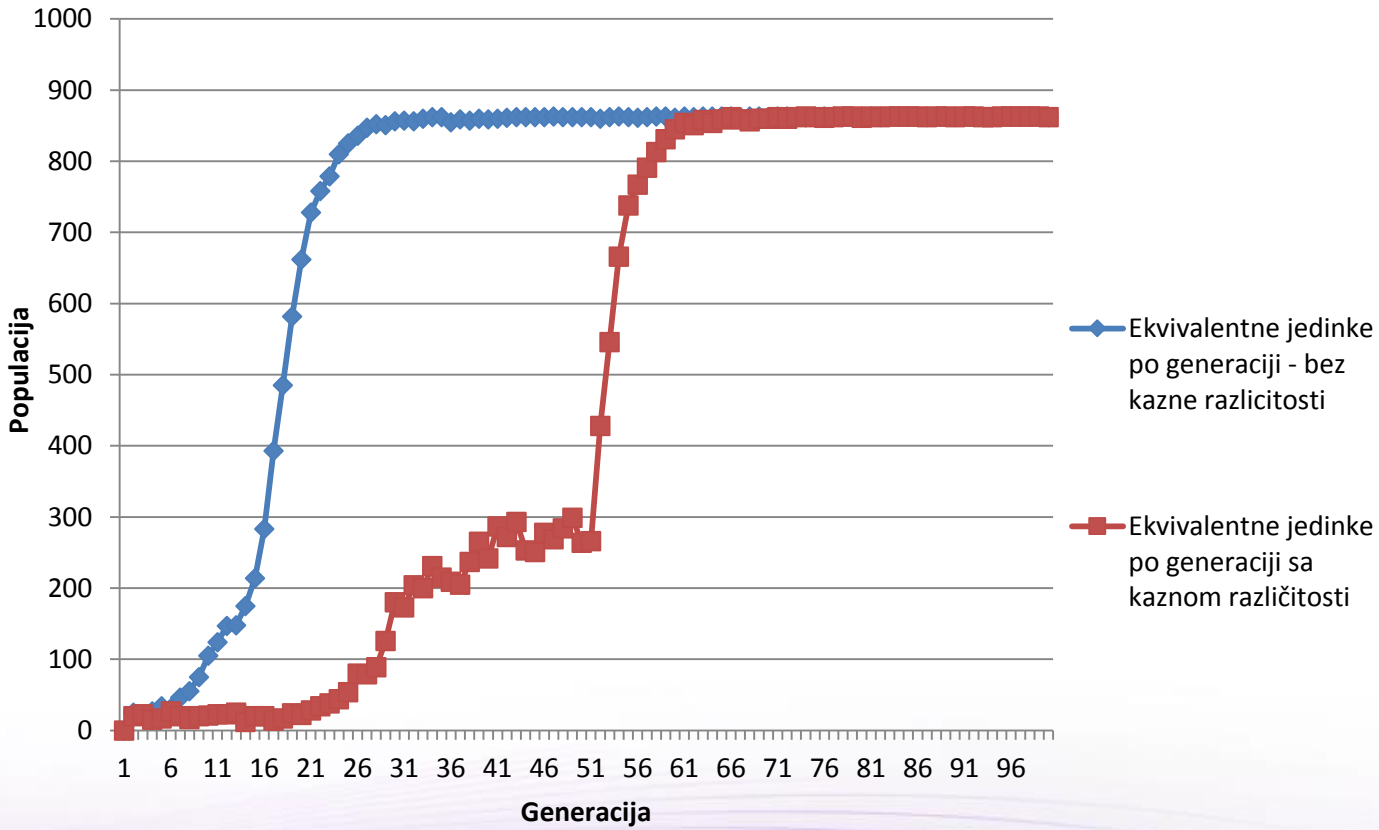
Jedinka 2

1^{41}	1^{42}	1^{43}	0^{44}	0^{45}	0^{46}	0^{47}	0^{48}	0^{49}	0^{50}
0^{31}	0^{32}	1^{33}	1^{34}	1^{35}	1^{36}	1^{37}	0^{38}	0^{39}	0^{40}
0^{21}	0^{22}	0^{23}	0^{24}	0^{25}	0^{26}	1^{27}	1^{28}	1^{29}	1^{30}
0^{11}	0^{12}	1^{13}	1^{14}	1^{15}	1^{16}	1^{17}	0^{18}	0^{19}	0^{20}
1^{1}	1^{2}	1^{3}	0^{4}	0^{5}	0^{6}	0^{7}	0^{8}	0^{9}	0^{10}

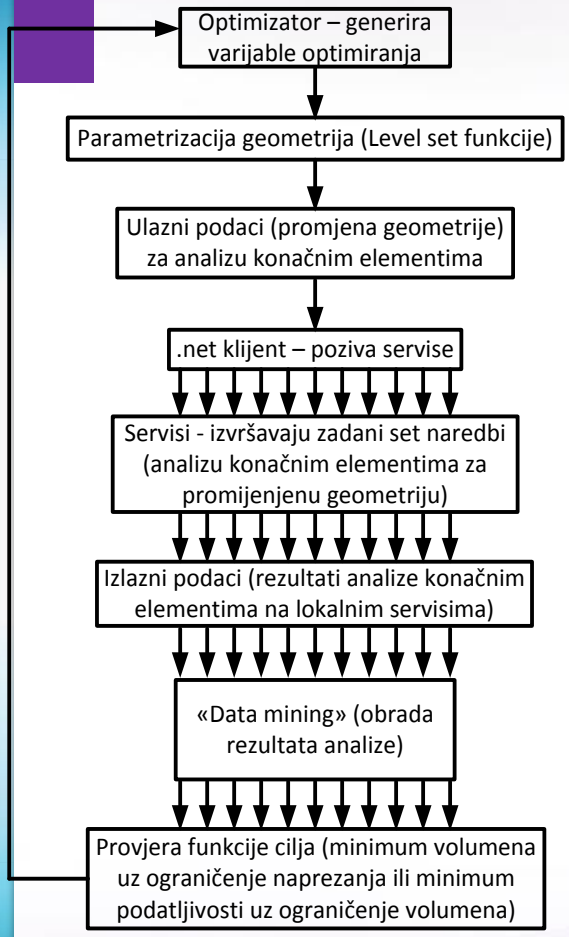
Usporedba = |Jedinka 1 - Jedinka 2|

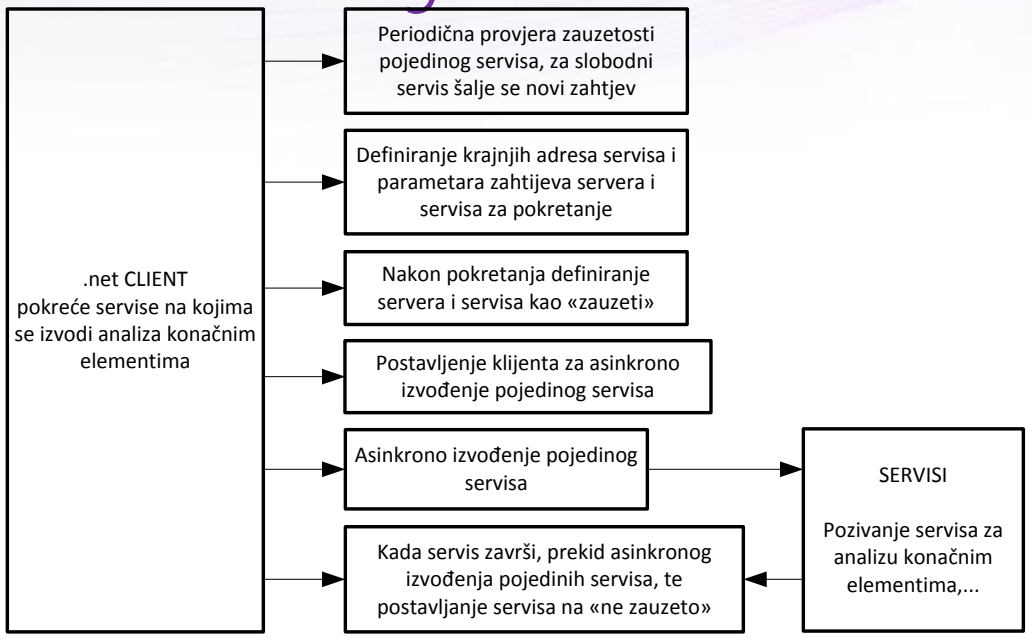
1^{41}	1^{42}	1^{43}	0^{44}	0^{45}	0^{46}	0^{47}	0^{48}	0^{49}	0^{50}
0^{31}	0^{32}	1^{33}	1^{34}	1^{35}	1^{36}	1^{37}	0^{38}	0^{39}	0^{40}
0^{21}	0^{22}	0^{23}	0^{24}	0^{25}	0^{26}	1^{27}	1^{28}	1^{29}	1^{30}
1^{11}	1^{12}	0^{13}	0^{14}	0^{15}	0^{16}	0^{17}	1^{18}	1^{19}	1^{20}
1^{1}	1^{2}	1^{3}	0^{4}	0^{5}	0^{6}	0^{7}	0^{8}	0^{9}	0^{10}

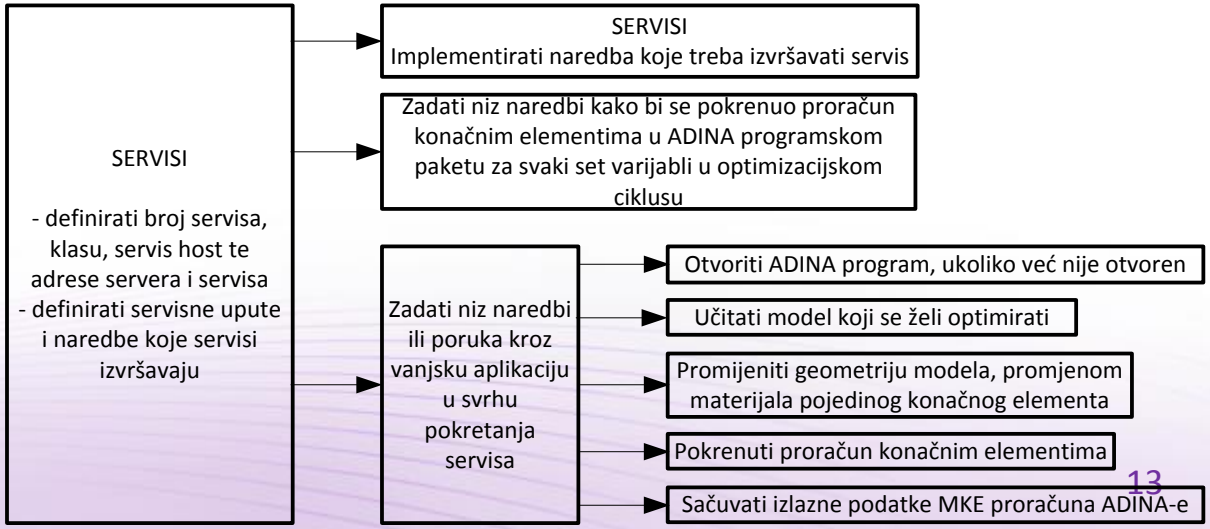
Kazneni GA operator



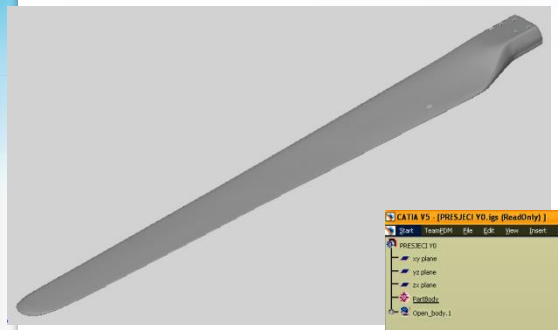
Cluster - paralelizacija

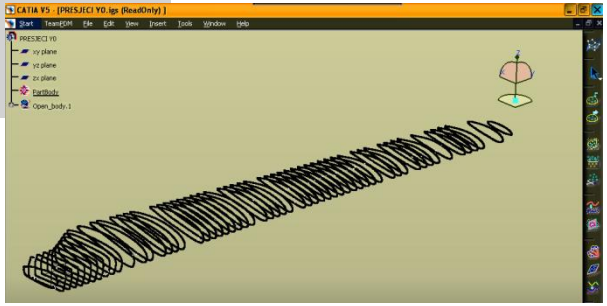


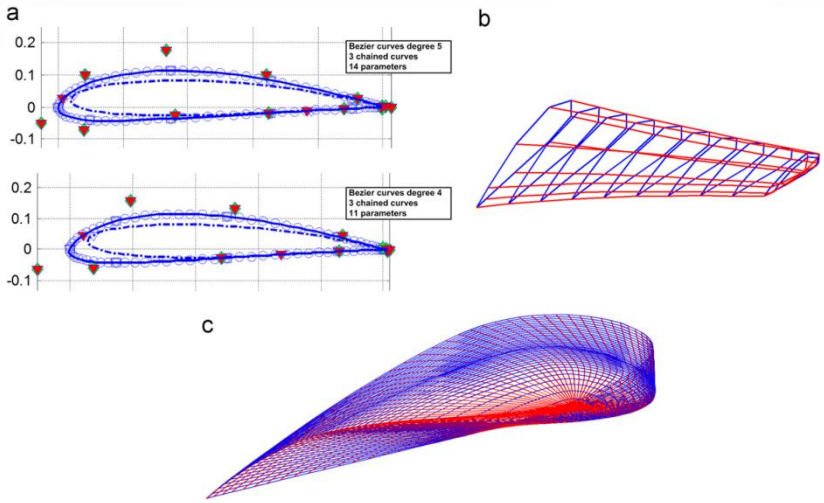


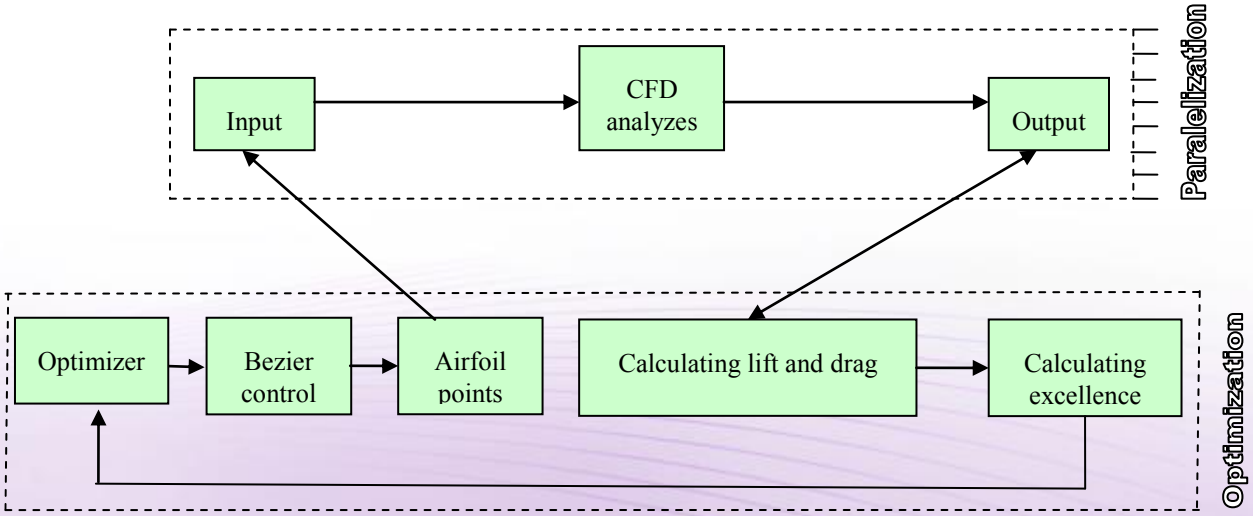


Lopatica vjetroturbine

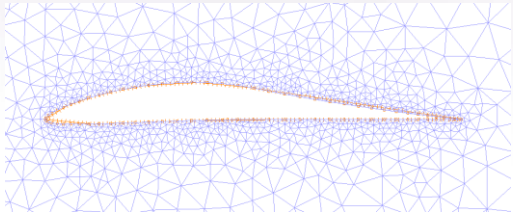


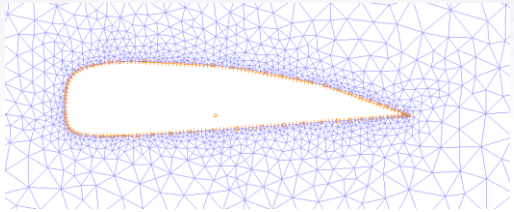


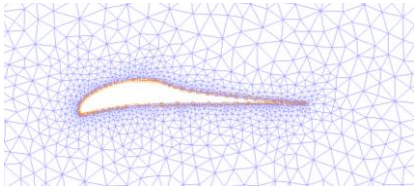


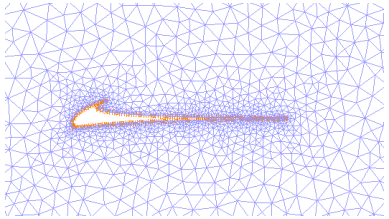


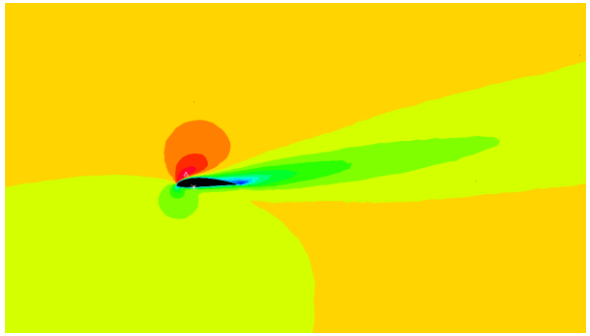
Optimizacija aeroprofila

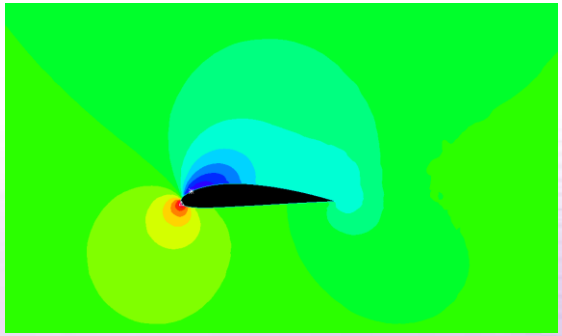


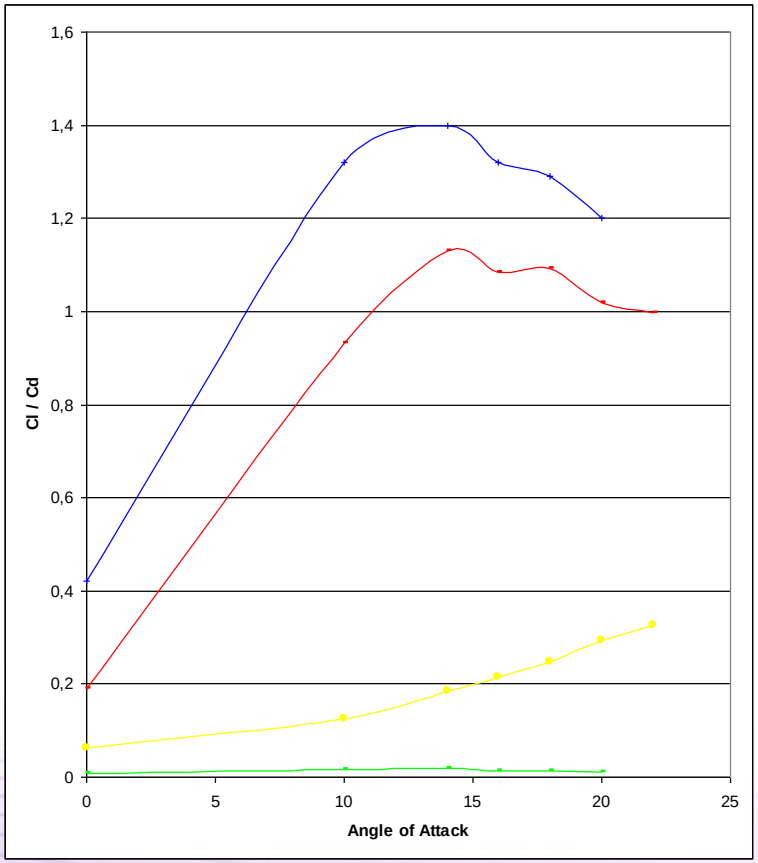




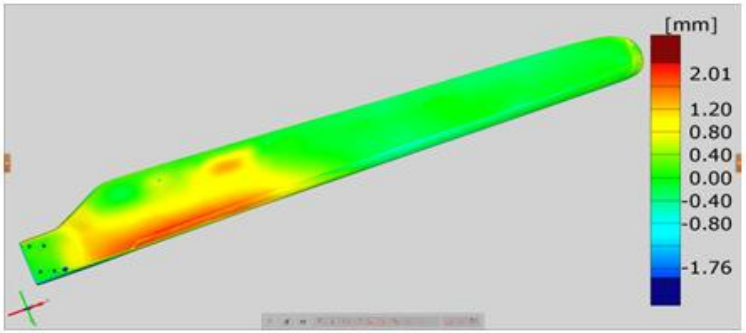


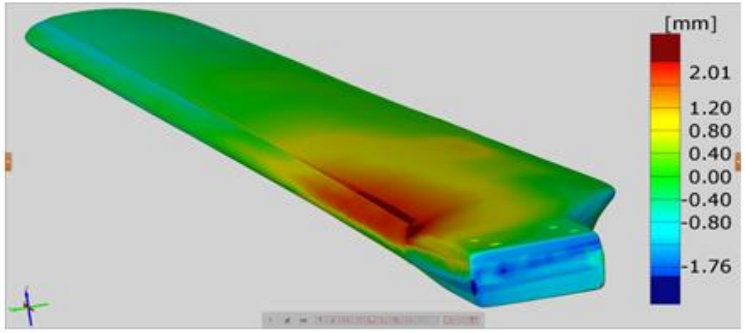


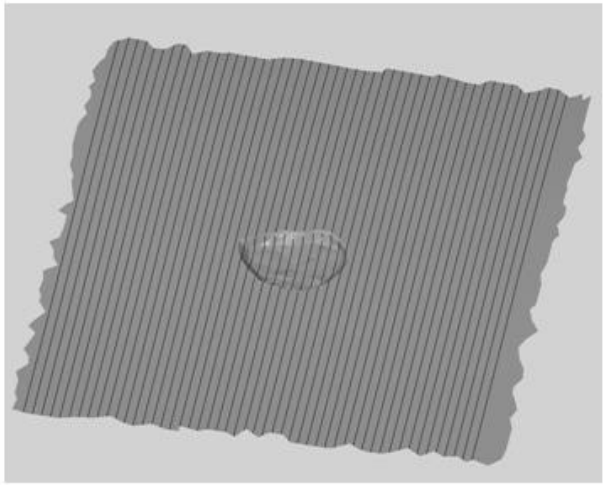


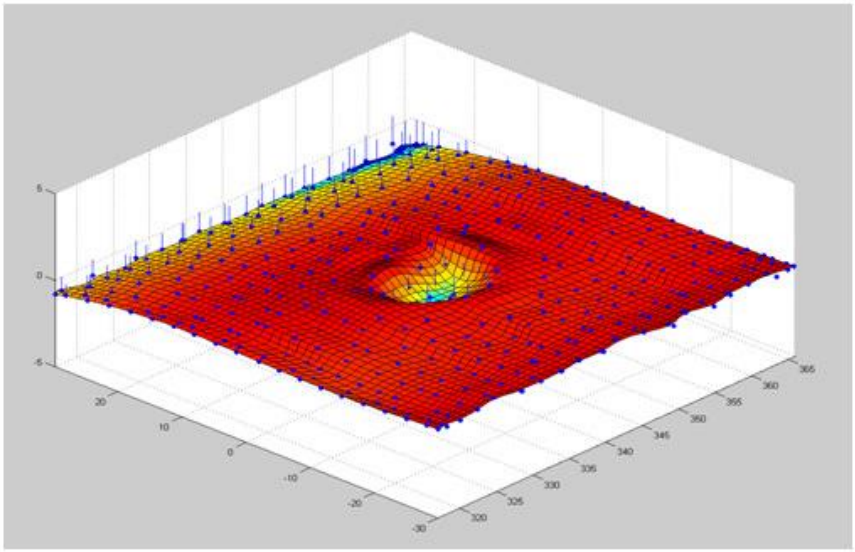


Detekcija oštećenja na lopatici vjetroturbine



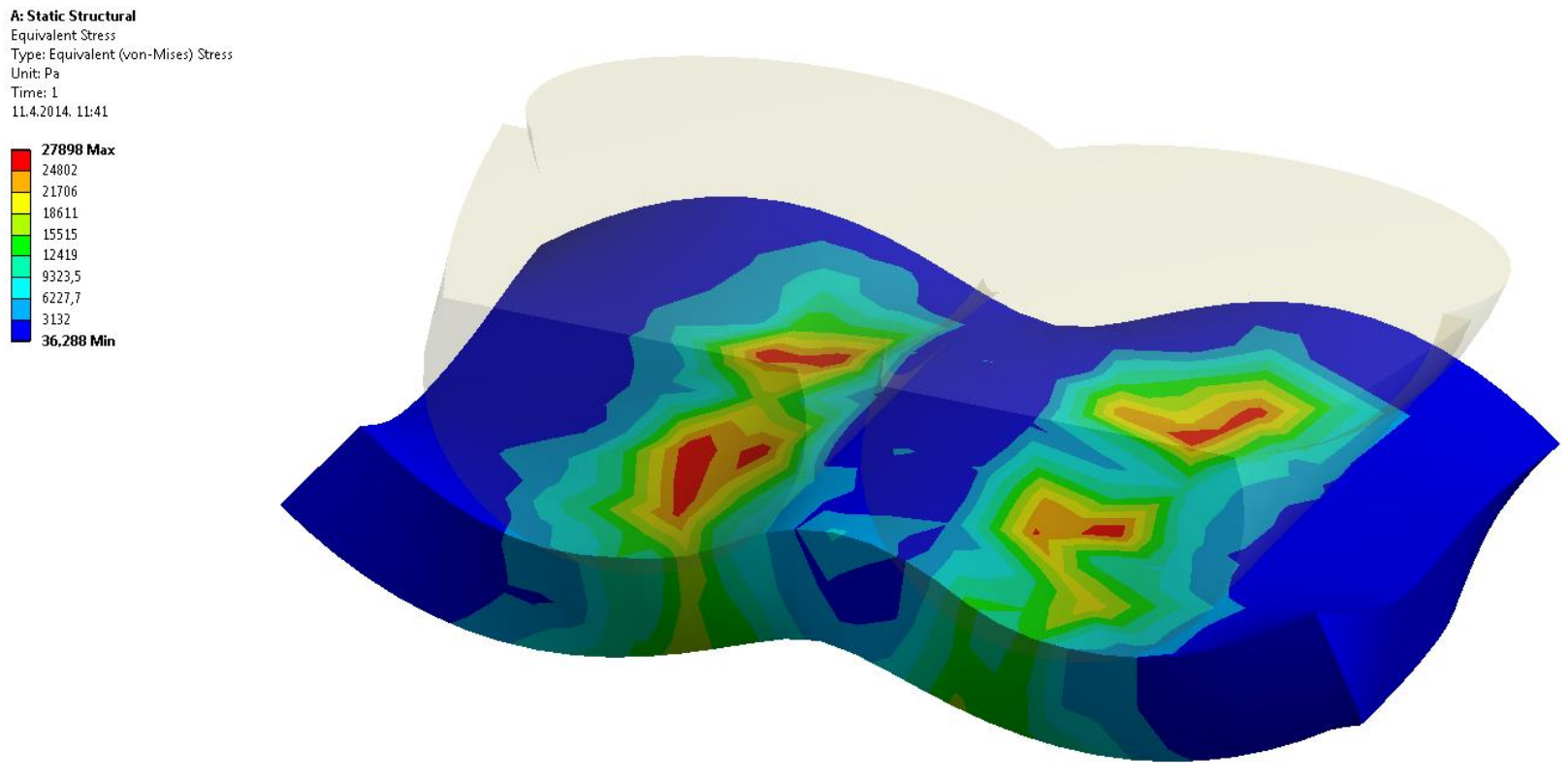




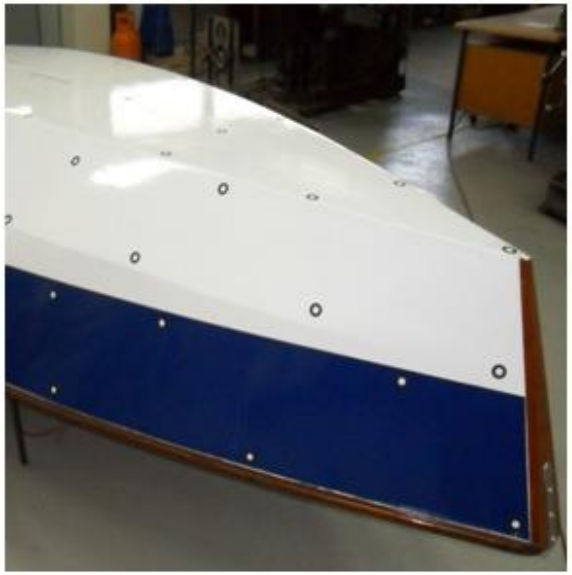


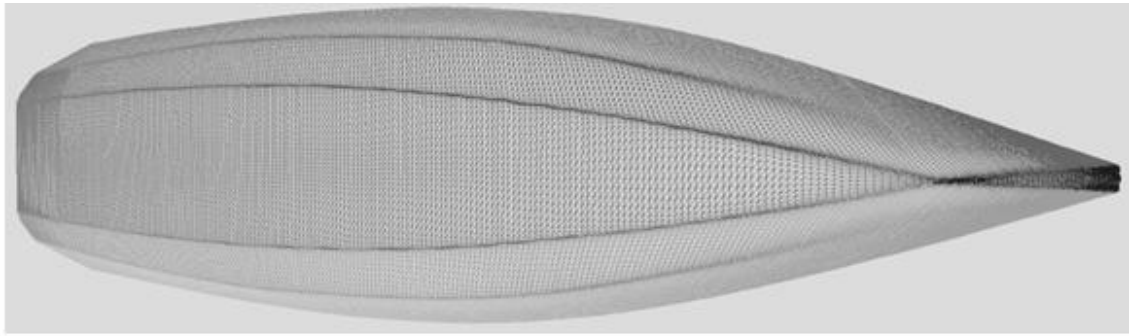
Komfor

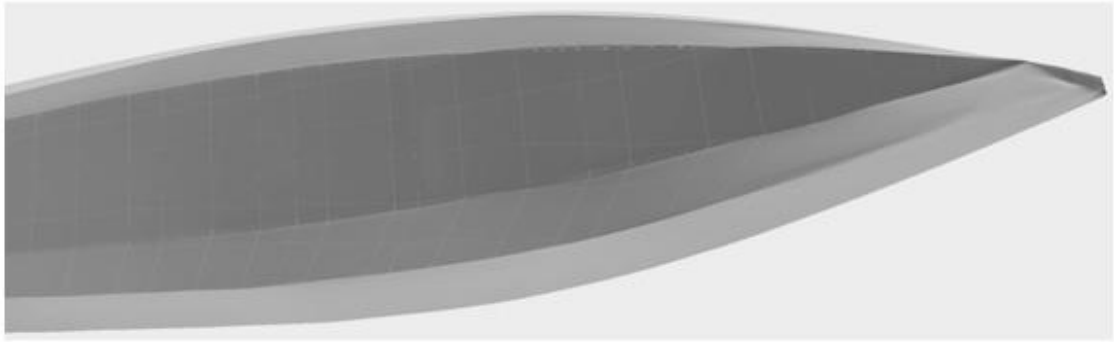
- Optimalna raspodjela pritisaka



Paramerizacija složenijih geometrija

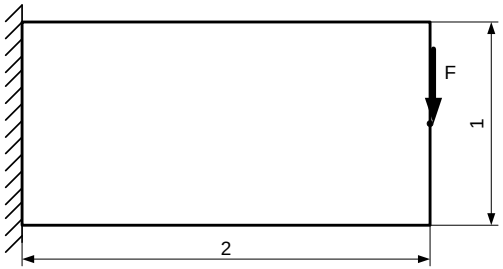




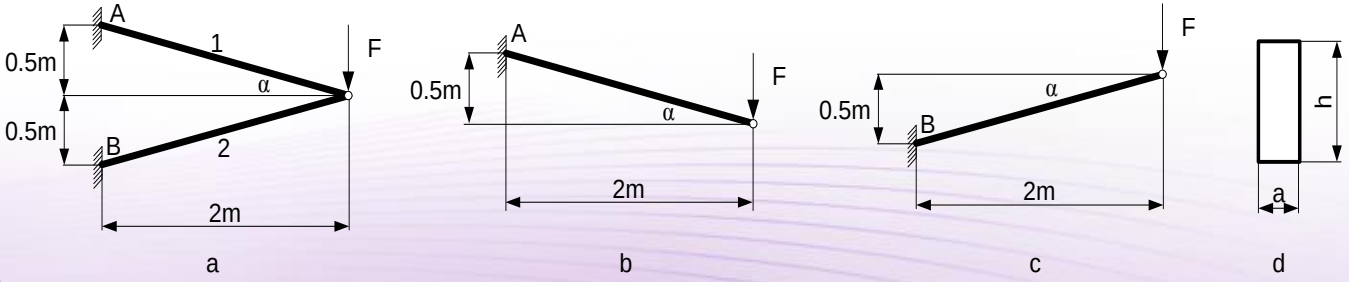


Topološka optimizacija 2D konzole opterećene silom na kraju

- Optimalna preraspodjela materijala
  - Minimizirati masu uz ograničenje nosivosti
  - Minimizirati podatljivost uz ograničenje volumena…

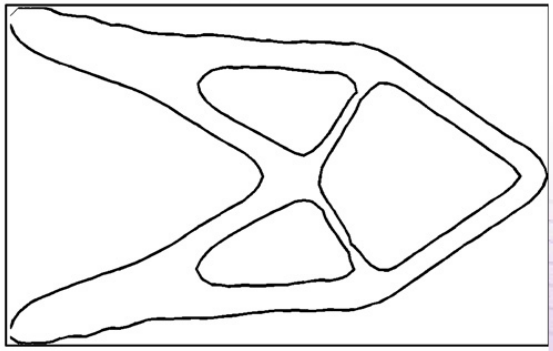


- Neka diskretna rješenja:



Topologija

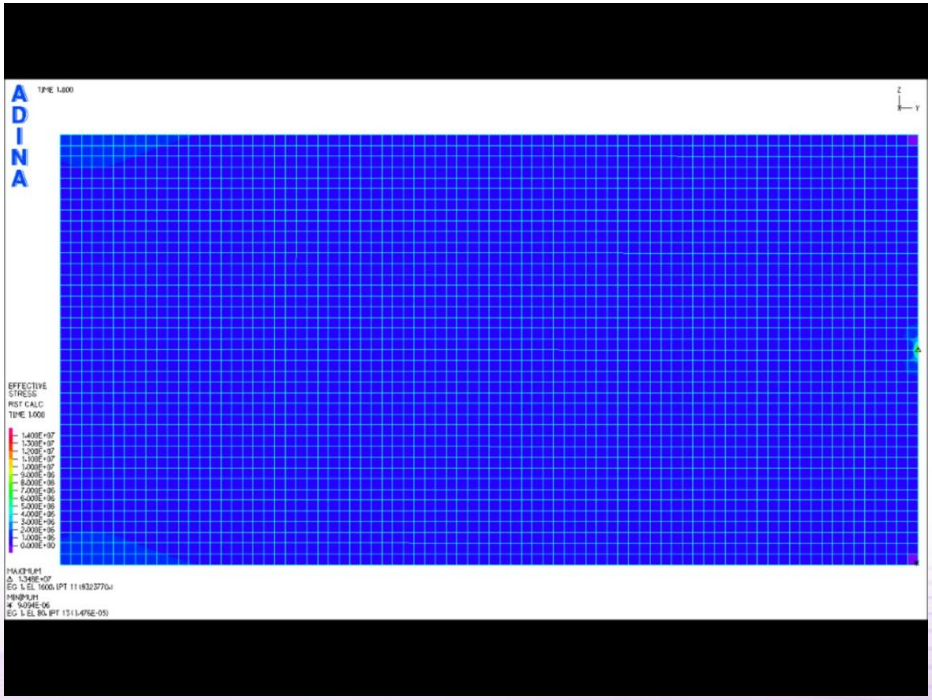
- Topologija povezanost elemenata sustava
- Topološkim optimiranjem mijenja se struktura domene
- Optimiranje topologije: dva nepoznata spregnuta polja (naprezanja i oblik-raspodjela materijala)
- Topološko optimiranje – multidisciplinarno

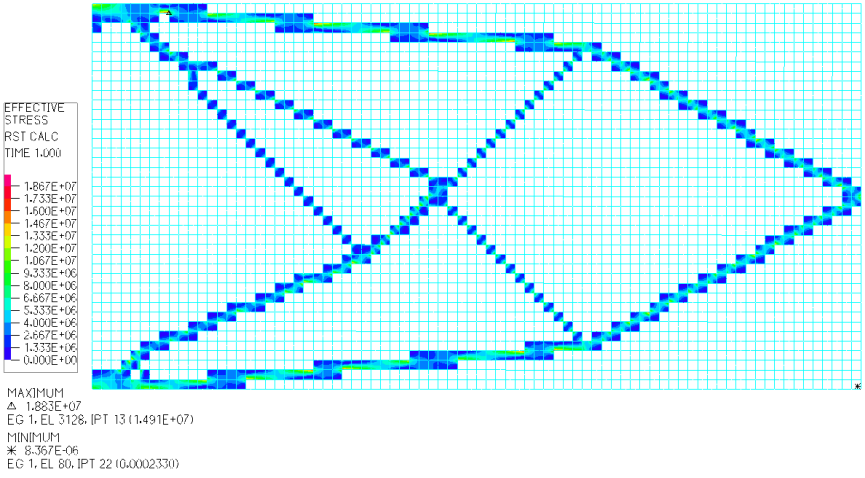


Topološko optimiranje

- Evolutionary structural optimization (ESO) metoda

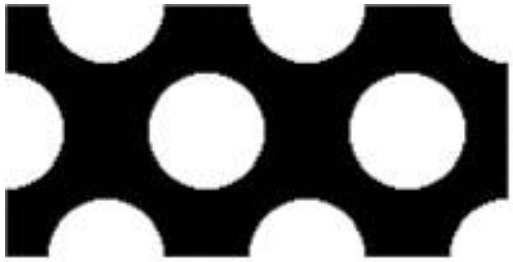
  na mjestima gdje je metoda konačnih elemenata dala manja naprezanja, uklanja (gricka) materijal.





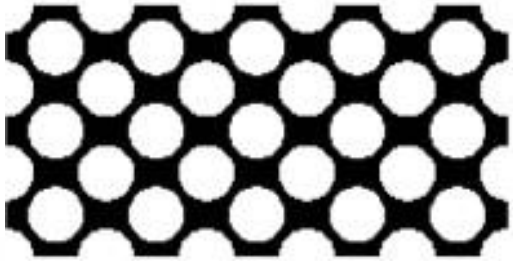
Topološko optimiranje

- Bubble metoda:
  - definiraju se praznine
  - mijenja se veličina praznina u promatranoj domeni kako bi dobili optimalni oblik.

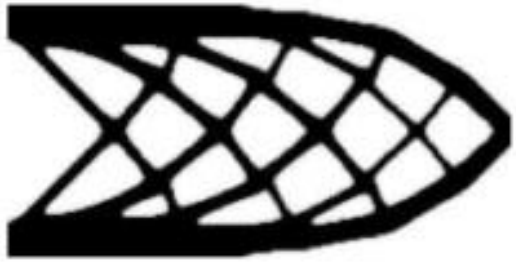


(a) Initial shape with 9 holes

(b) Optimal configuration with initial shape (a)



(c) Initial shape with 39 holes



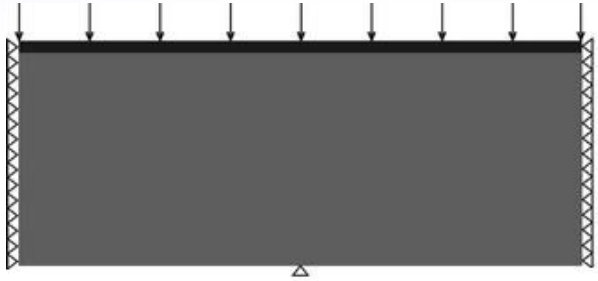
(d) Optimal configuration with initial shape (c)

Topološko optimiranje

- Solid Isotropic Material with Penalization (SIMP)
  - optimiranje raspodjele materijala.
  - varijabla koja govori o raspodjeli materijala je krutost materijala
  - krutost može poprimiti vrijednosti izotropnog materijala (ima materijala - 1) i nulu (nema materijala).
  - Binarni problem (0 i 1) relaksira se u kontinuirane varijable penalizacijom

$$\int_{\Omega} \rho(X) \cdot d\Omega \le V_0 \qquad 0 \le \rho(X) \le 1 \qquad D(X) = \rho(X)^p D^0$$

  - Gušća mreža KE – bolja točnost
    - pojava vrlo tanke mrežaste strukture
  - Uvode se ograničenja: kontrola opsega, metoda ograničavanja gradijenata, filtri…



Design domain of bridge

SIMP

SIMP-SRV

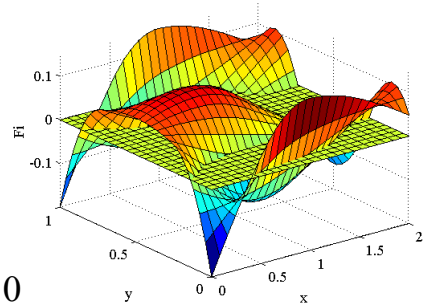
Topološko optimiranje

- Level set
  - Implicitna ploha u *n*+1 D, čija izo linija $\Phi(\boldsymbol{x},t)=0$ opisuje željenu geometriju u *n* D
  - Definiranje područja

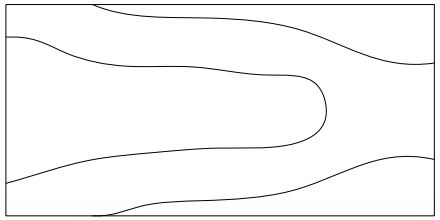
$$\chi^{-}(\boldsymbol{x})=\begin{cases}1 & ako\ je\ \phi(x)\le 0,\\ 0 & ako\ je\ \phi(\boldsymbol{x})>0\end{cases}$$

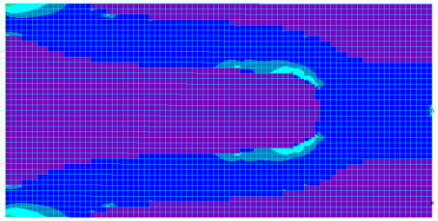
  - Težinska funkcija

$$H(\phi(\boldsymbol{x}))=\begin{cases}1 & ako\ je\ \phi(\boldsymbol{x})\le 0,\\ 0 & ako\ je\ \phi(\boldsymbol{x})>0\end{cases}$$



$\Phi(\boldsymbol{x},t)=0$

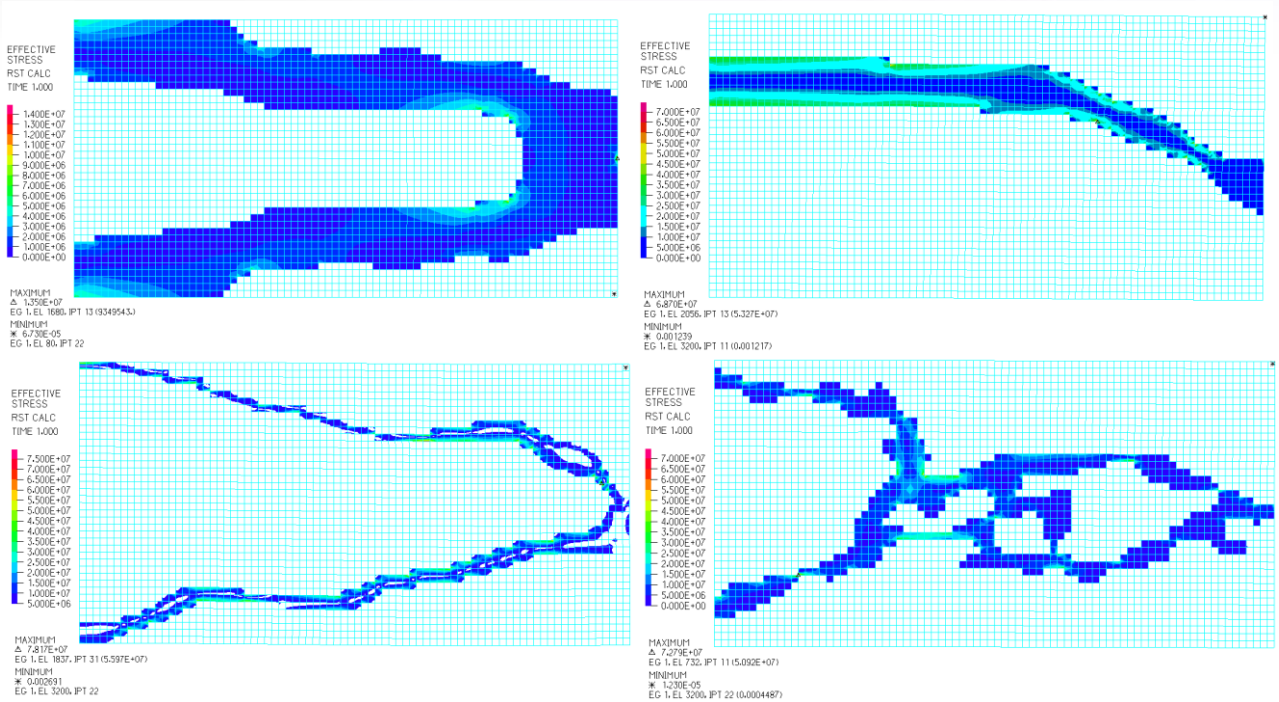




- Promjenom implicitne plohe u vremenu (u *n*+1 D) mijenja se geometrija u *n* D (promjenom izo linije) - H-J jednadžba:

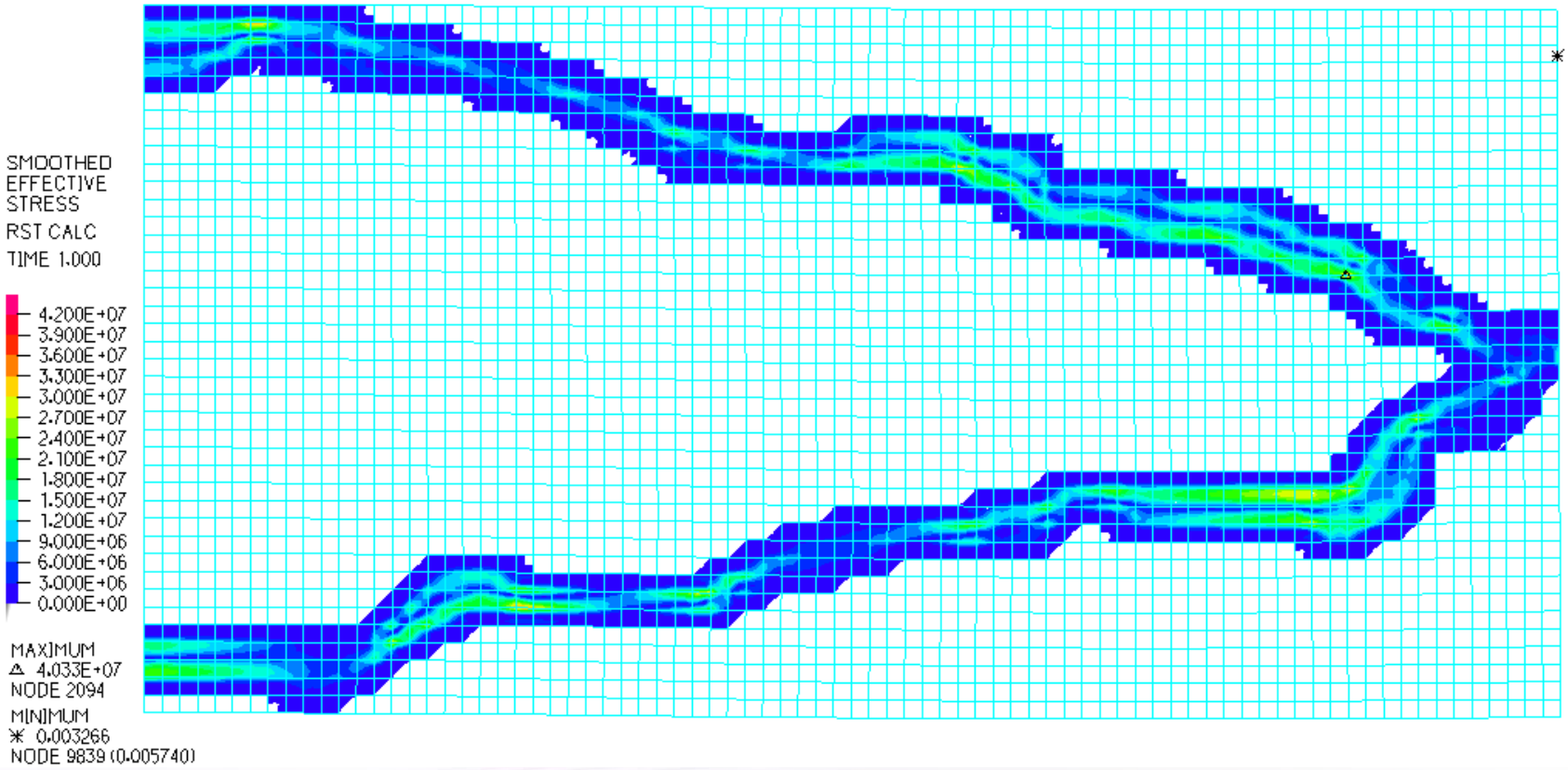
$$\frac{\partial\Phi(\boldsymbol{x},t)}{\partial t}+\nabla\Phi(\boldsymbol{x},t)\cdot\frac{d\boldsymbol{x}}{dt}=0$$

Rezultati topološkog optimiranja LS metodom



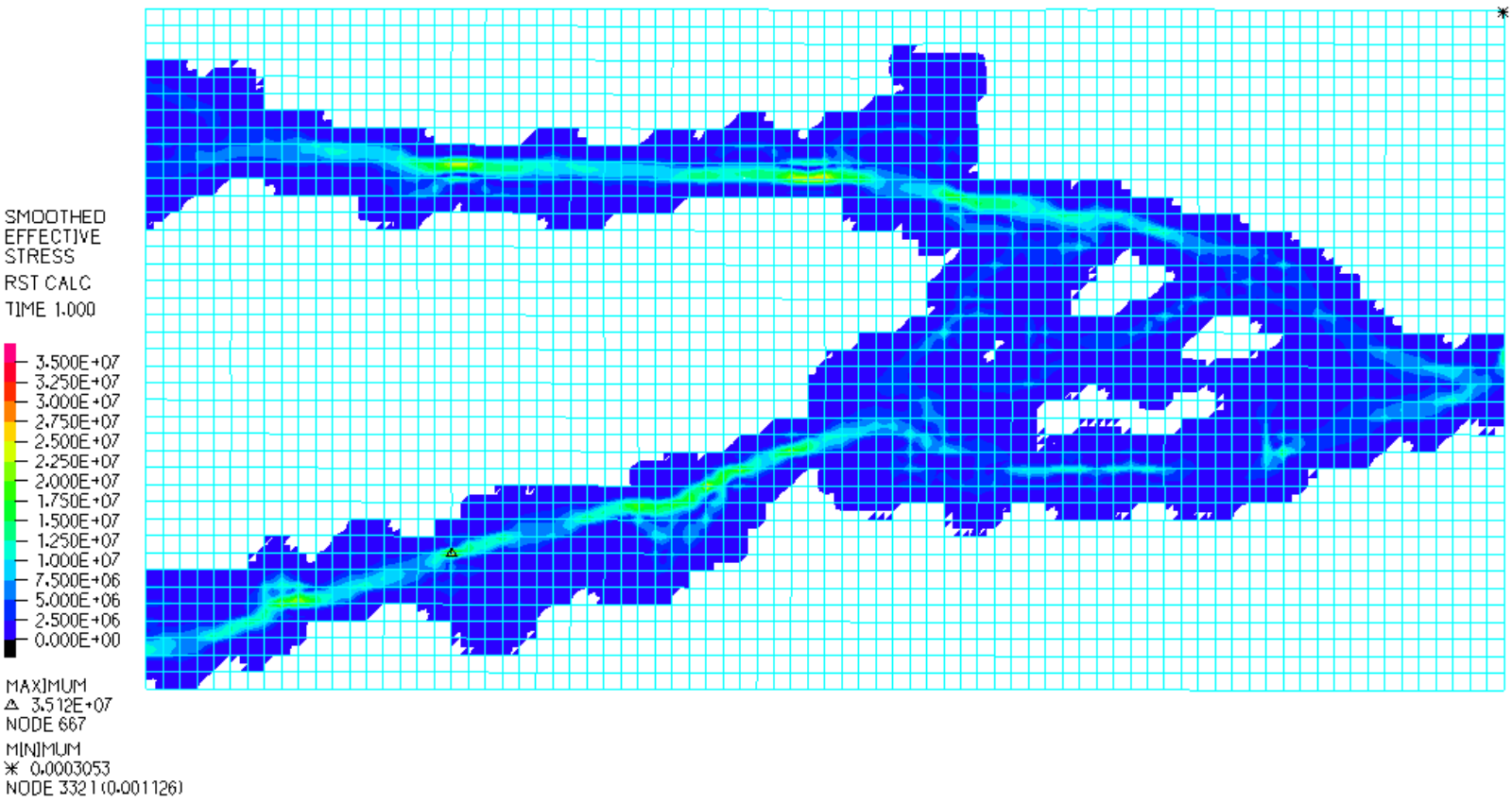
- 6x6 13.6% volumena pune ploče (GEN 500, POP 108)
- 12x12 11.8% volumena pune ploče (GEN 100, POP 864)
- 24x24 21% volumena pune ploče (GEN 200, POP 1152) - mala populacija

Rezultati topološkog optimiranja LS metodom



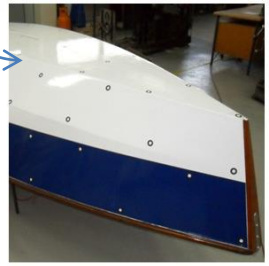
- 24x24 10,3% volumena od uz početno rješenje (GEN 100, POP 1728)

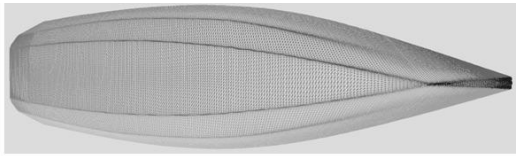
Rezultati topološkog optimiranja LS metodom

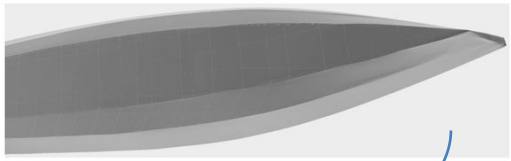


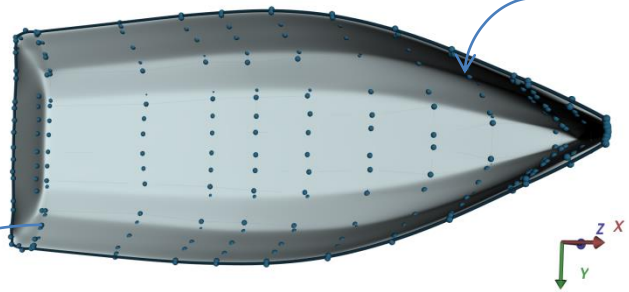
- 48x48 populacija 6192, 200 generacija, vrijeme trajanja 1320 sati (55 dana)

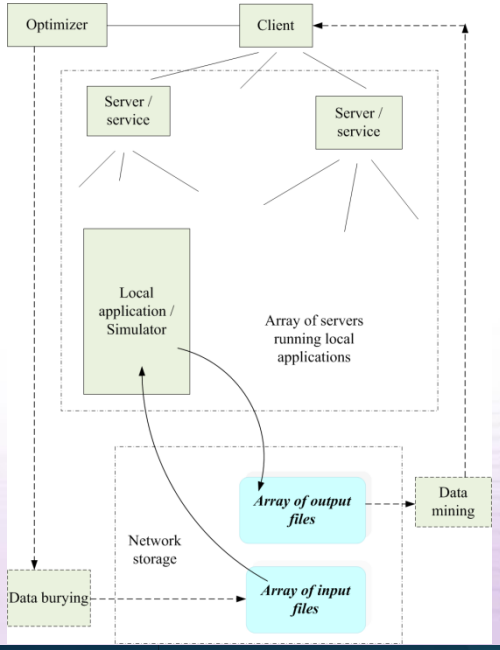
Zaključak i znanstveni doprinos











Hvala na pažnji!

Pitanja???