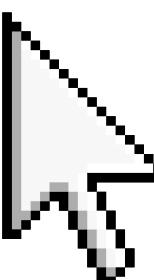


Home Content Contact

Projekat

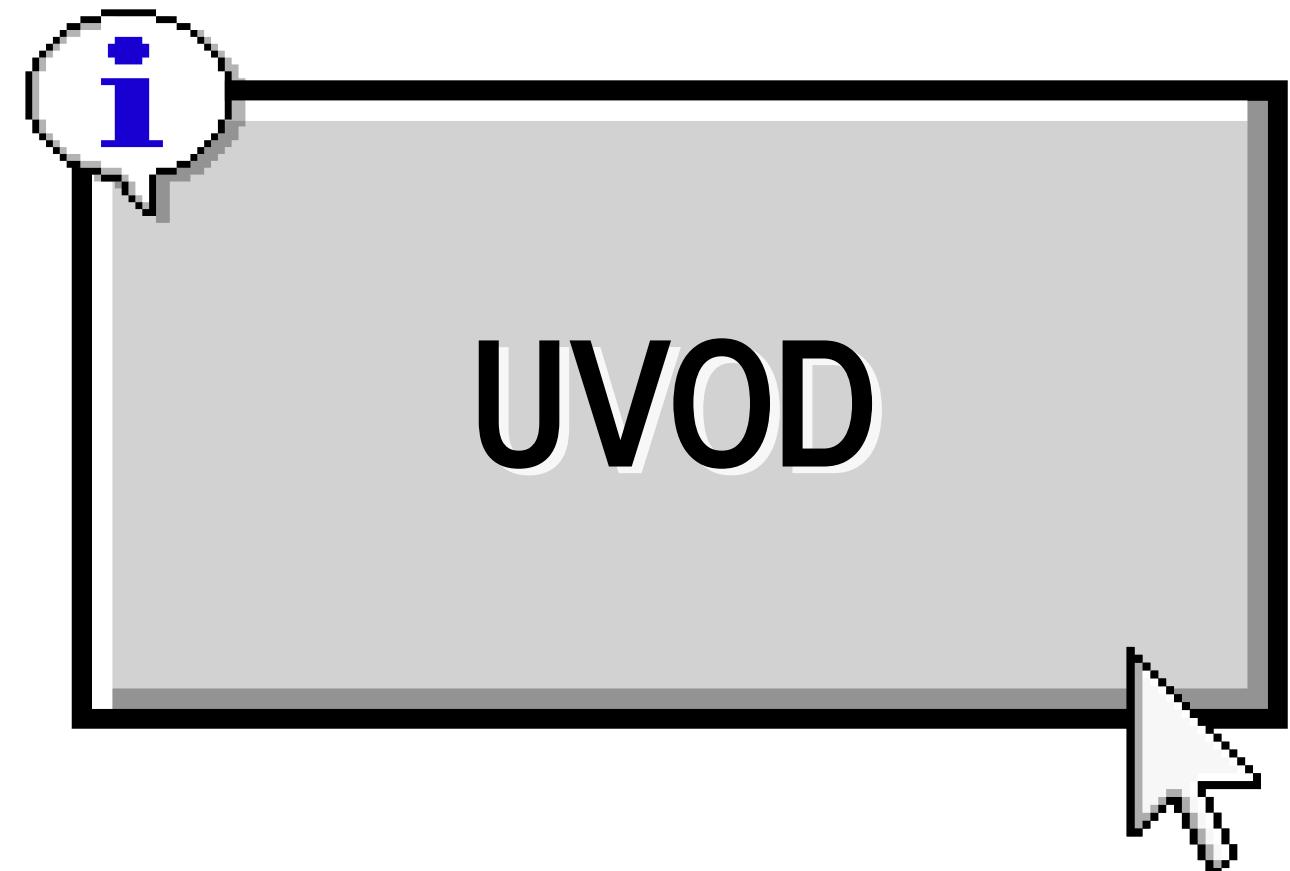
# ADAPTIVE SIMULATED ANNEALING

BOJANA STAMBOLIĆ & MAŠA MALIŠIĆ

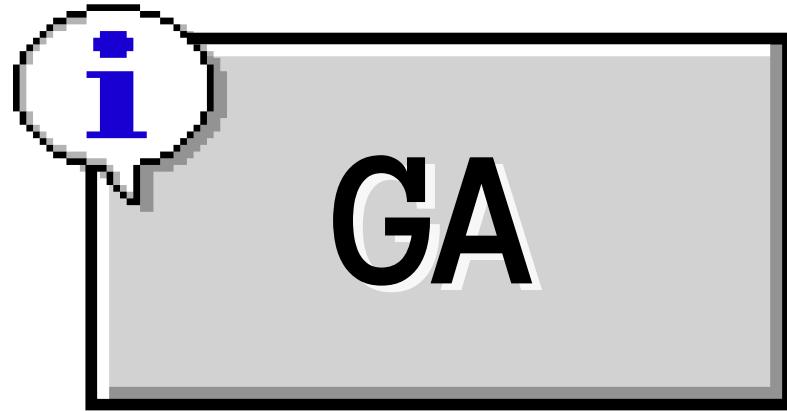


Start



[Home](#)[\*\*Content\*\*](#)[Contact](#)

Primena genetičkog algoritma (GA), algoritma simuliranog žarenja (SA) i adaptivnog algoritma simuliranog žarenja (ASA) na optimizaciji funkcija Rosenbrock, Rastrigin i Schwefel.



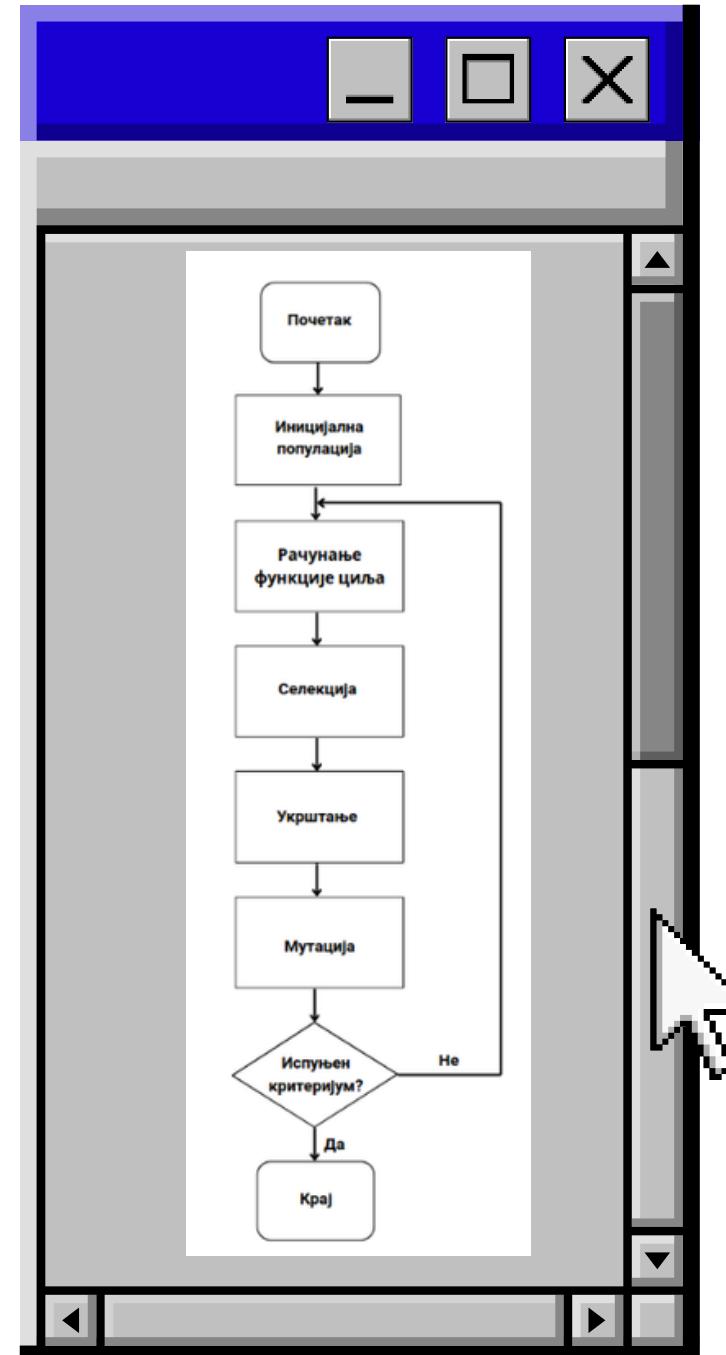
Najpoznatija i najstarija metoda za rešavanje optimizacionih problema

Inicijalizacija populacije - formiranje populacije slučajno generisanih jedinki

Funkcija cilja - prilagođena izabranoj šemi programiranja

Operatori genetičkih algoritama:

1. kodiranje - predstavljanje jedinke u obliku pogodnom za GA
2. selekcija - biranje pojedinaca iz populacije
3. ukrštanje - kombinovanje genetičkih materijala
4. mutacija - unošenje promena u genetički materijal





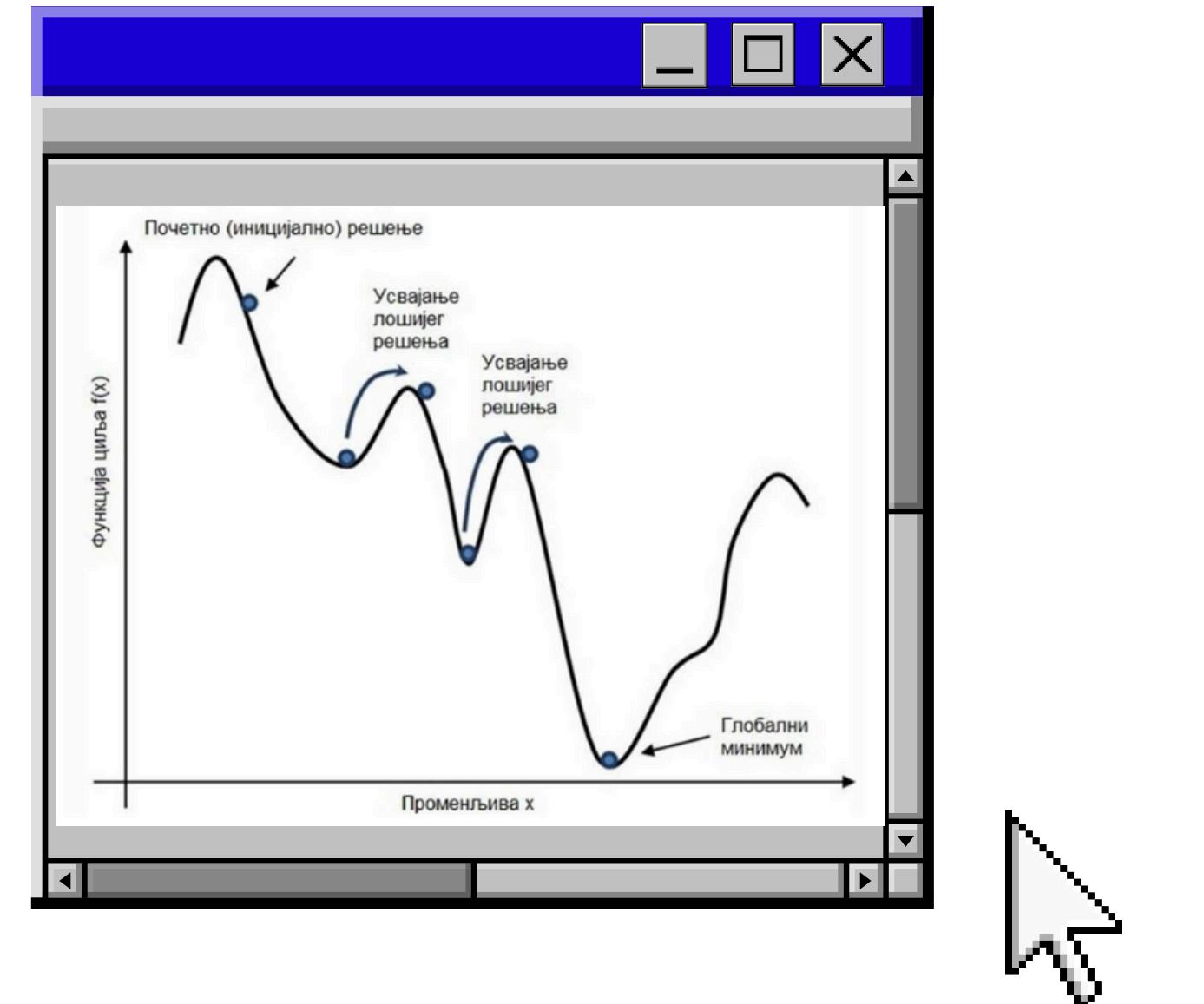
Stohastička metoda

Rešavanje diskretnih i kontinualnih problema

Stanje sistema odgovara jednom rešenju problema

Energija sistema odgovara vrednosti funkcije cilja

Temperatura predstavlja kontrolni parametar koji određuje verovatnoću prihvatanja lošijih rešenja



[Home](#)[Content](#)[Contact](#)

Izbor početnog rešenja i postavljanje temperature na visoku vrednost

Izbor novog rešenja iz okoline trenutnog

Razlika u energiji  $\Delta E = E_2 - E_1$

$\Delta E < 0$  novo rešenje se prihvata kao bolje  
 $\Delta E > 0$  lošije rešenje se može prihvatiti sa određenom verovatnoćom

Verovatnoća prihvatanja lošijeg rešenja  $P(\Delta E) = e^{-\frac{\Delta E}{kT}}$

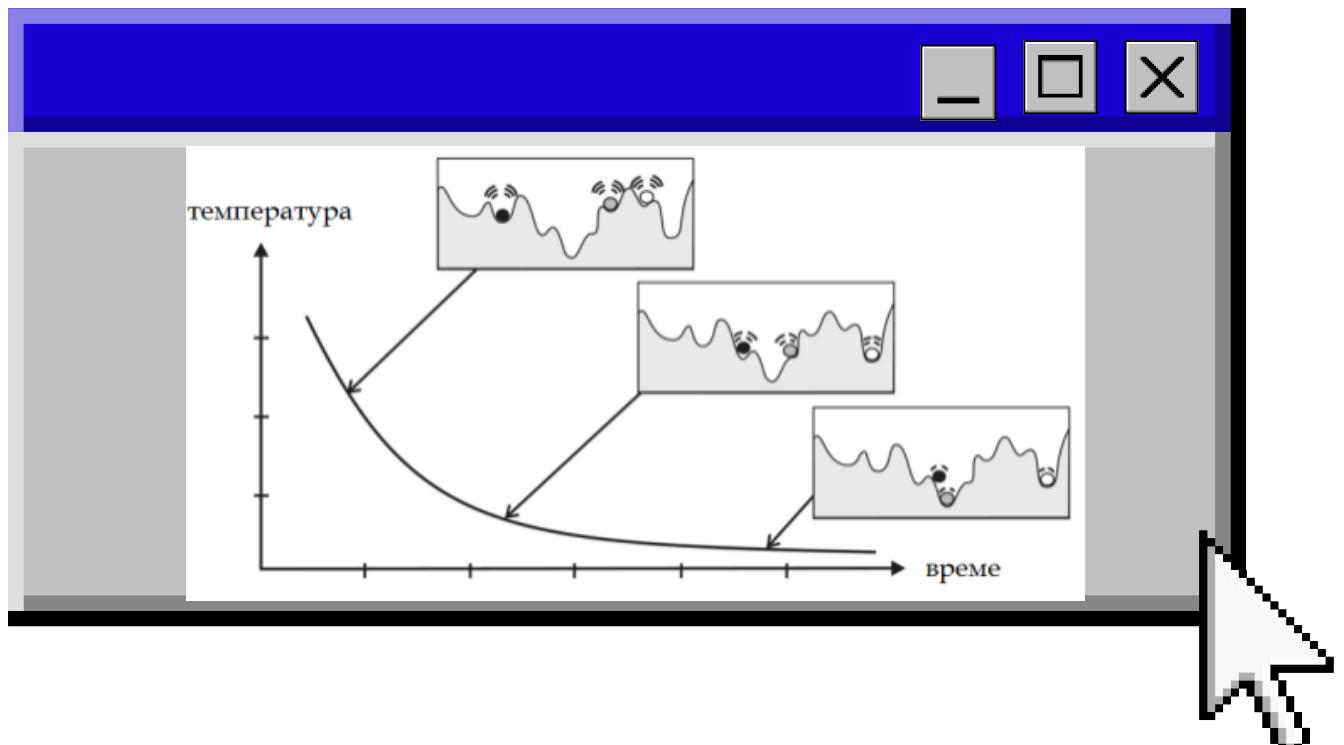
Na visokoj temperaturi prihvataju se i lošija rešenja gotovo sa sigurnošću

$$T \rightarrow \infty \quad \lim_{T \rightarrow \infty} e^{-\frac{\Delta E}{kT}} = 1$$

Na niskoj temperaturi prihvataju se samo bolja rešenja

$$T \rightarrow 0 \quad \lim_{T \rightarrow 0} e^{-\frac{\Delta E}{kT}} = 0$$

Temperatura opada eksponencijalno po pravilu  $T_{t+1} = T_c \cdot T_t$





Poboljšana verzija SA

ASA koristi dve temperature:

1. parametarsku  $T_0$  - kontroliše veličinu koraka po dimenziji

2. Temperatura prihvatanja  $T_{cost}$  - kontroliše verovatnoću prihvatanja lošijih rešenja

Uvodi adaptivne mehanizme:

- queching faktor - ubrzava hlađenje
- reanneling - ponovo zagrevanje

Temperurni raspored

$$T_i(k) = T_{0i} \cdot e^{-c_i \cdot k^{\frac{1}{D \cdot Q_i}}}$$



Prihvatanje rešenja

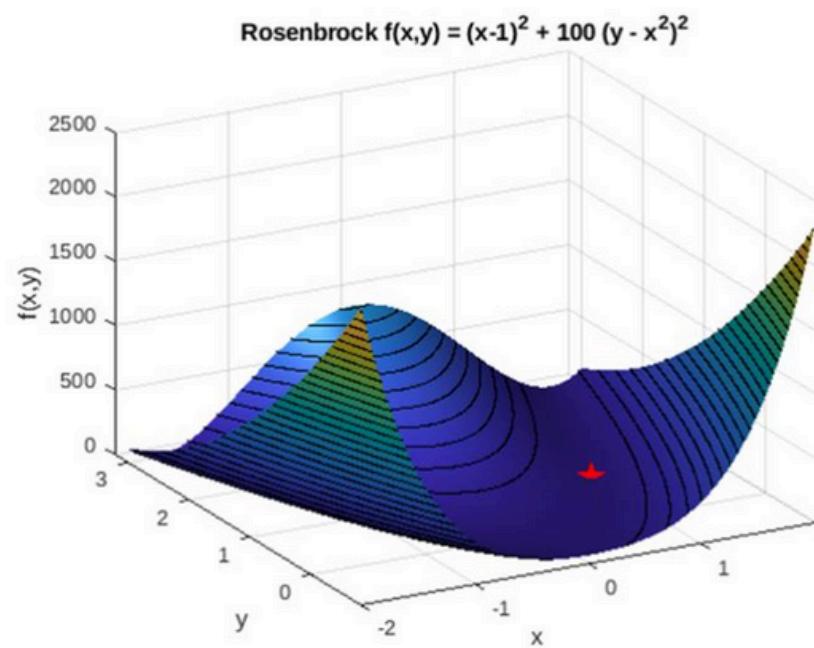
$$P_{accept} = f(x) = \begin{cases} 1, & \text{ako } \Delta f \leq 0 \\ \exp(-\frac{\Delta f}{T_{cost}}), & \text{ako } \Delta f > 0 \end{cases}$$

Temperatura prihvatanja se eksponencijalno smanjuje

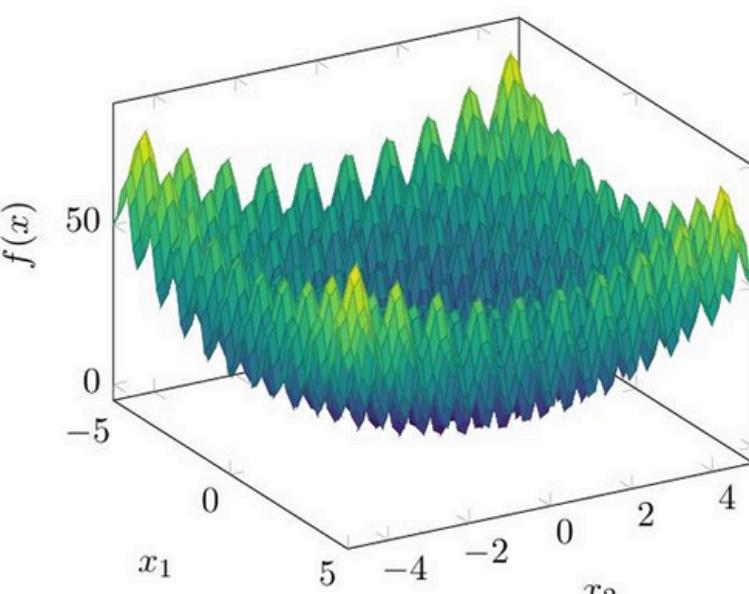
$$T_{cost}(a) = T_{0,cost} \cdot e^{-c_{cost}(a+1)^{\frac{1}{D \cdot Q_i}}}$$

[Home](#)[Content](#)[Contact](#)

Rosenbrock

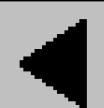
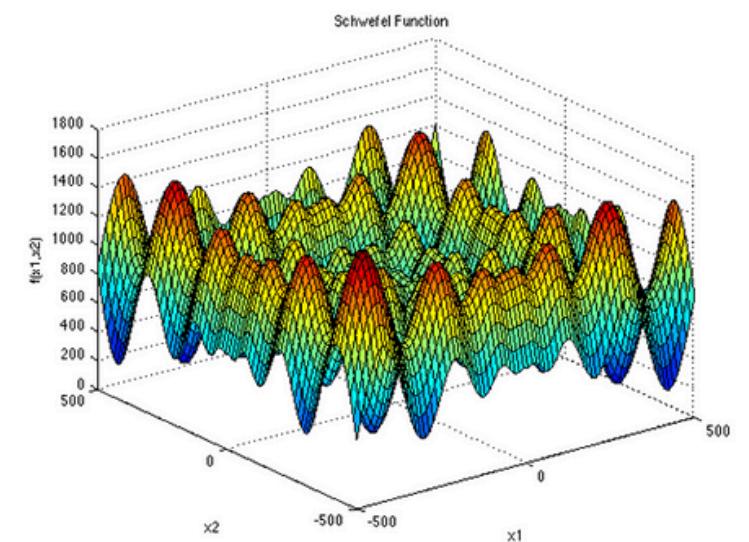


Rastrigin



Schwefel

$$f(x) = 418.9820d - \sum_{i=1}^d x_i \sin(\sqrt{|x_i|})$$



[Home](#)[Content](#)[Contact](#)

# REZULTATI – ROSENROCK

GA

Параметри	Максимум	#	Минимум	Средња вредно	Стандардна де
n=50,gens=100,cross=90%,mut=0.020,elite=5	0.37443269		0.002661126657	0.09188825642	0.1213685954
n=100,gens=100,cross=90%,mut=0.020,elite=5	0.2367898263		0.0002797792238	0.0282932096	0.07343428509
n=200,gens=100,cross=90%,mut=0.020,elite=5	0.07162645323		0.000241713614	0.01578560786	0.02160003273
n=400,gens=100,cross=90%,mut=0.020,elite=5	0.009017938503		0.0004355854874	0.004166521959	0.002836410935
n=800,gens=100,cross=90%,mut=0.020,elite=5	0.003980620992		0.0000577211614	0.0007956246249	0.001170938637
n=800,gens=50,cross=90%,mut=0.020,elite=5	0.007400880978		0.000101616893	0.002448171106	0.002679817576
n=800,gens=100,cross=90%,mut=0.020,elite=5	0.003818971893		0.000299162121	0.001251376035	0.00103947927
n=800,gens=200,cross=90%,mut=0.020,elite=5	0.001268996108		0.0000112916859	0.0005497034878	0.0003496405538
n=800,gens=400,cross=90%,mut=0.020,elite=5	0.001628708919		0.00002085027769	0.0004161309351	0.0005603795767
n=800,gens=800,cross=90%,mut=0.020,elite=5	0.0003567653931		0.000007708904134	0.0001786868593	0.0001362093423
n=800,gens=800,cross=50%,mut=0.020,elite=5	0.000503369167		0.00003087390121	0.0002110577471	0.0001608922205
n=800,gens=800,cross=70%,mut=0.020,elite=5	0.000422968079		0.000006439773618	0.00008123372933	0.0001233830413
n=800,gens=800,cross=80%,mut=0.020,elite=5	0.0007303551563		0.000001080000489	0.0001912171113	0.0002340946603
n=800,gens=800,cross=90%,mut=0.020,elite=5	0.0005838172006		0.00002585635431	0.0002031499686	0.0001660495803
n=800,gens=800,cross=100%,mut=0.020,elite=5	0.0004930203953		0.000002418617751	0.00009292381568	0.0001464928053



[Home](#)[Content](#)[Contact](#)

# REZULTATI – ROSENROCK

GA

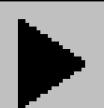
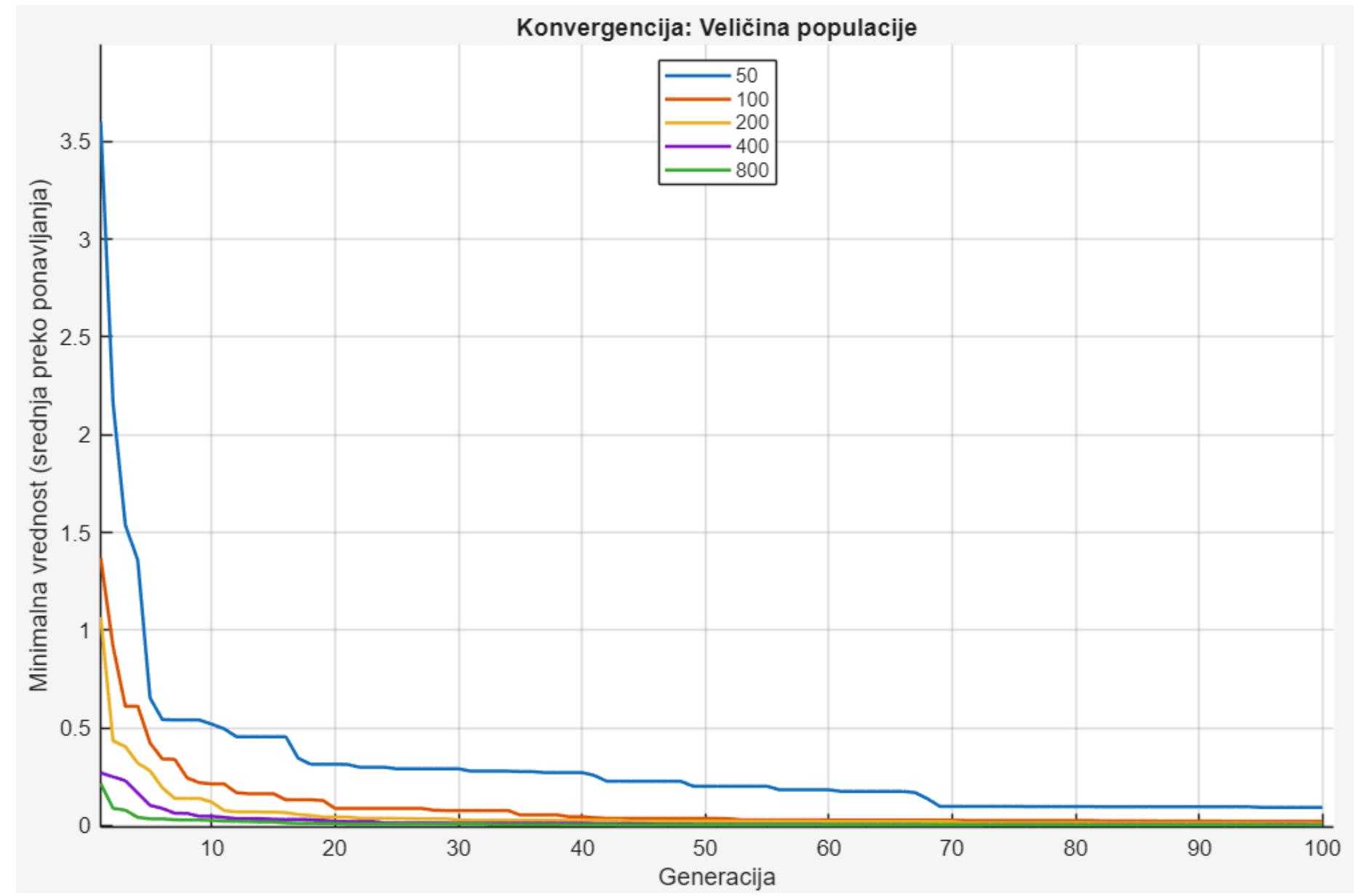
n=800,gens=800,cross=70%,mut=0.010,elite=5	0.001130663316	0.000002548161458	0.0003254476097	0.0004087278764
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n=800,gens=800,cross=70%,mut=0.050,elite=5	0.0006072421344	0.000009428011726	0.0001171061778	0.0001859661789
n=800,gens=800,cross=70%,mut=0.100,elite=5	0.000437801795	0.000002087093109	0.0001287335725	0.0001261951785
n=800,gens=800,cross=70%,mut=0.200,elite=5	0.0006099910949	0.000001993207451	0.0001656740269	0.0001936222252
n=800,gens=800,cross=70%,mut=0.050,elite=1	0.001376504982	0.00002478368209	0.0003877468573	0.0004726144427
n=800,gens=800,cross=70%,mut=0.050,elite=2	0.0004517305532	0.00001146593042	0.0001847147392	0.0001553745501
n=800,gens=800,cross=70%,mut=0.050,elite=5	0.001351406427	0.00002333170247	0.0003776401539	0.0004768137352
n=800,gens=800,cross=70%,mut=0.050,elite=10	0.0006619116608	0.0000005045909936	0.0001148195159	0.0002000738566
n=800,gens=800,cross=70%,mut=0.050,elite=20	0.0005269980418	0.000001039184475	0.0001779839246	0.0001717956442



[Home](#)[Content](#)[Contact](#)

## REZULTATI - ROSENROCK

GA



[Home](#)[Content](#)[Contact](#)

# REZULTATI – ROSENROCK

Параметри	#	Најбоља	#	Средња	Стандардна д
T0=50, Tmin=0.1, Tc=0.993		0.003842973311		0.05539497271	0.05815940796
T0=100, Tmin=0.1, Tc=0.993		0.002699018747		0.06352302616	0.0435995764
T0=200, Tmin=0.1, Tc=0.993		0.001677851131		0.08226520638	0.1118863668
T0=350, Tmin=0.1, Tc=0.993		0.001012861733		0.04740695293	0.05471983569
T0=700, Tmin=0.1, Tc=0.993		0.0009722769195		0.05532708785	0.1049452615
T0=350, Tmin=0.001, Tc=0.993		0.003079473263		0.02296972252	0.01569593764
T0=350, Tmin=0.01, Tc=0.993		0.0005574277122		0.04372286612	0.06054973158
T0=350, Tmin=0.05, Tc=0.993		0.0006963264645		0.05011568135	0.06045822599
T0=350, Tmin=0.1, Tc=0.993		0.001081368895		0.02043661497	0.02544469153
T0=350, Tmin=0.5, Tc=0.993		0.001840695861		0.06000750223	0.06325454272
T0=350, Tmin=0.1, Tc=0.9		0.1622135794		1.52562314	1.0618193
T0=350, Tmin=0.1, Tc=0.95		0.01785473055		1.006841463	1.751816113
T0=350, Tmin=0.1, Tc=0.98		0.02079540403		0.1112161502	0.1004885455
T0=350, Tmin=0.1, Tc=0.993		0.0002692983103		0.06407798417	0.0781728861
T0=350, Tmin=0.1, Tc=0.997		0.0005144875441		0.007624456206	0.009472591417

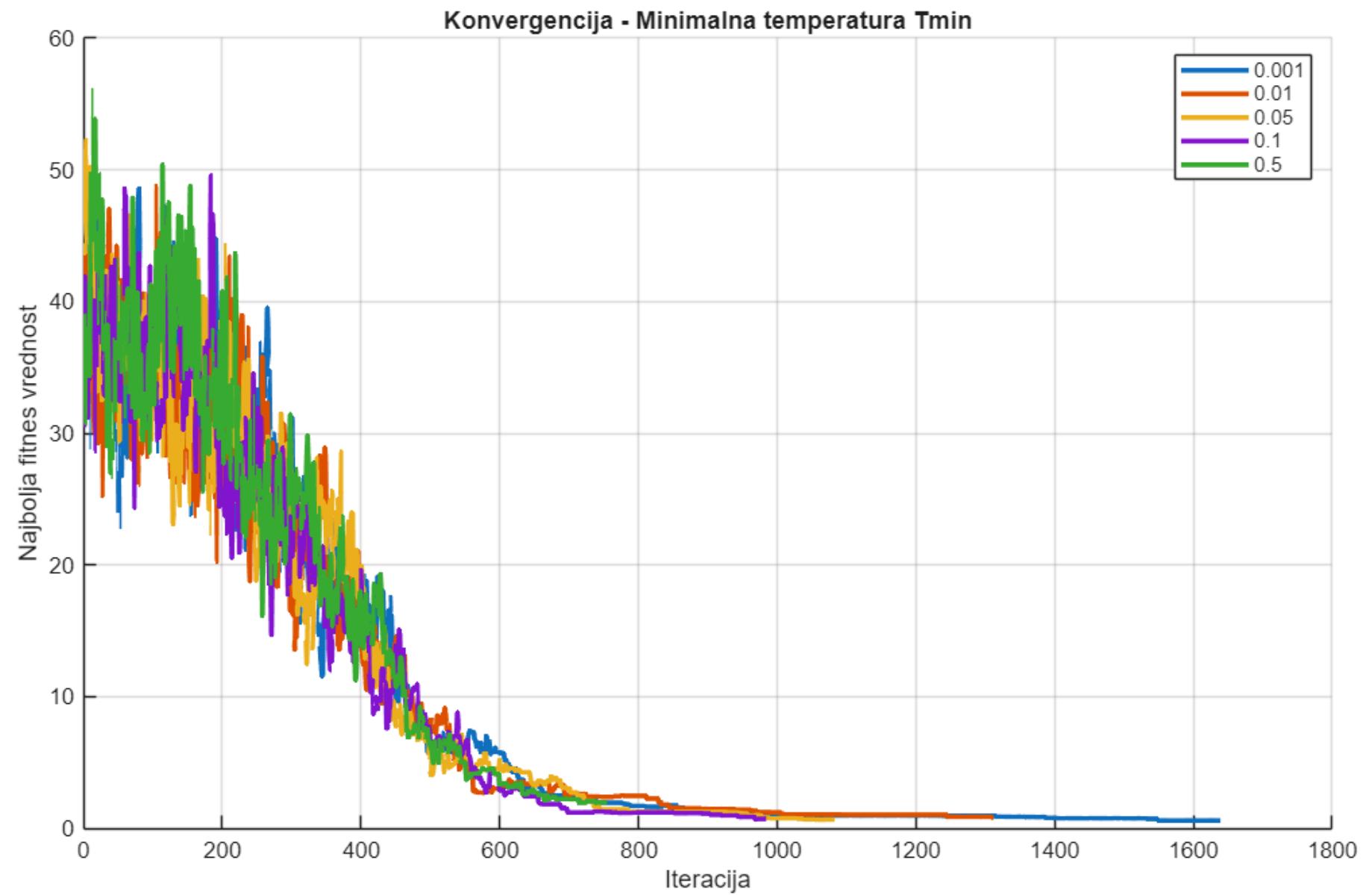
SA



[Home](#)[Content](#)[Contact](#)

## REZULTATI - ROSENROCK

SA

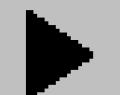


[Home](#)[Content](#)[Contact](#)

# REZULTATI – ROSENBROCK

ASA

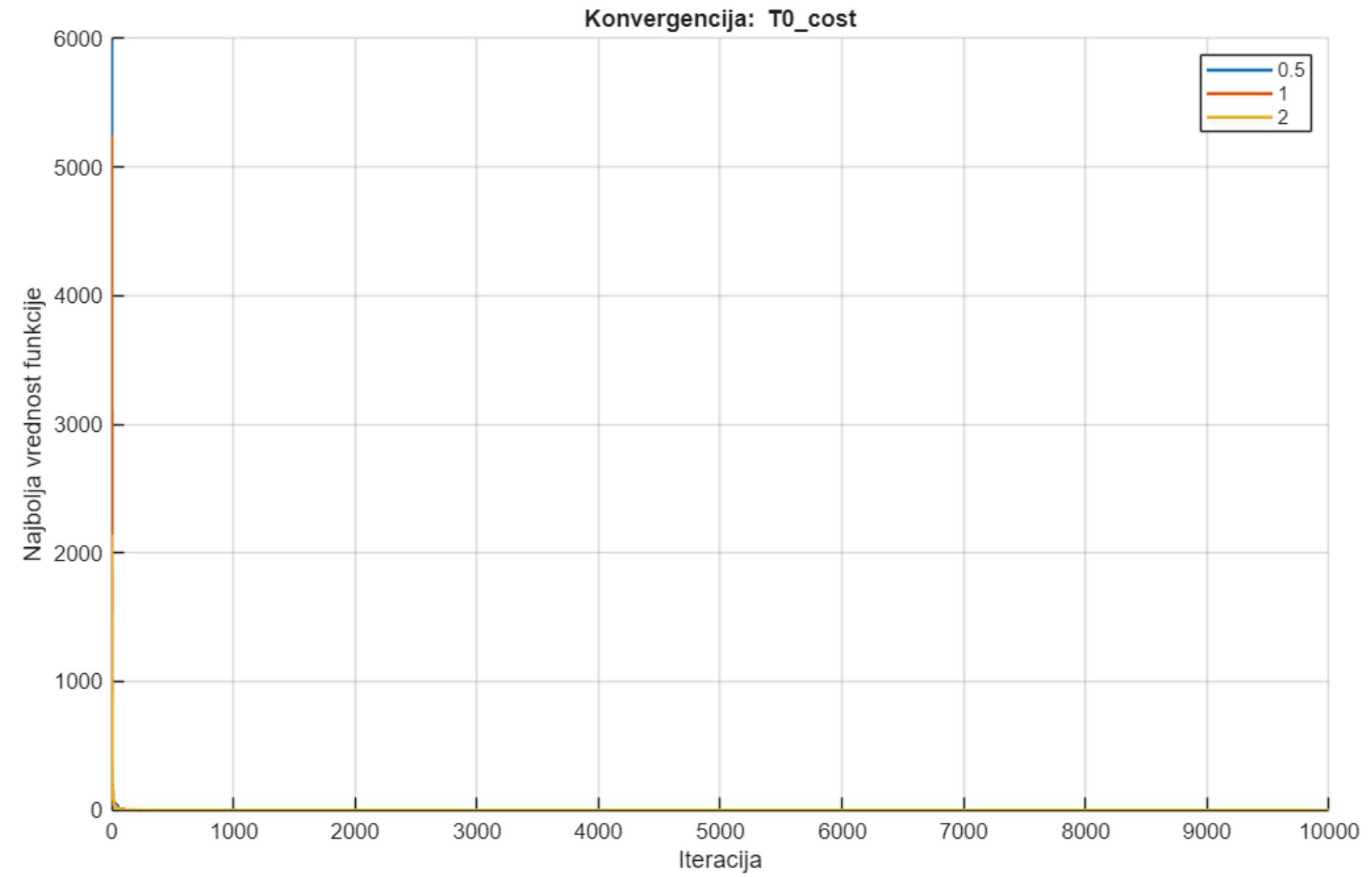
Параметри	Максимум	Минимум	Средња вре.	Стандардна
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	0.07112837553	0.002770648091	0.02199831723	0.02023877963
T0=1.00, c=1.00, T0_cost=1.00, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	0.1303874669	0.005307666008	0.03222667121	0.03651299792
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	0.2009703391	0.001356787406	0.03837226904	0.0605007145
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	0.09523674218	0.001285221177	0.03524343579	0.03332462144
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=2.00, reanneal=200, max_iter=10000	0.0799259442	0.000986898418	0.02680399772	0.02299795054
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=5.00, reanneal=200, max_iter=10000	0.1029326792	0.000379200922	0.03368926791	0.03442096311
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=2.00, reanneal=100, max_iter=10000	0.08788157185	0.0001066562031	0.03259355292	0.03047952239
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=2.00, reanneal=200, max_iter=10000	0.06830659043	0.0005606260345	0.02648103333	0.02420877147
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=2.00, reanneal=500, max_iter=10000	0.09667507756	0.00152731671	0.03594307526	0.02715597654
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=2.00, reanneal=200, max_iter=5000	0.1778859607	0.002951697142	0.06619471367	0.06871684518
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=2.00, reanneal=200, max_iter=10000	0.1240508084	0.004477541901	0.0523168863	0.04300223441
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=2.00, reanneal=200, max_iter=20000	0.03811940771	0.0004114841181	0.01546116364	0.01222547709

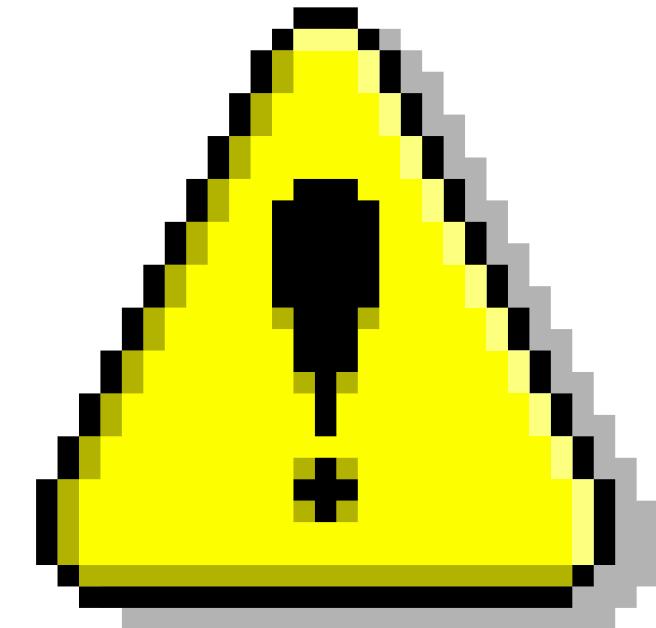


[Home](#)[Content](#)[Contact](#)

## REZULTATI - ROSENROCK

ASA





## POREĐENJE REZULTATA ALGORITAMA

Genetički algoritam (GA) se pokazao kao vrlo pouzdan u postizanju stabilnih rešenja: povećanjem broja generacija, veličine populacije i broja elitnih jedinki dobijane su niže vrednosti funkcije i manja standardna devijacija. Algoritam simuliranog žarenja (SA) takođe je dao zadovoljavajuće rezultate, pri čemu su najbolji ishodi postignuti pri umerenoj početnoj temperaturi ( $T_0 = 350$ ) i sporom hlađenju ( $T_c = 0.997$ ), što je omogućilo izbegavanje lokalnih minimuma i stabilnu konvergenciju. Adaptivni SA (ASA) dao je najbržu konvergenciju zahvaljujući adaptivnom podešavanju temperature i reannealing mehanizmu, čime je poboljšana preciznost u odnosu na klasični SA. Sveukupno, ASA je bio najprecizniji, SA najrobusniji, a GA najstabilniji u smislu konzistentnosti rezultata.



[Home](#)[Content](#)[Contact](#)

# REZULTATI – RASTRIGIN

GA

Параметри	Максимум	#	Минимум	Средња вреднос	Стандардна девијација
n=50,gens=100,cross=90%,mut=0.020,elite=5	0.3655424535		0.003459132416	0.1300581681	0.1278749064
n=100,gens=100,cross=90%,mut=0.020,elite=5	0.2903532592		0.0001197604758	0.0561023757	0.09131754366
n=200,gens=100,cross=90%,mut=0.020,elite=5	0.08067842186		0.000002936941755	0.02583190746	0.03142187386
n=400,gens=100,cross=90%,mut=0.020,elite=5	0.0095613453		0.0001997493907	0.002005238715	0.002755913677
n=800,gens=100,cross=90%,mut=0.020,elite=5	0.003423829327		0.00002346101832	0.001403830637	0.001177515536
n=800,gens=50,cross=90%,mut=0.020,elite=5	0.0371980171		0.0001570187872	0.007127279374	0.01124729046
n=800,gens=100,cross=90%,mut=0.020,elite=5	0.00370904059		0.0001935067482	0.001006608006	0.001096938519
n=800,gens=200,cross=90%,mut=0.020,elite=5	0.001374954958		0.000004281839068	0.0003331813473	0.0004370797752
n=800,gens=400,cross=90%,mut=0.020,elite=5	0.0002280087049		0.000004699609541	0.00007573121471	0.00007437224466
n=800,gens=800,cross=90%,mut=0.020,elite=5	0.00001116951929		0.000002296036001	0.000005455172183	0.000003303085881
n=800,gens=800,cross=50%,mut=0.020,elite=5	0.0001755928384		0.000001811041738	0.00006339972856	0.00006611859075
n=800,gens=800,cross=70%,mut=0.020,elite=5	0.00004906295084		0.000002220699201	0.00002542704246	0.00001807254296
n=800,gens=800,cross=80%,mut=0.020,elite=5	0.00001096970621		0.0000001920476791	0.000004461093407	0.000003535092594
n=800,gens=800,cross=90%,mut=0.020,elite=5	0.00002115003948		0.0000001832355494	0.000008653258395	0.000007890688698
n=800,gens=800,cross=100%,mut=0.020,elite=5	0.0002037842632		0.0000007872429997	0.00004762326978	0.00006590931667



[Home](#)[Content](#)[Contact](#)

## REZULTATI – RASTRIGIN

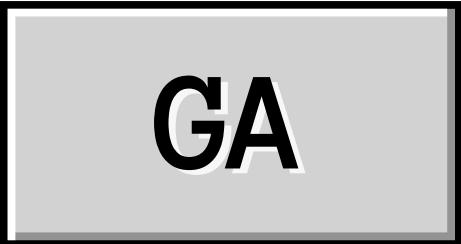
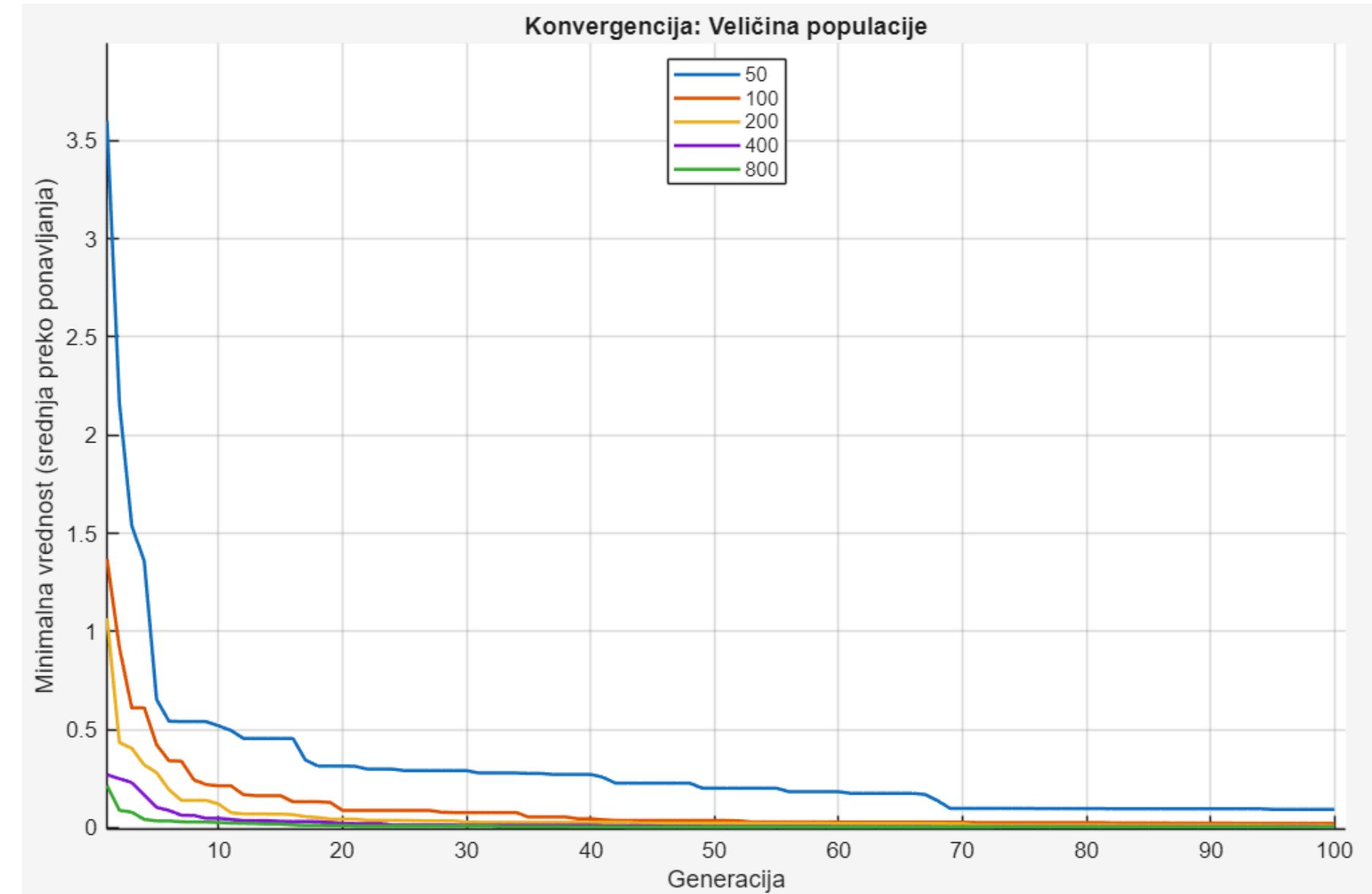
GA

n=800,gens=800,cross=80%,mut=0.010,elite=5	0.00006696608749	0.0000001192789121	0.00001281113015	0.00002092470561
n=800,gens=800,cross=80%,mut=0.030,elite=5	0.00001688708748	0.00000101667213	0.000006304718676	0.00000475592771
n=800,gens=800,cross=80%,mut=0.050,elite=5	0.00002356695462	0.0000001913002983	0.000007425392829	0.000007071260469
n=800,gens=800,cross=80%,mut=0.100,elite=5	0.0000358897361	0.0000001251417352	0.00001346095051	0.00001270772958
n=800,gens=800,cross=80%,mut=0.200,elite=5	0.00007170750899	0.000001340142866	0.00002025728801	0.00002509020072
n=800,gens=800,cross=80%,mut=0.030,elite=1	0.0001700826798	0.000003662647526	0.00003846431764	0.00005638740274
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n=800,gens=800,cross=80%,mut=0.030,elite=5	0.00003234445569	0.0000005586701306	0.00001438433148	0.00001108939275
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n=800,gens=800,cross=80%,mut=0.030,elite=20	0.00002205030294	0.0000001257262952	0.000004695114927	0.000006626744154



[Home](#)[Content](#)[Contact](#)

## REZULTATI - RASTRIGIN

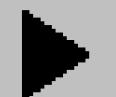
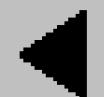


[Home](#)[Content](#)[Contact](#)

## РЕЗУЛТАТИ – RASTRIGIN

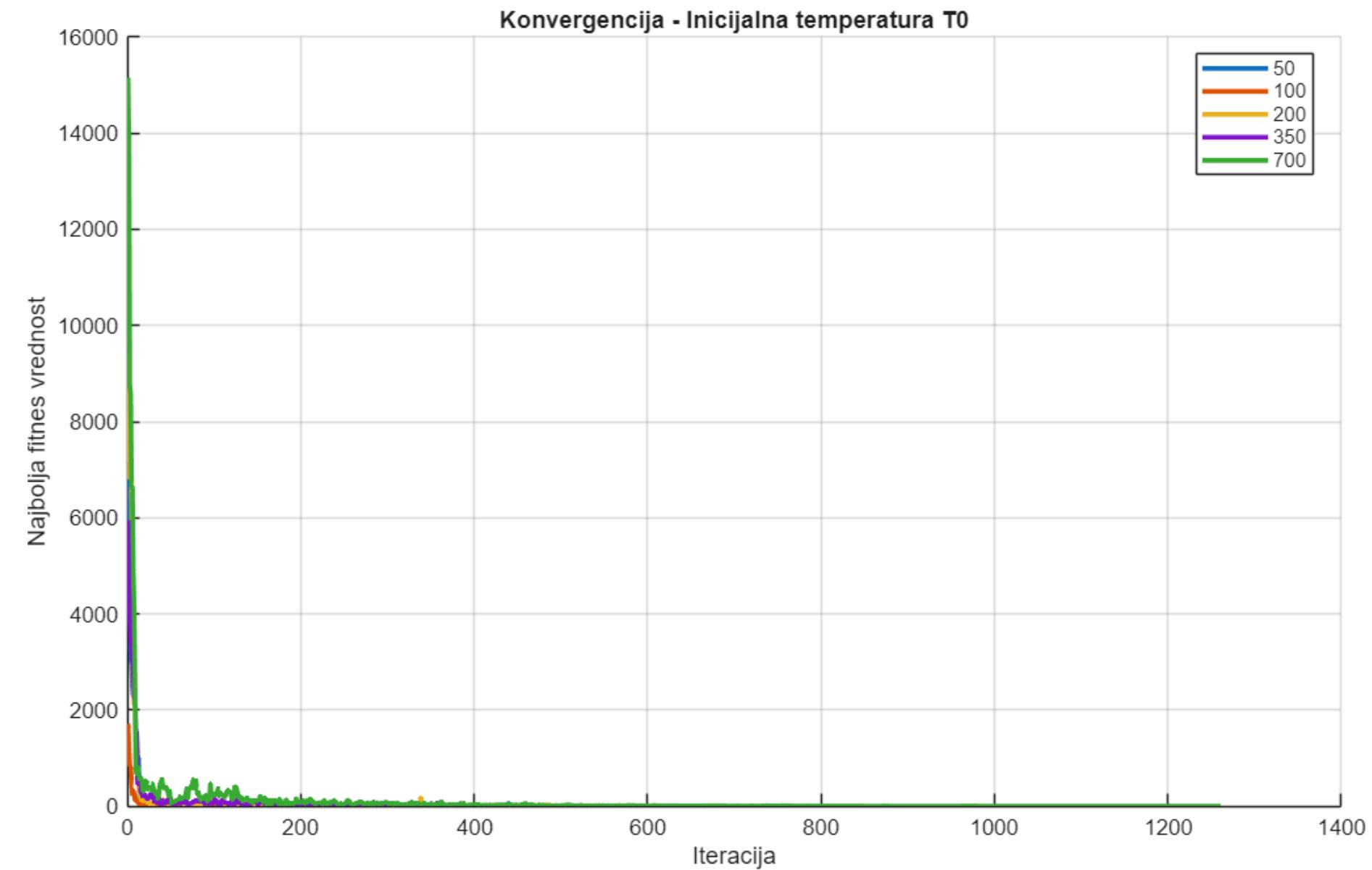
Параметри	Најбоља	Средња вред	Стандардн.
T0=50, Tmin=0.1, Tc=0.993	0.2179876631	0.5851196764	0.2649224158
T0=100, Tmin=0.1, Tc=0.993	0.02431538079	0.746045157	0.6029963939
T0=200, Tmin=0.1, Tc=0.993	0.2453500981	0.7916419424	0.414598179
T0=350, Tmin=0.1, Tc=0.993	0.3461008403	0.989730691	0.6256638584
T0=700, Tmin=0.1, Tc=0.993	0.05364669286	0.8321382454	0.5765440626
T0=50, Tmin=0.001, Tc=0.993	0.02228591145	0.553985433	0.4144871033
T0=50, Tmin=0.01, Tc=0.993	0.1064912466	0.5346874261	0.427683104
T0=50, Tmin=0.05, Tc=0.993	0.1170579924	0.6424153337	0.4119787309
T0=50, Tmin=0.1, Tc=0.993	0.08385854607	0.6421758342	0.6693446039
T0=50, Tmin=0.5, Tc=0.993	0.9139552865	1.290286547	0.342905637
T0=50, Tmin=0.01, Tc=0.9	0.06819948933	4.634909441	3.166738045
T0=50, Tmin=0.01, Tc=0.95	0.02142732836	2.034494551	1.530230946
T0=50, Tmin=0.01, Tc=0.98	0.1717988381	0.7939437131	0.5605863461
T0=50, Tmin=0.01, Tc=0.993	0.2720428972	0.8399483063	0.3262758556
T0=50, Tmin=0.01, Tc=0.997	0.07211928782	0.267177018	0.1267999328

SA



[Home](#)[Content](#)[Contact](#)

## REZULTATI - RASTRIGIN



SA



[Home](#)[Content](#)[Contact](#)

# REZULTATI – RASTRIGIN

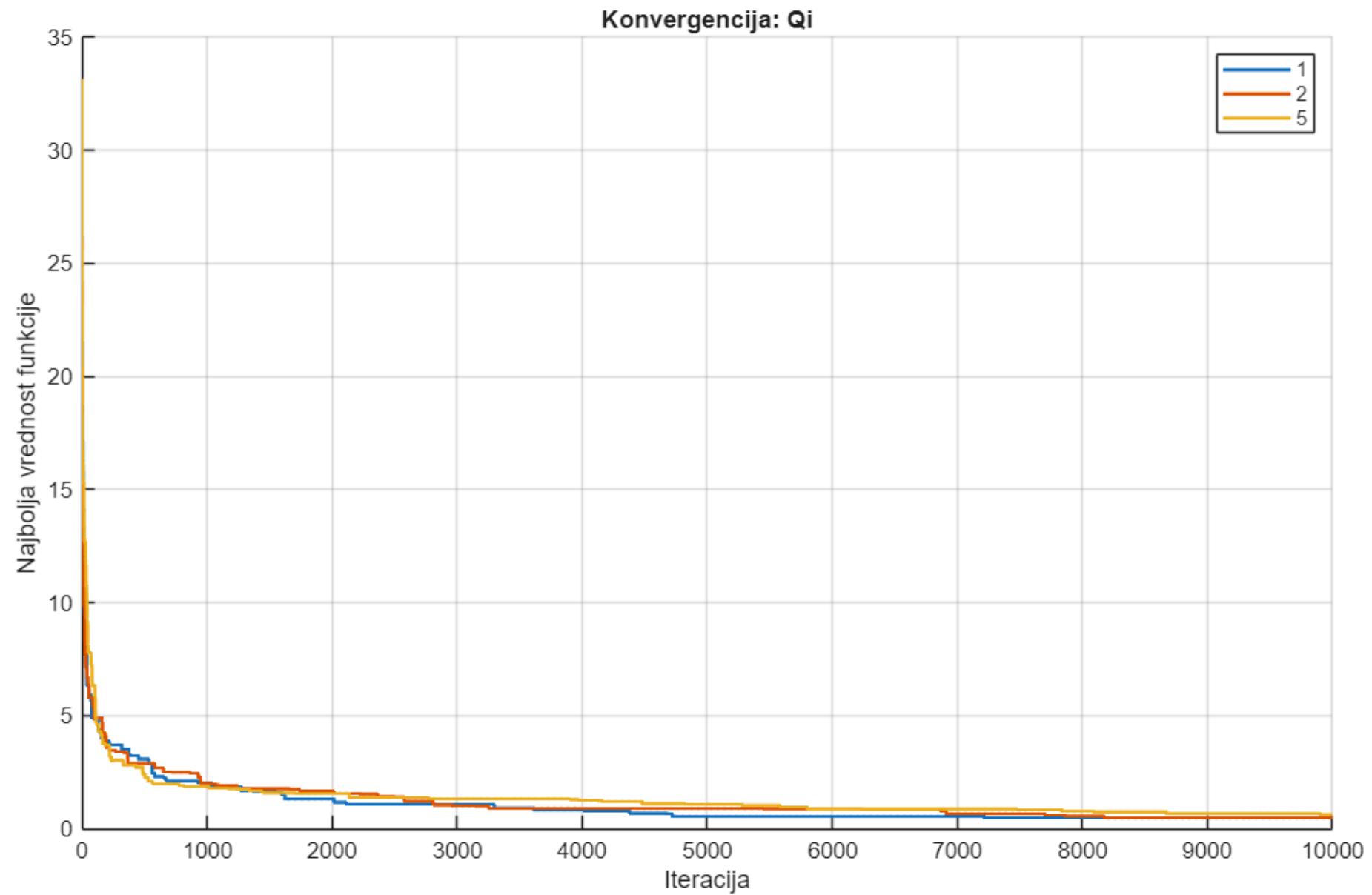
ASA

Параметар	Максимум	Минимум	Средња вр	Стандардн
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	1.131568652	0.106790455	0.5733202261	0.4105169412
T0=1.00, c=1.00, T0_cost=1.00, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	1.224772328	0.01840829158	0.6202484605	0.4041363967
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	1.623482792	0.2209669874	0.7467034831	0.5211932746
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	1.166181089	0.01502273046	0.405757462	0.4066834535
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=2.00, reanneal=200, max_iter=10000	1.316338865	0.05323489365	0.7560570226	0.4794707446
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=5.00, reanneal=200, max_iter=10000	1.123517658	0.0766141983	0.550402075	0.4029860822
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=100, max_iter=10000	1.546141603	0.009123322018	0.6224371588	0.5327508489
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	1.106537753	0.01228788696	0.4480301266	0.3415926757
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=500, max_iter=10000	0.9568926021	0.1574458065	0.3688169437	0.2653958696
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=500, max_iter=5000	1.473058385	0.4827329408	1.0642117	0.2959839208
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=500, max_iter=10000	1.110649858	0.01008760603	0.4719121012	0.410666047
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=500, max_iter=20000	0.8409849226	0.006183670078	0.2108649687	0.2468944804



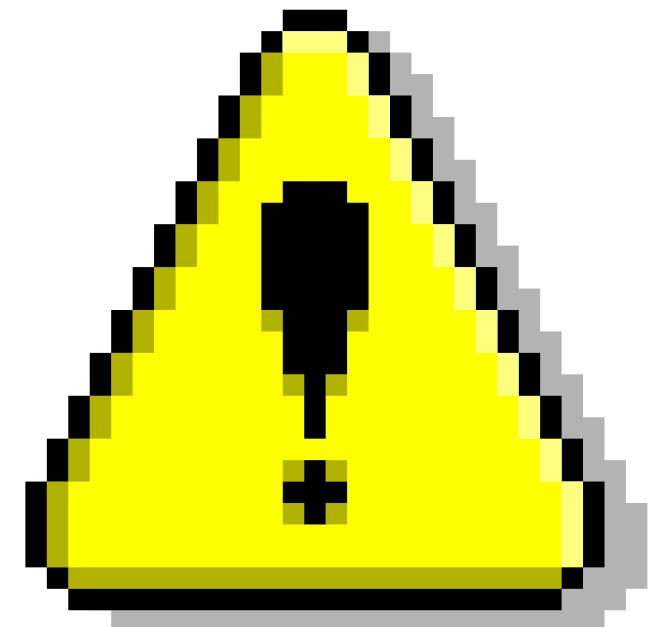
[Home](#)[Content](#)[Contact](#)

## REZULTATI – RASTRIGIN



ASA





GA je uspešno minimizovao funkciju, pokazujući najbolji balans između istraživanja i eksploracije prostora rešenja. Najbolji rezultati postignuti su sa crossover parametrom od 80%, mutacijom 0.01 i 10 elitnih jedinki. SA je pokazao dobre performanse kada su parametri bili pažljivo izabrani - najbolja kombinacija je  $T_0 = 100$ ,  $T_{min} = 0.001$  i  $T_c = 0.997$ , što je omogućilo najpreciznije i najstabilnije rezultate. ASA je, iako zadržao stabilnost, postigao nešto slabije rezultate u odnosu na Rosenbrock funkciju, pri čemu je uticaj parametra hlađenja bio osetljiviji. Generalno, GA je dao najbolji ukupan rezultat na Rastrigin funkciji, dok je SA bio efikasan pri pažljivo podešenim parametrima, a ASA je imao nešto veću oscilaciju vrednosti.

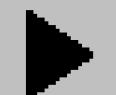


[Home](#)[Content](#)[Contact](#)

# РЕЗУЛТАТИ – SCHWEFEL

GA

Параметри	Максимум	#	Минимум	Средња вредно	Стандардна девија
n=50,gens=100,cross=90%,mut=0.020,elite=5	0.3529926791	0.00002599136997	0.06311161549	0.1204415214	
n=100,gens=100,cross=90%,mut=0.020,elite=5	0.1114498616	0.0000314731567	0.01156156437	0.03510097793	
n=200,gens=100,cross=90%,mut=0.020,elite=5	0.0006520729681	0.00002574988639	0.0002153648149	0.000239971911	
n=400,gens=100,cross=90%,mut=0.020,elite=5	0.0006655367257	0.00005715659893	0.000216134085	0.0002036978599	
n=800,gens=100,cross=90%,mut=0.020,elite=5	0.0003733544172	0.00002591361033	0.00007779027279	0.0001053749363	
n=800,gens=50,cross=90%,mut=0.020,elite=5	0.007919237011	0.00003608273528	0.00228328438	0.002839314599	
n=800,gens=100,cross=90%,mut=0.020,elite=5	0.0002083746705	0.00002570227491	0.00008064676568	0.00005797771613	
n=800,gens=200,cross=90%,mut=0.020,elite=5	0.0000474712424	0.00002631714585	0.00003438712359	0.000006984032553	
n=800,gens=400,cross=90%,mut=0.020,elite=5	0.00002683869729	0.00002546140365	0.00002584741123	0.00000045554955	
n=800,gens=800,cross=90%,mut=0.020,elite=5	0.0000264821366	0.00002547875897	0.000025807389	0.0000003649778177	
n=800,gens=800,cross=50%,mut=0.020,elite=5	0.0001119927624	0.00002815430366	0.00006688468143	0.00002798956456	
n=800,gens=800,cross=70%,mut=0.020,elite=5	0.00006146474186	0.00002566105718	0.00003359027427	0.0000120939457	
n=800,gens=800,cross=80%,mut=0.020,elite=5	0.00003150709745	0.00002546715439	0.00002630280247	0.000001856070042	
n=800,gens=800,cross=90%,mut=0.020,elite=5	0.00002707513522	0.00002549382486	0.00002589281415	0.0000005299225914	
n=800,gens=800,cross=100%,mut=0.020,elite=5	0.00002554910748	0.00002547034467	0.00002549891343	0.00000003101877056	



[Home](#)[Content](#)[Contact](#)

# REZULTATI – SCHWEFEL

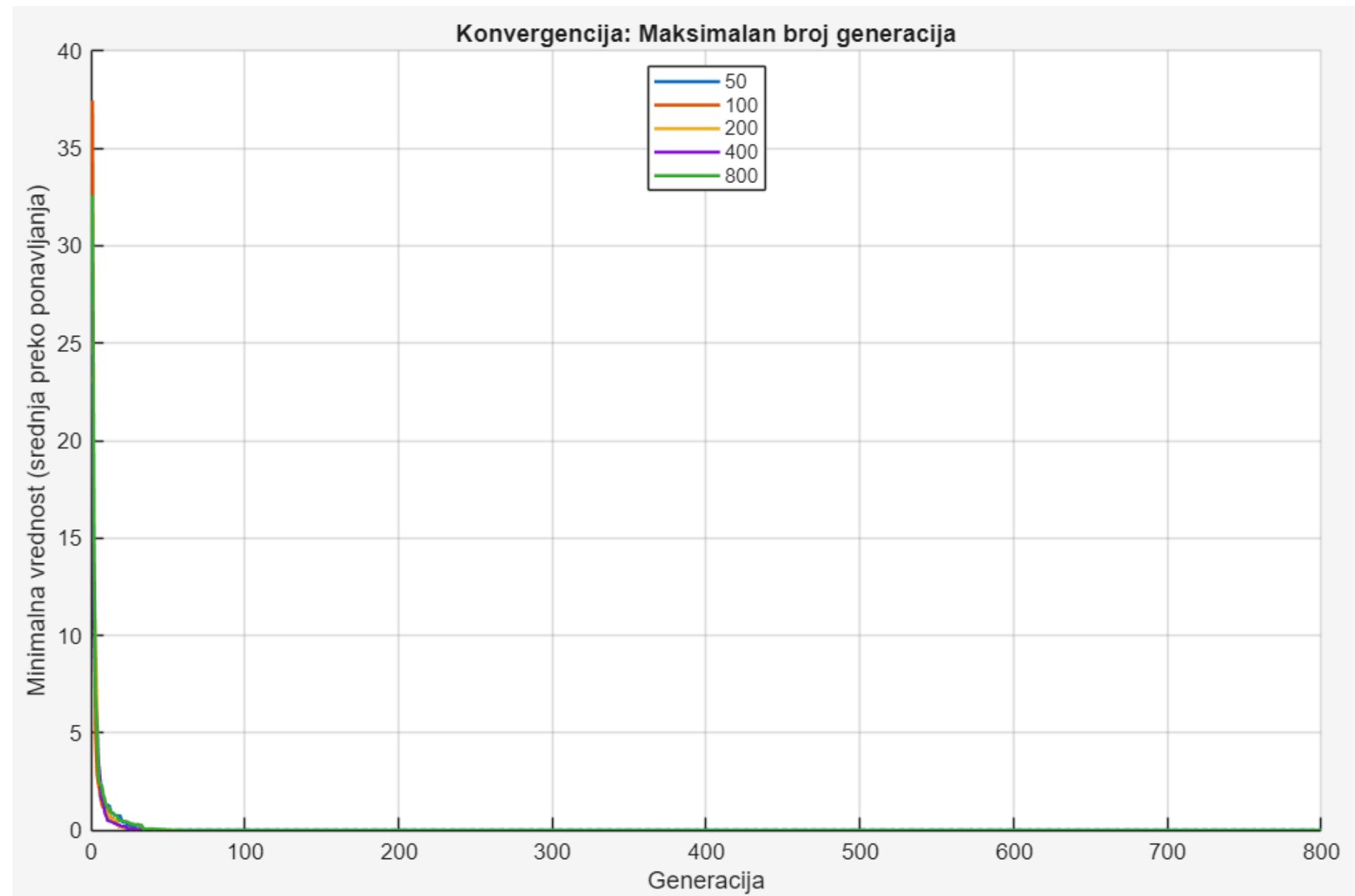
GA

n=800,gens=800,cross=100%,mut=0.010,elite=5	0.00002694027592	0.00002545838197	0.00002574838697	0.000000459604614
n=800,gens=800,cross=100%,mut=0.030,elite=5	0.00002598720653	0.00002545554935	0.00002557363356	0.0000001835767893
n=800,gens=800,cross=100%,mut=0.050,elite=5	0.00002559558231	0.00002545557618	0.00002548248284	0.00000004657746976
n=800,gens=800,cross=100%,mut=0.100,elite=5	0.00002561326778	0.00002545717473	0.0000254850194	0.00000004670970783
n=800,gens=800,cross=100%,mut=0.200,elite=5	0.00002556346806	0.00002545531856	0.00002548465377	0.00000004008400752
n=800,gens=800,cross=100%,mut=0.050,elite=1	0.00002731835366	0.00002546509279	0.00002592918855	0.0000005612969947
n=800,gens=800,cross=100%,mut=0.050,elite=2	0.00002575761846	0.00002545547977	0.00002549589835	0.00000009261898398
n=800,gens=800,cross=100%,mut=0.050,elite=5	0.00002562644397	0.00002545579946	0.00002549816929	0.00000005127359491
n=800,gens=800,cross=100%,mut=0.050,elite=10	0.00002546945097	0.00002545703296	0.00002546102182	0.00000000423145057
n=800,gens=800,cross=100%,mut=0.050,elite=20	0.00002549171018	0.00002545520158	0.00002546050804	0.00000001107220513



[Home](#)[Content](#)[Contact](#)

## REZULTATI – SCHWEFEL



GA

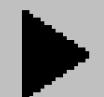
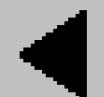


[Home](#)[Content](#)[Contact](#)

## РЕЗУЛТАТИ – SCHWEFEL

Параметри	#	Најбоља	Средња вред	Стандардн
T0=50, Tmin=0.1, Tc=0.993	0.000428142479	396.1900435	229.4192851	
T0=100, Tmin=0.1, Tc=0.993	118.4448076	390.1069901	162.2838195	
T0=200, Tmin=0.1, Tc=0.993	118.4384794	387.4762709	186.6672486	
T0=350, Tmin=0.1, Tc=0.993	118.4384467	303.6843313	157.1396137	
T0=700, Tmin=0.1, Tc=0.993	0.001405644905	349.4281077	223.3623591	
T0=350, Tmin=0.001, Tc=0.993	0.0003876010934	354.8177943	184.4456149	
T0=350, Tmin=0.01, Tc=0.993	217.1397732	539.5928068	152.6485119	
T0=350, Tmin=0.05, Tc=0.993	0.001239777992	319.804457	208.2636945	
T0=350, Tmin=0.1, Tc=0.993	118.4387109	417.3210147	178.6583016	
T0=350, Tmin=0.5, Tc=0.993	0.002741368202	404.7110179	182.6797454	
T0=350, Tmin=0.05, Tc=0.9	335.5288518	550.4583785	185.0052257	
T0=350, Tmin=0.05, Tc=0.95	57.19478579	576.8674782	295.3097969	
T0=350, Tmin=0.05, Tc=0.98	0.006451163603	428.036687	235.0689241	
T0=350, Tmin=0.05, Tc=0.993	236.8770529	485.3066555	116.8655514	
T0=350, Tmin=0.05, Tc=0.997	118.4385133	395.9626581	146.968014	

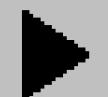
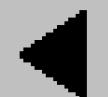
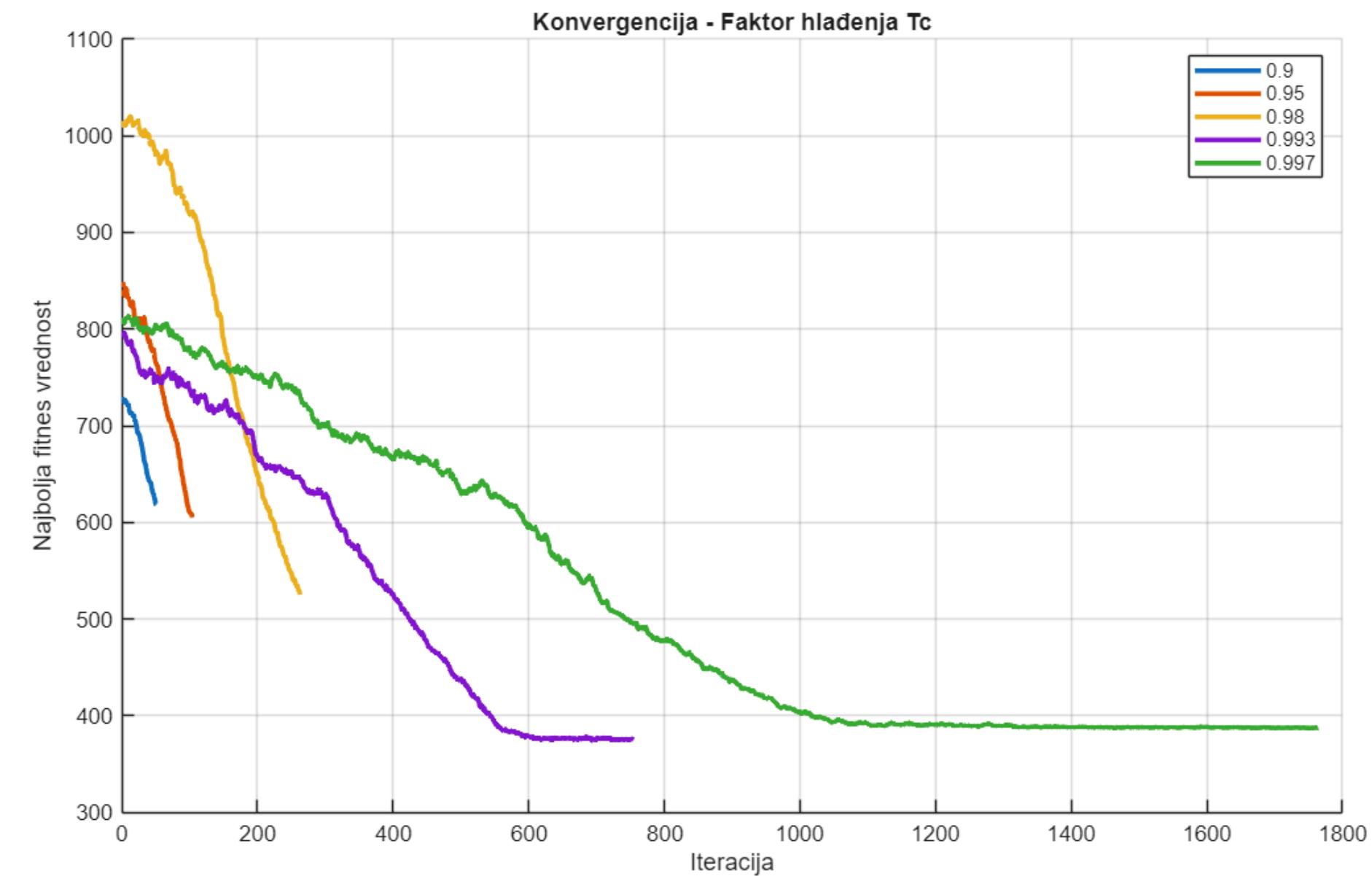
SA



[Home](#)[Content](#)[Contact](#)

## REZULTATI - SCHWEFEL

SA



## РЕЗУЛТАТИ – SCHWEFEL

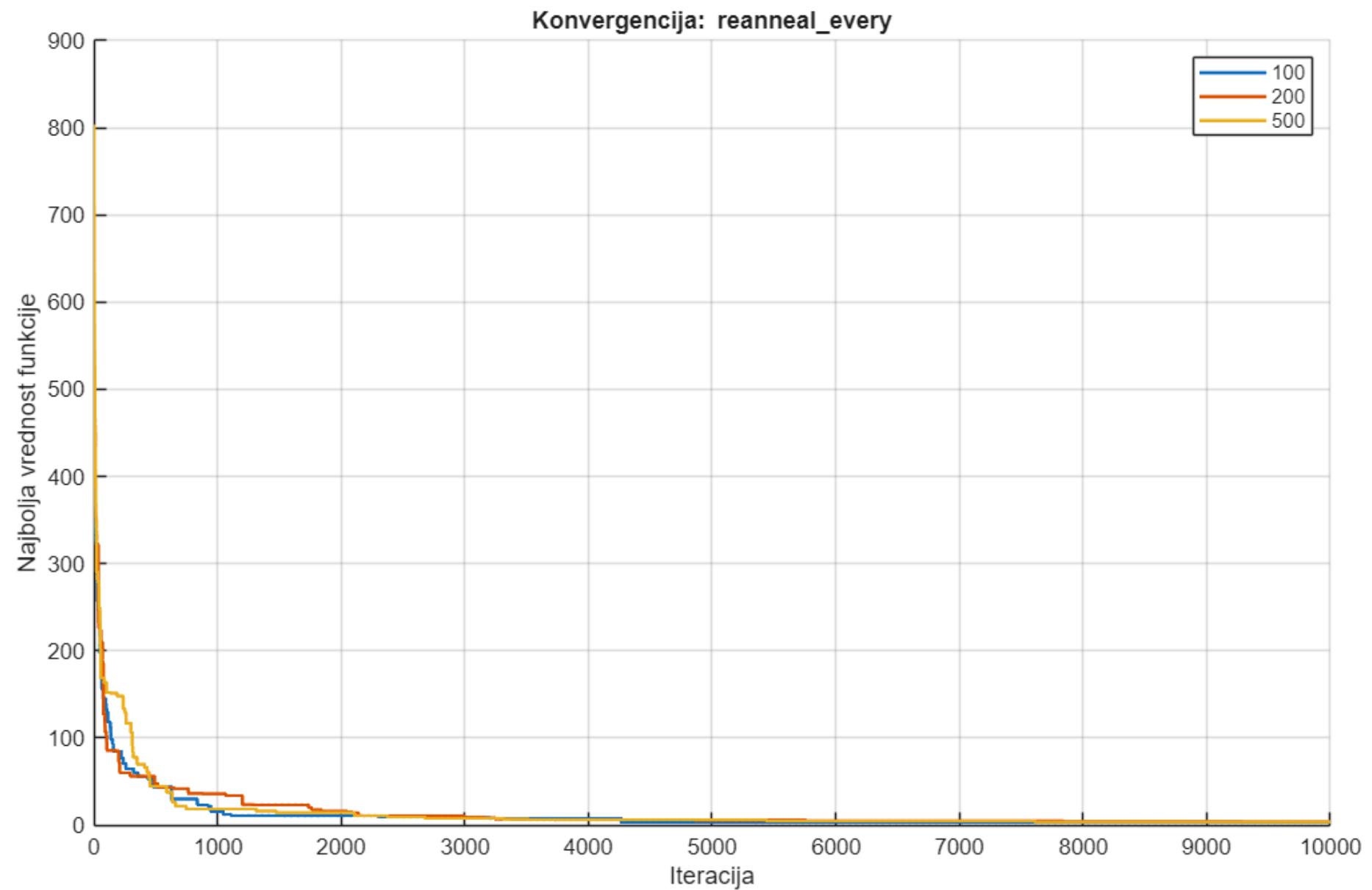
ASA

Параметри	Максимум	Минимум	Средња вр	Стандардн
T0=1.00, c=1.00, T0_cost=0.50, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	26.06570032	0.8728858921	4.937937191	7.634386006
T0=1.00, c=1.00, T0_cost=1.00, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	11.27400318	0.09341519449	5.692903785	4.058205216
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	6.441283472	0.1736753785	3.333750058	2.778571907
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=1.00, reanneal=200, max_iter=10000	25.7163318	0.04576619751	6.515525359	8.87418833
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=2.00, reanneal=200, max_iter=10000	12.57810186	1.057353579	4.569052379	3.363235837
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=5.00, reanneal=200, max_iter=10000	10.58658957	0.9600032501	3.319973336	2.99798561
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=5.00, reanneal=100, max_iter=10000	19.52167	0.4639543885	5.427031956	6.09955775
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=5.00, reanneal=200, max_iter=10000	12.57617516	0.7286880771	4.03443197	3.879929054
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=5.00, reanneal=500, max_iter=10000	14.04593827	0.01749903948	4.568227239	5.134619468
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=5.00, reanneal=200, max_iter=5000	23.1995993	0.3706479285	5.608443289	6.67355865
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=5.00, reanneal=200, max_iter=10000	15.42293858	0.1040787644	4.524798247	4.812179912
T0=1.00, c=1.00, T0_cost=2.00, c_cost=1.00, Qi=5.00, reanneal=200, max_iter=20000	9.459824044	0.1115649863	3.147776906	2.621669069

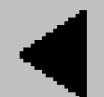


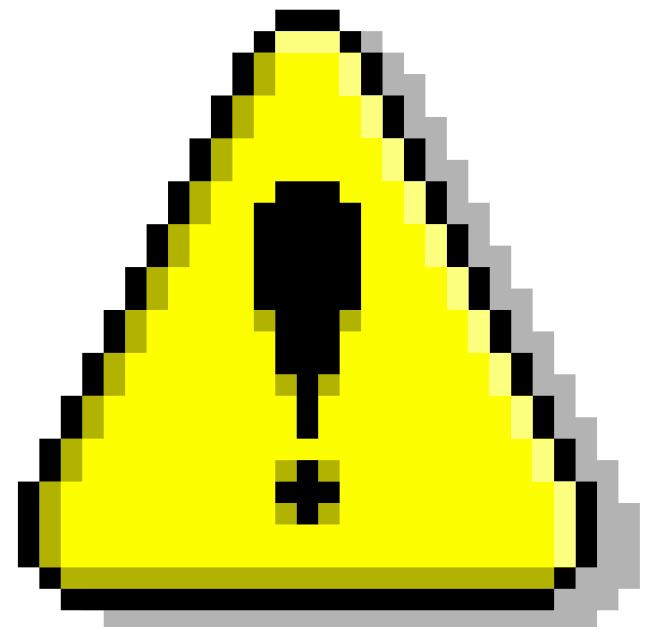
[Home](#)[Content](#)[Contact](#)

## REZULTATI - SCHWEFEL



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## POREĐENJE REZULTATA ALGORITAMA

Genetički algoritam je i u ovom slučaju bio stabilan, sa poboljšanjem rezultata pri većim populacijama i brojevima generacija. SA je postigao najbolji balans između preciznosti i stabilnosti pri umerenim vrednostima parametara ( $T_0 \approx 200$ ,  $T_{min} \approx 0.001-0.05$ ,  $T_c \approx 0.98-0.993$ ), što mu je omogućilo precizniju lokalnu pretragu bez prerano zaustavljanja. ASA, međutim, nije postigao tako stabilnu konvergenciju kao kod prethodne dve funkcije – rezultati su imali visoku standardnu devijaciju i oscilacije, što ukazuje na veću osetljivost algoritma na parametre. Ukupno gledano, SA je bio najuspešniji za Schwefel funkciju, GA stabilan ali manje precizan, dok je ASA pokazao manju pouzdanost.



Home

Content

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Maša Mališić

