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DNIPRO UNIVERSITY of TECHNOLOGY 1899

Efficiency improvement of the algorithm based on an artificial immune system modeling applied to continuous and combinatorial problems

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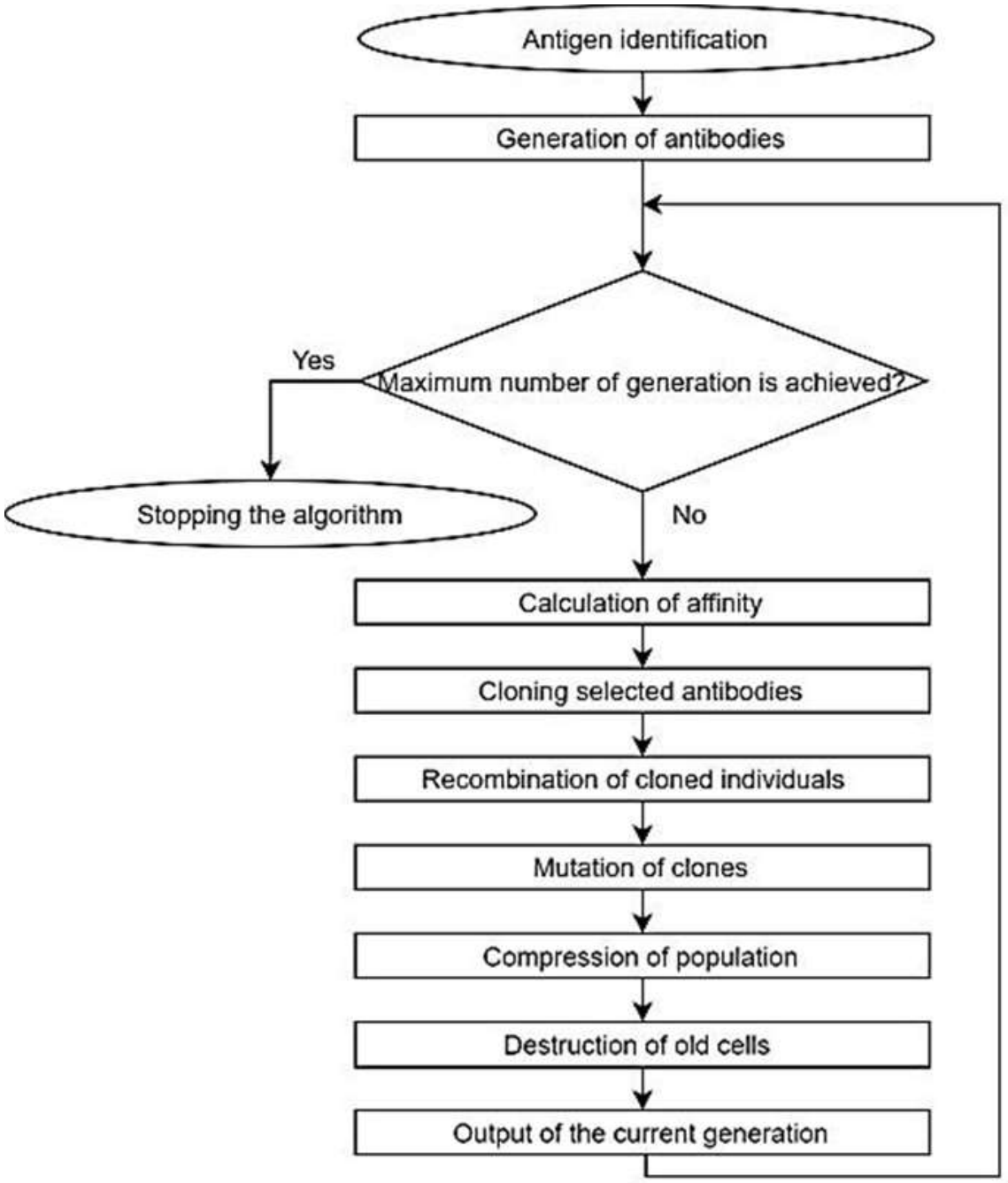
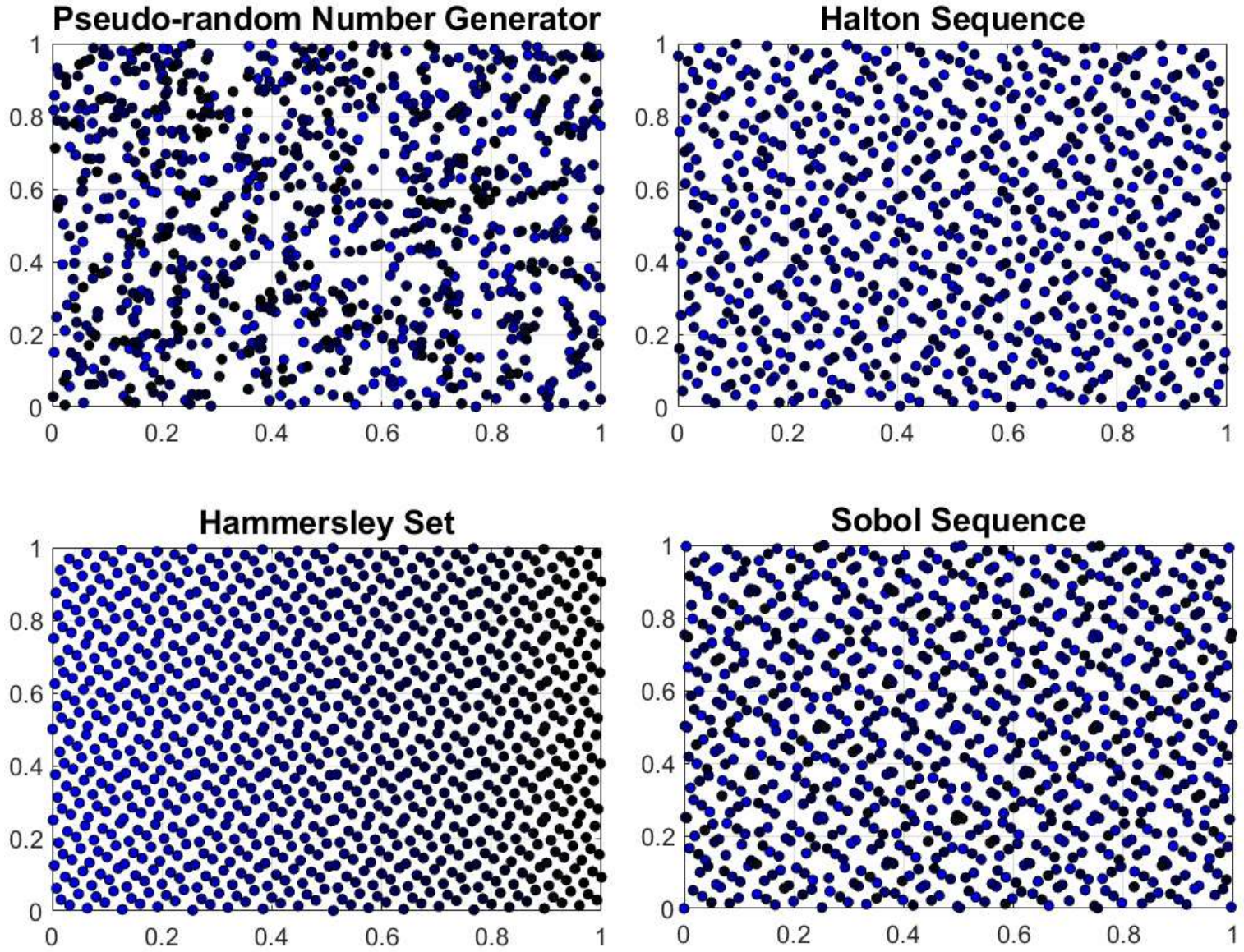
Algorithm of modelling artificial immune systems



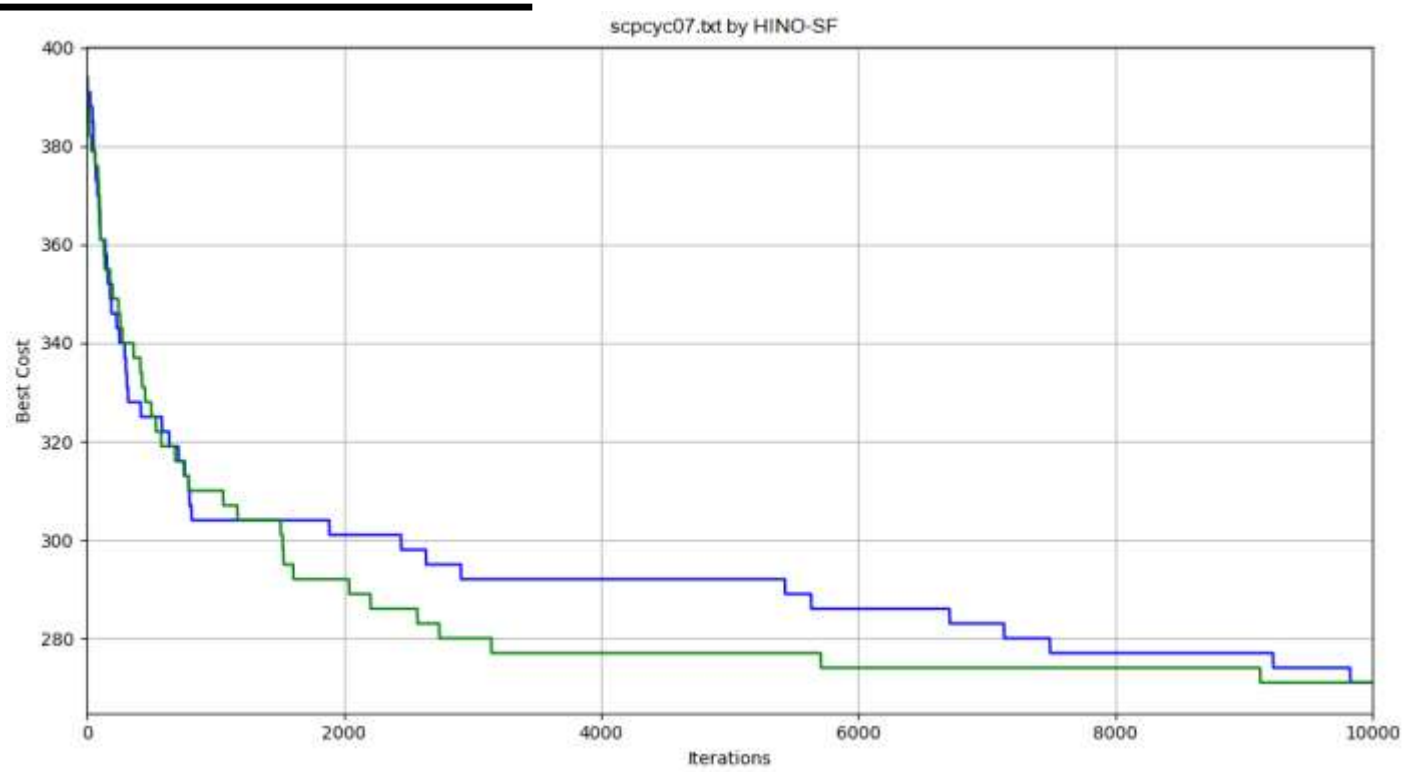
Uniformity of new search agents generation



Uniformity of new search agents generation 2

Time to fist finding of global optimum, iterations

Generator		Dimension of space			
		10	25	65	100
pseudo-random	Mersenne vortex (default)	136	1702	10274	64987
	Combined recursive	118	1476	11320	103951
	Multiplicative Fibonacci	86	1099	9920	68357
quasi-random	Halton sequence	111	1375	9811	61159
	Hammersley set	103	1258	8917	51478
	Sobol sequence	84	1005	8497	66123



Parental individuals selection

Selection operator based on Saaty's pairwise comparisons

The rating of each of candidate j is $a_j = 1 + \lfloor \varphi(X_j) \cdot k \rfloor$, where k - the dimension of the scale (default $k = 9$).
Traditionally for the matrix of pairwise comparisons: $b_{1i} = a_1 / a_i$ (first line), and $b_{ij} = b_{1j} / b_{1i}$ (rest lines).

A modified selector: $b_{ji} = \begin{cases} |a_i - a_j| + 1, & if\ j \geq i \\ \frac{1}{b_{ji}}, & if\ j < i \end{cases}$

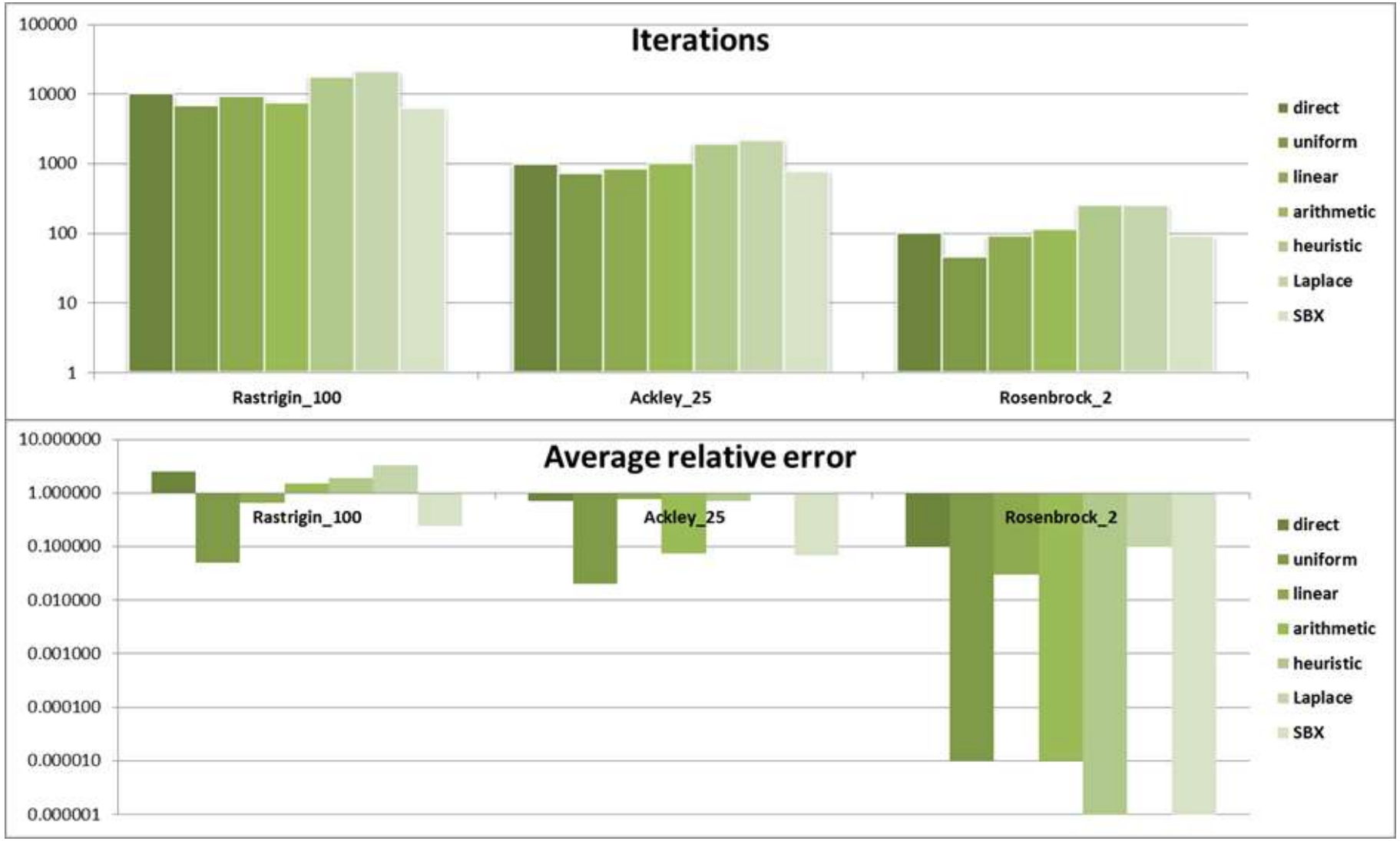
Membership functions of candidates: $\mu(\varphi(X_i)) = \sqrt[n]{\prod_{j=1}^{n} b_{ji}}$.

The speed of the AIS algorithm depending on the selection operator

Problem	↓ Dimensionality Selector →	Iterations				Fitness Function Calls			
		Rank	Tournament	Saaty	Modif.Saaty	Rank	Tournament	Saaty	Modif.Saaty
Knapsack	1000	126	105	256	97	14015	11505	29711	10095
MinTree	100	536	455	450	143	59935	52869	53159	14865
SetCovP	672	829	746	758	807	87544	81991	82634	83505
Rastrigin	100	8426	7913	9510	6374	101206	88725	108462	78124
Ackley	25	889	849	1024	765	45873	44562	51268	36630
Rosenbrock	2	104	80	105	91	2518	1998	2478	2235

Crossover choice for combinatorial problems

Crossover choice for the continuous problems



Mutation width and type

The choice of mutation range performance (wide or narrow) is based on the usefulness assessment of the current cell on the utility assessments scale on the current iteration throughout the population

$$mutSelect_j = \left(1 - \gamma \frac{t}{T_{max}}\right) \frac{\varphi_{max} - \varphi_j}{\varphi_{max} - \varphi_{min}}, \qquad j = [1 : N_c],$$

where j – clone number in the population of clones; N_c – clone population size; t – current iteration number; T_{max} – provided maximum number of iterations; φ_{max} – the worst value of the objective function in the generation; φ_{min} – the best value of the objective function in the generation; φ_j – the value of the objective function for the current clone; γ – the maximum allowable proportion of wide mutations.

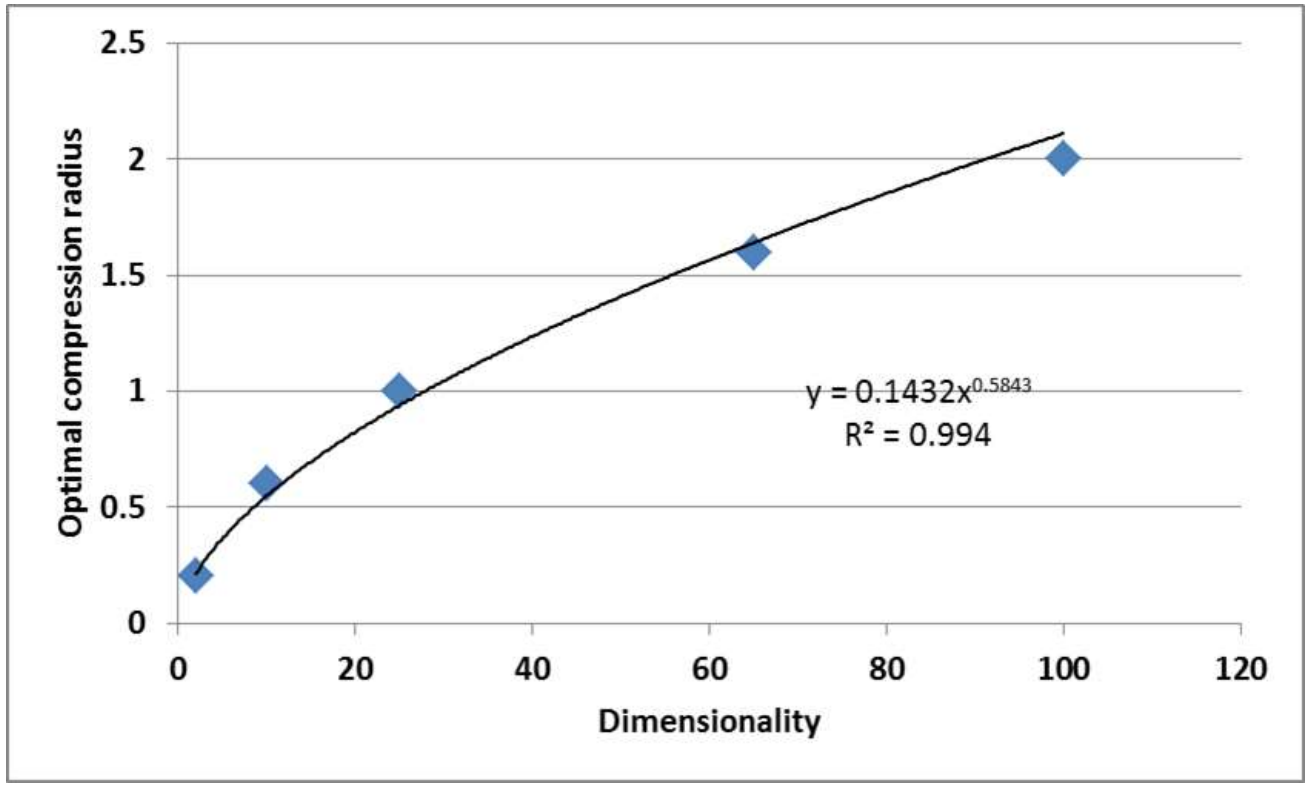
If a random $U(0;1) \leq mutSelect_j$, a narrow mutation is performed for clone j (search in the solution neighborhood). Otherwise - a broad mutation is performed - the transition to a new search area.

When solving combinatorial problems, a point mutation of a certain number of genes is performed as a narrow mutation. The number of inverted genes is determined with the formula

$$mutLevel(t) = \begin{cases} MLevel_{min}\left(1 + P^0_{mut} - \dfrac{2t \cdot P^0_{mut}}{T_{max}}\right), & if\ t < T_{max}/2 \\ MLevel_{min}, & if\ t \geq T_{max}/2 \end{cases},$$

For continuous space, it is proposed to use a combination of a broad Gaussian mutation and a narrow polynomial distribution mutation.

Population compression



The desired dependence can be assumed to have the form

$$R(N_{dim}) = a_0 \sqrt[2]{N_{dim}},$$

where N_{dim} – problem dimension in continuous space; a_0 – a constant term, depending on the problem type and must be obeyed empirically, for example

$$a_0 = 1/N_{pop}$$

Discussion

• Applying of quasi-random generators instead of pseudo-random ones for first and new individuals generation during the algorithm reduces the global optimum searching time by 12-20%.

• Adopting of the modified selection operator, based on the Saaty`s paired comparison method, allows to improve the solution finding dynamics by 1.5-3 times, comparing with the previous realization and to achieve greater reliability than in case of the rank or tournament selection operators using.

• The global optimum finding becomes more reliable applying the crossover operator. The two-point crossover is the best for combinatorial problem, uniform crossover – for continuous problems relatively.

• The proposed adaptive mutation operator adjusts the narrow and wide mutations ratio, depending on the clone fitness and the iteration number. As soon as the space dimensionality increases, the proportion of wide mutations should be increased.

• The existing one-dimensional local search operator is considered to be ineffective and should be replaced. Applying one of the quasi-Newtonian methods instead of the zero-order methods might be promising.

• The population compression operator should be adaptive, considering the mutation radius at the current iteration, population size and space dimension.

Conclusions

1. For the first time, an attempt of finding a universal approach to solving both combinatorial and continuous problems applying the proposed algorithm was implemented, using a common approach to the algorithm operators
2. The proposed settings of the algorithm operators allow to reduce the optimization time by 2-4 times without losing accuracy for some solving problemsthe adaptation mechanism formation of the mutation operator
3. The practical value of the work is to make possible the developed algorithm applying for solving the planning and control problems in metallurgical production to optimize technological processes

The direction of further research

1. The best local search operator selection
2. The adaptation mechanism formation of the mutation operator
3. The formation of an adaptive population compression operator

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