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Supplementary materials for

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A The pseudocode of three types of epigenetic operators: position effect operator (PEO), gene imprinting operator (GIO), and paramutation operator (PMO)

A1 Position effect

The position effect operator (PEO) is an order-sensitive epigenetic operator (OSEO) established by the gene position effect. The gene position effect consists of gene expression changes in relation to shifts in gene location, often caused by translocation. The gene position effect greatly increases the randomness of variation by randomly changing the gene sequence, especially in solving combinatorial optimization problems. To realize PEO, first, the solution vector and nucleosome vector of the affected individual were extracted. The solution vector was split at Section 0 or Section 1 of the nucleosome vector according to the rule described in Algorithm S1.

Algorithm S1 Position effect

Input:
An epigenetic individual, I;
Environmental influence possibility, P_e;
Output:
The epigenetic operator modified individual, I;
$nucleosome$ ←ExtractNucleosome(I);
$gene$ ←ExtractGene(I);
if random()$<P_e$ **then**
  split $gene$ into $pieces$ according to $nucleosome$;//mark the borders of the “0”s and “1”s of the nucleosome on the DNA chain, then split the DNA chain at these marked sites.
  i_1, i_2 ← randomInteger();//generate two random numbers i_1, i_2 within the range of pieces.
  $temp$ ← $pieces[i_1]$;//change the order of pieces.
  $pieces[i_1]$ ← $pieces[i_2]$;
  $pieces[i_2]$ ← $temp$;
  I ←put $pieces$ together;
else
  Do nothing.
end if
return I;

A2 Gene imprinting

The gene imprinting operator (GIO) is a position-sensitive epigenetic operator (PSEO) that refers to an epigenetic modification marker with a gene bookmark on the parental DNA strand. When this marker is detected, the gene is expressed in the parent-specific source, regardless of where it originally came from. An epigenetic marker is generated as an individual is created. If the location of the gene is critical, to avoid failure to converge, we choose to periodically clean up these epigenetic marks and regenerate them to replace the original gene sequence.

Algorithm S2 Gene imprinting

Input:
An epigenetic individual, I;
Environmental influence possibility, P_e;
Output:
The epigenetic operator modified individual, I;

```
gene ←ExtractGene(I);
motherGene, fatherGene ←ExtractParentalGene(I);
for i ∈ [0, length] do
    if detect gene modification on site i then
        if father gene is forced to express then
            gene[i] ← fatherGene[i];
        end if
        if mother gene is forced to express then
            gene[i] ← motherGene[i];
        end if
    end if
end for
I ← gene;
return I;
```

A3 Paramutation

The paramutation operator (PMO) refers to the transformation of the source of the expressed gene. This operator uses the genetic information of the parents recorded in $\boldsymbol{H}^{n\times 2}$. In particular, the PMO has a lower priority than the GIO.

Algorithm S3 Paramutation

Input:
An epigenetic individual, I;
Environmental influence possibility, P_e;
Output:
The epigenetic operator modified individual, I;

```
gene ←ExtractGene(I);
motherGene, fatherGene ←ExtractParentalGene(I);
for i ∈ [0, length] do
    //if the father's gene and mother's gene are different here, then could make an exchange.
    if random() < P_e and motherGene[i] != fatherGene[i] then
        if gene[i] = motherGene[i] then
            gene[i] ← fatherGene[i];
        else
            gene[i] ← motherGene[i];
        end if
    end if
end for
I ← gene;
return I;
```

B The ablation experimental results of the probabilistic environmental gradient (PEG) and variable nucleosome reorganization (VNR) strategies

The population size (N) was set to be 500, n was set to be $15\times D$, the possibility of nucleosome generation (P_n) was set to 0.4, the nucleosome radius (R) was set to 25, and the probability of environmental influence was set to 0.15. The accuracy and stability of the results are listed in Tables S4 and S5. If the PEGA exhibits a significant improvement (>1%) in accuracy or stability, the result is marked (−); if it is weakened, the result is marked (+); if there is no obvious effect, the result is marked (≈).

Table. S1 PEG strategy vs. VNR strategy vs. PEG+VNR strategy on accuracy

Func	Base line	PEG		VNR		PEG+VNR	
		Acc.	Gain	Acc.	Gain	Acc.	Gain
F1	1.5937E+10	5.1429E+09	(-)67.73%	1.0378E+10	(-)34.88%	9.8126E+06	(-)99.94%
F2	3.9366E+05	4.0636E+05	(+)3.22%	3.7716E+05	(-)4.19%	3.4426E+05	(-)12.55%
F3	1.7756E+03	3.1474E+02	(-)82.27%	3.0295E+02	(-)82.94%	2.6018E+02	(-)85.35%
F4	5.9701E+02	1.0378E+03	(+)73.83%	1.0195E+03	(+)70.77%	7.4875E+01	(-)87.46%
F5	3.4684E+01	6.3812E+00	(-)81.60%	8.7997E+00	(-)74.63%	5.7563E+00	(-)83.40%
F6	2.0897E+03	9.8082E+02	(-)53.06%	1.8991E+03	(-)9.12%	2.6353E+02	(-)87.39%
F7	5.9340E+02	1.0564E+02	(-)82.20%	1.2895E+02	(-)78.27%	7.8344E+01	(-)86.80%
F8	6.2399E+03	1.2453E+03	(-)80.04%	5.8869E+03	(-)5.66%	6.7025E+01	(-)98.93%
F9	1.2393E-04	1.5456E+03	(+)1.2E+07	7.1636E+02	(+)5.8E+06	1.5290E+02	(-)98.77%
F10	2.8222E+04	2.3957E+04	(-)15.11%	2.3199E+04	(-)17.80%	2.2643E+04	(-)19.77%
F11	2.2259E-08	7.7117E+07	(+)3.5E+15	7.8460E+07	(+)3.5E+15	1.6858E+05	(-)99.92%
F12	4.3433E+06	2.1195E+05	(-)95.12%	1.2467E+07	(+)1.9E+00	5.2568E+02	(-)99.99%
F13	7.5326E+02	4.3238E+02	(-)42.60%	4.3049E+03	(+)4.7E+00	5.1147E+01	(-)93.21%
F14	5.8943E+04	5.1767E+06	(+)8.7E+01	6.9788E+04	(+)18.40%	1.9265E+02	(-)99.67%
F15	1.9633E-03	1.7788E+02	(+)9.1E+04	9.4442E+01	(+)4.8E+04	8.3518E+01	(-)95.75%
F16	1.1786E+03	1.4501E+02	(-)87.70%	1.5180E+02	(-)87.12%	7.6292E+01	(-)93.53%
F17	4.6893E+03	1.4724E+03	(-)68.60%	2.3038E+04	(+)391.30%	7.0506E+01	(-)98.50%
F18	1.7904E+05	1.3264E+04	(-)92.59%	1.2750E+06	(+)612.11%	4.4582E+01	(-)99.98%
F19	7.0339E+02	8.3629E+01	(-)88.11%	9.0044E+01	(-)87.20%	7.1137E+01	(-)89.89%
F20	1.3839E+03	1.1590E+03	(-)16.25%	1.1723E+03	(-)15.29%	1.1185E+03	(-)19.18%
F21	1.2423E+04	1.2766E+04	(+)2.76%	1.2476E+04	(≈)0.42%	9.0790E+03	(-)26.92%
F22	2.2579E+03	5.1878E+03	(+)129.76%	5.1408E+03	(+)127.68%	1.9602E+03	(-)13.18%
F23	2.6461E-03	2.3537E+03	(+)8.9E+05	2.4258E+03	(+)9.2E+05	2.2744E+03	(-)14.05%
F24	3.9491E+03	3.2366E+03	(-)18.04%	3.2619E+03	(-)17.40%	3.2048E+03	(-)18.85%
F25	1.0485E+04	7.3484E+03	(-)29.91%	7.7859E+03	(-)25.74%	7.2906E+03	(-)30.47%
F26	2.1389E+03	2.1309E+03	(≈)0.37%	2.1460E+03	(≈)0.33%	2.1121E+03	(-)1.25%
F27	8.5865E-03	5.1106E+03	(+)6.0E+05	5.1323E+03	(+)6.0E+05	4.8482E+03	(-)43.54%
F28	2.9922E+03	7.8054E+03	(+)160.86%	7.7128E+03	(+)157.76%	3.2387E+03	(+)8.24%
F29	2.2889E+08	1.4673E+08	(-)35.90%	1.4672E+08	(-)35.90%	1.4558E+08	(-)36.40%
-/+			17/11		14/13		28/1

Table. S2 PEG strategy vs. VNR strategy vs. PEG+VNR strategy on stability

Func	Base line	PEG		VNR		PEG+VNR	
		Sta.	Gain	Sta.	Gain	Sta.	Gain
F1	2.2599E+09	2.6008E+09	(+)3.2E+02	1.0378E+10	(+)1.3E+03	7.9865E+06	(-)99.65%
F2	3.0191E+04	2.6980E+04	(+)13.88%	3.7716E+05	(+)1.5E+01	2.3691E+04	(-)21.53%
F3	2.5529E+02	9.8105E+01	(+)36.67%	3.0295E+02	(+)322.05%	7.1781E+01	(-)71.88%
F4	4.5386E+01	1.0727E+01	(-)42.07%	1.0195E+03	(+)9.4E+01	1.0727E+01	(-)76.36%
F5	4.1902E+00	1.6716E+00	(+)5.70%	8.7997E+00	(+)456.42%	1.5815E+00	(-)62.26%
F6	3.2476E+02	2.1958E+02	(+)108.49%	1.8991E+03	(+)1.7E+01	1.0532E+02	(-)67.57%
F7	4.0380E+01	1.5084E+01	(+)43.49%	1.2895E+02	(+)1.1E+01	1.0512E+01	(-)73.97%
F8	6.0698E+02	6.8803E+02	(+)2.1E+01	5.8869E+03	(+)1.9E+02	3.1530E+01	(-)94.81%
F9	1.2082E+03	5.5047E+02	(+)5.6E+00	7.1636E+02	(+)7.6E+00	8.3471E+01	(-)93.09%
F10	1.0361E+04	6.3781E+03	(+)16.06%	2.3199E+04	(+)322.13%	5.4957E+03	(-)46.96%
F11	2.8644E+07	5.0383E+07	(+)2.7E+02	7.8460E+07	(-)4.1E+02	1.8877E+05	(-)99.34%
F12	1.1007E+06	2.9586E+05	(+)2.5E+03	1.2467E+07	(+)1.1E+05	1.1858E+02	(-)99.99%
F13	1.3122E+02	1.1967E+01	(-)4.0E+01	4.3049E+03	(-)3.6E+02	1.1967E+01	(-)90.88%
F14	2.5792E+04	7.2654E+06	(+)1.1E+05	6.9788E+04	(+)1.1E+03	6.5233E+01	(-)99.75%
F15	5.3319E+02	8.3320E+01	(+)2.1E+00	9.4442E+01	(+)2.5E+00	2.6655E+01	(-)95.00%
F16	2.4388E+02	6.9082E+01	(+)715.70%	1.5180E+02	(-)1.7E+01	8.4690E+00	(-)96.53%
F17	1.1053E+03	1.0519E+03	(+)6.1E+01	2.3038E+04	(+)1.4E+03	1.6929E+01	(-)98.47%
F18	9.2102E+04	1.8182E+04	(+)9.7E+02	1.2750E+06	(-)6.8E+04	1.8735E+01	(-)99.98%
F19	2.3878E+02	1.0364E+01	(-)44.12%	9.0044E+01	(+)385.44%	1.8549E+01	(-)92.23%
F20	8.0154E+01	6.0804E+01	(-)31.56%	1.1723E+03	(+)1.8E+01	6.0804E+01	(-)24.14%
F21	3.7439E+03	1.0588E+03	(+)6.53%	1.2476E+04	(+)1.2E+01	9.9396E+02	(-)73.45%
F22	4.1633E+01	3.9804E+01	(-)4.84%	5.1408E+03	(+)1.3E+02	3.9804E+01	(-)4.39%
F23	5.8698E+01	4.0591E+01	(-)6.7E-01	2.4258E+03	(-)1.9E+01	1.2264E+02	(+)108.93%
F24	4.8010E+02	1.8197E+02	(+)0.36%	3.2619E+01	(-)1.7E+01	1.8132E+02	(-)62.23%
F25	5.5579E+02	3.2180E+02	(-)12.55%	7.7859E+01	(-)2.0E+01	3.6800E+02	(-)33.79%
F26	5.4790E+01	3.9946E+01	(+)8.65%	2.1460E+03	(+)5.7E+01	3.6767E+01	(-)32.89%
F27	1.5791E+03	6.5594E+02	(-)1.4E-01	5.1323E+01	(-)5.7E+00	7.6610E+02	(-)51.49%
F28	4.8189E+02	3.6966E+02	(+)0.11%	7.7128E+01	(-)2.0E+01	3.6926E+02	(-)23.37%
F29	1.5451E+08	5.5968E+07	(-)1.83%	1.4672E+06	(-)162.15%	5.5968E+07	(-)63.78%
-/+			9/20		10/19		28/1

C The complete experimental results of performance experiments of the probabilistic environmental gradient-driven epigenetic algorithm (PEGA) (D=100, 50, 30, and 10)

The results reported in Tables S1, S2, and S3 were obtained from over 30 runs for each algorithm with 10, 30, 50, and 100 dimensions, solving the 29 benchmark functions of the Congress on Evolutionary Computation-2017 (CEC'17). The performance metrics were established considering the metrics outlined by CEC'17.

$$SNE = 0.1\sum_{i=1}^{29} ne_{10} + 0.2\sum_{i=1}^{29} ne_{30} + 0.3\sum_{i=1}^{29} ne_{50} + 0.4\sum_{i=1}^{29} ne_{100} \tag{S1}$$

where ne is an algorithm's mean error value for a given function and dimension, and SNE is the weighted sum of error values over all functions and dimensions.
where SNE_{min} is the minimal sum of errors among all algorithms. $Score2$ begins as a weighted sum of four sums of ranks (SR) and is computed as shown in Eq. S2.

$$SR = 0.1\sum_{i=1}^{29} rank_{10} + 0.2\sum_{i=1}^{29} rank_{30} + 0.3\sum_{i=1}^{29} rank_{50} + 0.4\sum_{i=1}^{29} rank_{100} \tag{S2}$$

where rank is the algorithm's rank among all algorithms for a given function and dimension based on its mean error value.

Table. S3 Results of comparison on two unimodal and seven multimodal benchmark functions for PEGA and other algorithms

D = 100	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F1	3.38E+06	3.58E+06	**0**	3.67E+09	**0**	1.78E+10	5.82E+09	2.08E+11	1.46E+08	1.97E+11	9.78E+06
F2	1.24E+05	1.00E+03	**0**	9.63E+03	1.68E+05	2.52E+05	9.45E+04	2.69E+05	1.53E+04	2.60E+05	2.28E+05
F3	1.03E+02	7.95E-01	**0**	7.29E+02	**0**	2.19E+03	3.35E+02	4.33E+04	3.33E+01	3.65E+04	1.90E+02
F4	1.70E+02	7.67E+00	**0**	6.37E+02	**0**	3.39E+02	6.48E+02	1.41E+03	4.66E+01	9.26E+02	5.72E+01
F5	2.61E+01	4.65E-01	**0**	1.38E+01	**0**	**0**	2.51E+01	1.14E+02	3.35E+00	7.27E+01	3.73E+00
F6	1.09E+03	6.34E+01	**0**	1.01E+03	**0**	1.45E+03	1.27E+03	9.19E+03	6.71E+02	8.76E+03	1.55E+02
F7	1.64E+02	7.02E+00	**0**	6.38E+02	**0**	3.35E+02	6.82E+02	1.40E+03	4.39E+01	9.11E+02	6.11E+01
F8	4.09E+03	1.06E+01	6.14E+00	1.24E+03	**3.79E+00**	8.42E+03	4.01E+03	6.67E+04	6.25E+01	1.65E+04	6.13E+01
F9	1.28E+04	1.55E+02	**1.09E-10**	1.71E+04	**1.09E-10**	7.08E+03	2.59E+04	3.20E+04	9.94E+02	1.97E+04	1.34E+02
D = 50	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F1	6.69E+02	8.79E+05	**0**	9.61E+08	**0**	9.70E+08	1.06E+09	8.00E+10	6.92E+07	6.65E+10	2.79E+04
F2	3.43E+04	1.17E+02	**0**	2.81E+03	6.65E+04	1.04E+05	2.81E+04	1.12E+05	4.78E+03	1.10E+05	7.06E+04
F3	4.83E+01	2.75E-01	**0**	2.68E+02	**0**	3.78E+02	1.18E+02	1.18E+04	1.49E+01	8.57E+03	3.86E+01
F4	9.25E+01	2.04E+00	**0**	2.32E+02	**0**	6.75E+01	2.39E+02	6.21E+02	1.02E+01	3.30E+02	1.36E+01
F5	2.30E+01	3.37E-01	**0**	9.73E+00	**0**	**0**	1.96E+01	9.55E+01	2.87E+00	5.93E+01	1.32E+00
F6	4.62E+02	2.43E+01	**0**	4.06E+02	**0**	2.30E+02	4.87E+02	3.51E+03	2.83E+02	3.26E+03	6.73E+01
F7	9.05E+01	2.63E+00	**0**	2.35E+02	**0**	8.32E+01	2.34E+02	6.16E+02	1.11E+01	3.20E+02	1.35E+01
F8	1.41E+03	4.91E+00	2.42E+00	3.25E+02	**1.56E+00**	1.20E+03	1.50E+03	2.36E+04	2.51E+01	6.46E+03	4.09E+00
F9	5.96E+03	7.96E+01	**1.82E-11**	6.24E+03	**1.82E-11**	1.26E+03	1.03E+04	1.42E+04	2.30E+02	7.49E+03	1.22E+01
D = 30	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F1	6.95E+02	1.29E+05	**0**	2.94E+08	**0**	1.43E+07	2.07E+08	3.41E+10	3.10E+07	2.37E+10	2.82E+01
F2	7.93E+03	1.10E+01	**0**	1.05E+03	2.20E+04	5.57E+04	9.11E+03	5.62E+04	1.22E+03	5.09E+04	4.27E+04
F3	2.80E+01	3.72E-02	**0**	1.27E+02	**0**	1.20E+02	4.39E+01	3.19E+03	7.24E+00	1.80E+03	2.35E+01
F4	5.08E+01	6.58E-01	**0**	9.31E+01	**0**	2.28E+01	9.75E+01	3.15E+02	2.25E+00	1.60E+02	3.96E+00
F5	1.66E+01	2.23E-01	**0**	6.84E+00	**0**	**0**	1.51E+01	7.89E+01	2.26E+00	5.13E+01	6.61E-01
F6	2.24E+02	8.79E+00	**0**	1.93E+02	**0**	7.32E+01	2.43E+02	1.55E+03	1.38E+02	1.33E+03	3.46E+01
F7	4.93E+01	8.31E-01	**0**	9.47E+01	**0**	1.79E+01	9.66E+01	3.20E+02	2.52E+00	1.57E+02	3.61E+00
F8	7.05E+02	2.48E+00	9.64E-01	1.05E+02	**7.05E-01**	1.08E+02	4.62E+02	9.66E+03	1.18E+01	3.48E+03	1.16E+00
F9	3.34E+03	2.61E+01	**0**	2.57E+03	**0**	3.22E+02	5.02E+03	7.50E+03	4.38E+01	3.97E+03	5.21E+00
D = 10	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F1	3.38E+06	3.58E+06	**0**	3.67E+09	**0**	1.78E+10	5.82E+09	2.08E+11	1.46E+08	1.97E+11	1.07E-02
F2	1.34E-07	1.57E-05	**0**	8.10E+01	1.35E+02	8.76E+03	2.56E+02	7.12E+03	4.98E+00	2.04E+03	2.56E+03
F3	1.03E+02	7.95E-01	**0**	7.29E+02	**0**	2.19E+03	3.35E+02	4.33E+04	3.33E+01	3.65E+04	7.37E+00
F4	1.24E+01	3.89E-03	**0**	2.86E+00	3.60E+00	1.42E+00	1.12E+01	5.66E+01	4.42E-02	2.92E+01	1.78E-06
F5	3.68E+00	4.52E-03	**0**	1.99E+00	**0**	9.85E-01	4.50E+00	3.70E+01	2.83E-01	2.02E+01	3.42E-02
F6	3.05E+01	1.66E-01	**0**	2.93E+01	4.64E+01	1.15E+01	3.86E+01	1.71E+02	4.89E+00	1.17E+02	6.36E+00
F7	1.64E+02	7.02E+00	**0**	6.38E+02	**0**	3.35E+02	6.82E+02	1.40E+03	4.39E+01	9.11E+02	1.64E-06
F8	1.31E+01	7.63E-02	7.46E-02	4.49E+00	8.01E-02	**8.57E-07**	1.30E+01	7.02E+02	1.81E-01	3.38E+02	3.82E-01
F9	1.28E+04	1.55E+02	**1.09E-10**	1.71E+04	**1.09E-10**	7.18E+03	2.59E+04	3.20E+04	9.94E+02	1.97E+04	1.34E+00

Table. S4 Results of comparison on 10 hybrid functions for PEGA and other algorithms

D = 100	ALO	SSA	GSKA	GA	GWO	MSA	PSO	ASO	SSO	ABC	PEGA
F10	5.87E+03	1.36E+01	**1.09E-10**	1.69E+03	1.06E+04	3.91E+04	7.43E+03	6.09E+04	1.18E+03	5.80E+04	2.06E+04
F11	6.27E+07	6.89E+05	**0**	7.32E+08	**0**	8.77E+08	8.57E+08	6.51E+10	3.14E+07	5.58E+10	1.68E+05
F12	6.35E+03	1.36E+05	**0**	2.92E+08	**0**	8.79E+08	2.17E+08	3.48E+10	1.75E+07	3.02E+10	3.83E+02
F13	1.18E+06	7.42E+01	**0**	1.50E+06	**0**	2.01E+03	1.54E+06	1.33E+08	1.19E+05	8.33E+07	3.23E+01
F14	5.98E+03	4.69E+03	**0**	1.05E+08	9.88E-03	2.24E+05	5.13E+07	1.57E+10	6.73E+06	1.25E+10	1.43E+02
F15	5.48E+03	3.01E+01	**4.54E-13**	3.86E+03	7.45E-02	1.20E+03	5.19E+03	1.51E+04	2.56E+02	9.97E+03	5.75E+01
F16	3.30E+03	1.85E+01	**1.13E-12**	2.43E+03	1.72E-03	8.55E+02	3.28E+03	3.43E+04	2.49E+02	1.92E+04	4.77E+01
F17	2.08E+06	1.05E+02	2.95E-12	2.65E+06	**0**	9.79E+02	4.45E+06	2.39E+08	1.75E+05	1.60E+08	4.62E+01
F18	7.98E+04	4.74E+03	6.82E-13	1.08E+08	**0**	9.55E+05	3.57E+07	1.53E+10	7.02E+06	1.25E+10	2.79E+01
F19	2.59E+03	2.34E+01	**6.82E-13**	1.35E+03	5.30E-02	3.53E+02	2.78E+03	4.86E+03	1.27E+02	2.79E+03	3.41E+01
D = 50	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F10	2.81E+02	2.39E+00	**0**	5.25E+02	4.11E+01	1.20E+04	1.68E+03	1.83E+04	5.76E+01	1.51E+04	1.77E+03
F11	1.56E+07	2.81E+04	1.13E-12	1.41E+08	**0**	1.30E+07	1.00E+08	1.89E+10	1.33E+07	1.25E+10	3.21E+02
F12	4.70E+03	2.65E+02	**0**	4.42E+07	**0**	1.42E+04	1.16E+07	8.11E+09	5.30E+06	4.25E+09	1.10E+02
F13	2.10E+05	1.20E+01	2.95E-12	1.03E+05	**0**	1.72E+02	1.75E+05	1.10E+07	5.15E+03	2.55E+06	1.25E+01
F14	3.96E+03	1.65E+01	**0**	1.01E+07	2.12E-02	1.07E+03	1.59E+06	2.10E+09	1.34E+06	5.46E+08	2.34E+01
F15	2.01E+03	7.55E+00	**2.27E-13**	1.02E+03	1.01E-01	1.83E+02	1.64E+03	5.24E+03	9.26E+01	3.09E+03	1.58E+01
F16	1.21E+03	9.35E+00	**0**	6.00E+02	**0**	2.47E+02	1.03E+03	3.98E+03	1.17E+02	2.33E+03	2.45E+01
F17	5.43E+05	1.14E+01	**0**	3.54E+05	3.39E-02	5.38E+02	3.52E+05	3.46E+07	1.71E+04	8.26E+06	1.64E+01
F18	1.13E+05	1.69E+01	**0**	9.52E+06	**0**	5.07E+02	1.60E+06	2.22E+09	1.42E+06	6.18E+08	1.52E+01
F19	9.29E+02	1.25E+01	**1.62E-10**	2.89E+02	5.97E-03	9.22E+01	6.23E+02	1.79E+03	4.70E+01	1.02E+03	1.99E+01
D = 30	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F10	7.41E+01	3.85E-01	**0**	2.06E+02	1.58E+01	1.97E+03	3.33E+02	5.85E+03	2.77E+01	2.89E+03	2.46E+02
F11	4.79E+06	6.42E+02	**0**	3.73E+07	**0**	6.27E+04	1.72E+07	6.02E+09	4.70E+06	1.44E+09	2.42E+02
F12	3.28E+03	2.65E+01	**0**	7.04E+06	**0**	7.43E+02	7.12E+05	1.35E+09	1.33E+06	6.51E+07	2.56E+01
F13	3.35E+04	3.60E+00	**0**	8.47E+03	**0**	4.59E+01	9.70E+03	6.60E+05	5.50E+02	5.87E+04	5.81E+00
F14	3.76E+03	1.73E+00	**0**	7.67E+05	3.03E-02	1.53E+02	5.23E+04	1.93E+08	7.80E+03	6.67E+03	2.45E+01
F15	8.83E+02	2.58E+00	**0**	3.15E+02	2.81E-02	1.13E+02	5.47E+02	2.29E+03	3.53E+01	1.09E+03	8.55E+00
F16	5.77E+02	6.05E+00	**0**	2.01E+02	6.79E+01	3.42E+01	3.05E+02	1.48E+03	6.55E+01	6.72E+02	3.06E+00
F17	1.85E+05	4.89E+00	**0**	6.11E+04	1.77E-02	9.03E+01	8.15E+04	7.21E+06	3.63E+03	3.97E+05	7.70E+00
F18	1.10E+05	3.21E+00	**0**	9.04E+05	**0**	4.34E+01	5.91E+04	1.66E+08	3.18E+04	6.57E+05	1.27E+00
F19	4.26E+02	7.83E+00	**3.43E-09**	1.14E+02	2.98E-03	4.43E+01	2.20E+02	7.52E+02	2.62E+01	4.38E+02	1.22E+01
D = 10	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F10	1.31E+01	4.81E-05	**0**	1.27E+01	3.98E-01	2.30E+00	1.24E+01	1.23E+02	2.72E-01	3.29E+01	1.08E+00
F11	5.63E+05	7.33E-02	**0**	2.6157E+05	**0**	1.14E+01	1.63E+05	4.74E+07	2.61E+03	8.52E+06	6.88E-01
F12	2.88E+03	9.64E-02	**0**	5.53E+02	**0**	8.39E+00	1.43E+03	1.32E+05	1.44E+02	2.69E+04	5.83E+00
F13	5.49E+01	1.28E-01	**0**	3.85E+01	**0**	8.61E+00	8.24E+01	2.04E+02	2.83E+01	5.04E+01	4.41E-01
F14	5.98E+03	4.69E+03	**0**	1.05E+08	9.88E-03	2.24E+05	5.13E+07	1.57E+10	6.73E+06	1.25E+10	1.06E+00
F15	5.48E+03	3.01E+01	**4.54E-13**	3.86E+03	7.45E-02	1.20E+03	5.19E+03	1.51E+04	2.56E+02	9.97E+03	1.57E+00
F16	3.30E+03	1.85E+01	**2.95E-12**	2.43E+03	**0**	9.79E+02	3.28E+03	3.43E+04	2.49E+02	1.92E+04	9.22E-01
F17	2.08E+06	1.05E+02	**1.36E-12**	2.65E+06	4.06E-02	4.26E+04	4.45E+06	2.39E+08	1.75E+05	1.60E+08	7.48E-02
F18	8.81E+01	1.36E-01	**0**	1.49E+01	**0**	1.82E+00	1.08E+02	1.12E+03	8.73E+00	1.88E+01	6.26E-02
F19	5.37E+01	2.06E+00	1.40E-08	2.39E+01	**0**	2.77E+01	5.24E+01	1.14E+02	3.16E+00	6.88E+01	4.87E+00
F20	7.28E+02	1.47E+03	1.19E+03	1.55E+03	1.42E+03	5.60E+02	1.45E+03	2.00E+03	1.36E+03	1.55E+03	**1.15E+02**

Table. S5 Results of comparison on 10 composition benchmark functions for PEGA and other algorithms

D = 100	ALO	SSA	GSKA	GA	GWO	MSA	PSO	ASO	SSO	ABC	PEGA
F20	7.28E+02	1.47E+03	1.19E+03	1.55E+03	1.42E+03	5.60E+02	1.45E+03	2.00E+03	1.36E+03	1.55E+03	**4.62E+02**
F21	1.49E+04	1.36E+04	2.08E+04	2.46E+04	7.28E+03	**7.25E+03**	2.86E+04	3.19E+04	1.32E+04	1.99E+04	8.13E+03
F22	1.46E+03	2.41E+03	2.17E+03	4.27E+03	2.75E+03	1.01E+03	2.68E+03	3.93E+03	2.43E+03	3.41E+03	**7.82E+02**
F23	1.65E+03	2.62E+03	2.31E+03	4.65E+03	3.18E+03	1.21E+03	3.03E+03	5.26E+03	2.96E+03	5.03E+03	**9.58E+02**
F24	**1.22E+03**	1.08E+04	1.24E+03	1.31E+03	5.20E+03	5.33E+03	4.72E+03	4.23E+04	8.74E+03	3.83E+04	1.34E+03
F25	1.18E+04	1.93E+04	1.40E+04	2.18E+04	1.66E+04	6.00E+03	1.55E+04	3.23E+04	2.00E+04	2.93E+04	**3.96E+03**
F26	1.88E+03	2.83E+03	**5.00E+02**	6.74E+03	**5.00E+02**	7.51E+02	3.20E+03	6.33E+03	2.57E+03	5.70E+03	6.68E+02
F27	1.26E+03	1.13E+04	**5.00E+02**	1.19E+04	**5.00E+02**	7.50E+03	4.09E+03	2.61E+04	1.11E+04	2.48E+04	3.02E+03
F28	7.59E+03	1.10E+04	9.09E+03	4.45E+04	1.01E+04	1.95E+03	8.27E+03	6.62E+04	9.63E+03	4.70E+04	**2.05E+03**
F29	1.67E+08	2.46E+09	4.88E+08	1.10E+10	1.46E+09	**1.78E+07**	2.77E+09	2.05E+10	1.26E+09	1.79E+10	1.33E+08
SNE_{100}	2.36E+08	2.47E+09	4.88E+08	1.59E+10	1.46E+09	1.87E+10	9.77E+09	3.60E+11	1.47E+09	3.26E+11	**1.43E+08**
D = 50	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F20	4.07E+02	7.01E+02	5.76E+02	7.12E+02	6.11E+02	**2.88E+02**	6.67E+02	9.63E+02	6.49E+02	6.29E+02	2.92E+02
F21	5.91E+03	3.35E+03	7.19E+03	5.19E+03	1.05E+04	1.58E+03	8.07E+03	1.34E+04	2.71E+03	8.10E+03	**5.97E+02**
F22	6.79E+02	1.06E+03	9.18E+02	1.72E+03	1.16E+03	5.12E+02	1.00E+03	1.61E+03	1.03E+03	1.30E+03	**4.96E+02**
F23	7.87E+02	1.11E+03	1.07E+03	1.87E+03	1.34E+03	6.03E+02	1.27E+03	2.03E+03	1.19E+03	1.79E+03	**5.87E+02**
F24	**6.79E+02**	3.21E+03	6.70E+02	5.03E+03	2.05E+03	9.47E+02	1.38E+03	1.44E+04	2.44E+03	1.16E+04	7.64E+02
F25	4.59E+03	7.17E+03	6.01E+03	9.19E+03	6.84E+03	1.93E+03	6.23E+03	1.23E+04	6.94E+03	1.00E+04	**1.81E+03**
F26	9.62E+02	1.14E+03	**5.00E+02**	3.30E+03	**5.00E+02**	5.38E+02	1.36E+03	2.70E+03	1.19E+03	2.17E+03	5.61E+02
F27	6.24E+02	3.33E+03	**5.00E+02**	4.53E+03	**5.00E+02**	3.18E+03	1.19E+03	8.59E+03	2.50E+03	7.46E+03	8.19E+02
F28	2.98E+03	3.28E+03	3.43E+03	1.08E+04	3.47E+03	**4.66E+02**	2.63E+03	6.44E+03	2.64E+03	4.09E+03	5.61E+02
F29	2.09E+07	2.07E+08	8.13E+07	1.93E+09	5.89E+07	**2.54E+05**	1.06E+08	2.79E+09	5.45E+07	1.10E+09	1.18E+07
SNE_{50}	3.75E+07	2.08E+08	8.13E+07	3.10E+09	5.90E+07	9.83E+08	1.28E+09	1.14E+11	1.45E+08	8.56E+10	**1.20E+07**
D = 30	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F20	2.91E+02	4.11E+02	3.45E+02	3.63E+02	3.81E+02	**2.27E+02**	4.05E+02	5.76E+02	3.78E+02	3.93E+02	2.48E+02
F21	7.06E+02	9.51E+02	**1.37E+02**	1.69E+03	2.41E+03	3.06E+02	9.37E+02	5.16E+03	6.04E+02	4.32E+03	2.41E+02
F22	4.55E+02	6.20E+02	5.68E+02	1.00E+03	6.50E+02	**3.66E+02**	6.27E+02	9.18E+02	6.18E+02	7.42E+02	3.75E+02
F23	5.34E+02	6.83E+02	6.43E+02	1.05E+03	7.60E+02	**4.55E+02**	7.12E+02	1.12E+03	7.08E+02	9.57E+02	4.55E+02
F24	**5.48E+02**	1.05E+03	5.41E+02	2.21E+03	8.77E+02	5.68E+02	6.74E+02	5.07E+03	9.75E+02	3.08E+03	6.11E+02
F25	2.34E+03	3.08E+03	3.00E+03	4.23E+03	3.24E+03	**1.01E+03**	2.65E+03	5.63E+03	3.05E+03	3.84E+03	1.21E+03
F26	6.49E+02	6.38E+02	5.00E+02	1.91E+03	5.00E+02	**4.63E+02**	7.93E+02	1.21E+03	6.89E+02	1.00E+03	4.65E+02
F27	5.36E+02	1.16E+03	**4.98E+02**	1.91E+03	5.61E+02	8.27E+02	9.99E+02	3.16E+03	1.05E+03	2.43E+03	5.76E+02
F28	1.86E+03	1.74E+03	1.54E+03	5.54E+03	1.91E+03	**4.31E+02**	1.32E+03	3.26E+03	1.28E+03	1.91E+03	4.04E+02
F29	5.07E+06	2.16E+07	4.35E+07	7.45E+08	3.45E+06	**1.92E+04**	1.28E+07	4.59E+08	2.69E+06	7.09E+07	4.60E+05
SNE_{30}	1.02E+07	2.18E+07	4.36E+07	1.08E+09	3.48E+06	1.44E+07	2.38E+08	4.24E+10	3.98E+07	2.53E+10	**5.08E+05**
D = 10	**ALO**	**SSA**	**GSKA**	**GA**	**GWO**	**MSA**	**PSO**	**ASO**	**SSO**	**ABC**	**PEGA**
F20	7.28E+02	1.47E+03	1.19E+03	1.55E+03	1.42E+03	5.60E+02	1.45E+03	2.00E+03	1.36E+03	1.55E+03	**1.14E+02**
F21	1.49E+04	1.36E+04	2.08E+04	1.54E+04	2.46E+04	7.28E+03	2.86E+04	3.19E+04	1.32E+04	1.99E+04	**1.03E+02**
F22	1.46E+03	2.41E+03	2.17E+03	4.27E+03	2.75E+03	1.01E+03	2.68E+03	3.93E+03	2.43E+03	3.41E+03	**3.06E+02**
F23	1.65E+03	2.62E+03	2.31E+03	4.65E+03	3.18E+03	1.21E+03	3.03E+03	5.26E+03	2.96E+03	5.03E+03	**2.72E+02**
F24	**4.00E+02**	4.62E+02	4.20E+02	6.75E+02	4.67E+02	4.80E+02	4.44E+02	7.46E+02	4.05E+02	5.16E+02	4.86E+02
F25	2.66E+02	2.90E+02	2.85E+02	4.33E+02	3.95E+02	3.03E+02	2.59E+02	7.90E+02	**2.46E+02**	4.15E+02	2.98E+02
F26	4.44E+02	4.33E+02	4.25E+02	6.83E+02	4.27E+02	4.19E+02	4.58E+02	5.26E+02	4.45E+02	4.94E+02	**4.17E+02**
F27	3.26E+02	4.81E+02	4.12E+02	7.73E+02	3.99E+02	4.17E+02	4.57E+02	7.53E+02	**3.09E+02**	5.83E+02	4.24E+02
F28	7.59E+03	1.10E+04	9.09E+03	4.45E+04	1.01E+04	1.95E+03	8.27E+03	6.62E+04	9.63E+03	4.70E+04	**2.20E+02**
F29	2.30E+04	8.71E+04	6.90E+03	1.16E+06	6.72E+03	3.47E+05	9.27E+03	1.15E+06	1.12E+03	1.80E+05	**4.24E+02**
SNE_{10}	6.11E+06	3.70E+06	4.39E+04	3.78E+09	5.06E+04	1.78E+10	5.88E+09	2.24E+11	1.53E+08	2.09E+11	**5.66E+03**