**TABLE I** Benchmark Functions

|  |  |  |  |
| --- | --- | --- | --- |
| Benchmark function | Dim | Range | Actual optimal value |
|  | 30 | [-100,100] | 0 |
|  | 30 | [-10,10] | 0 |
|  | 30 | [-100,100] | 0 |
|  | 30 | [-100,100] | 0 |
|  | 30 | [-1.28,1.28] | 0 |
|  | 30 | [-100,100] | 0 |
|  | 30 | [-100,100] | 0 |
|  | 30 | [-5.12,5.12] | 0 |
|  | 30 | [-32,32] | 0 |
|  | 30 | [-600,600] | 0 |
|  | 30 | [-10,10] | 0 |
|  | 30 | [-4,5] | 0 |
|  | 2 | [-100,100] | 0 |
|  | 2 | [-5,5] | 0 |
|  | 4 | [-5,5] | 0.00030 |
|  | 4 | [0,10] | -10.1532 |
|  | 4 | [0,10] | -10.4029 |
|  | 4 | [0,10] | -10.5364 |
|  | 3 | [0,1] | -3.86278 |
|  | 6 | [0,1] | -3.32237 |

**TABLE II** Parameters Setting of Six Algorithms

|  |  |
| --- | --- |
| Algorithm | Parameters setting |
| CSO | *G*=10,*rPercent*=0.15,*hPercent*=0.7,*mPercent*=0.5 |
| WOA | *a*=2 |
| CSA | *AP*=0.1, *fl*=2 |
| MISCSA | *AP*=0.1, *fl*=2, *a1*=0.4, *a7*=0.7, |
| SCACSA | *AP*=0.1, *fl*=2 |
| PCSA | *AP*=0.1, *fl*=2 |

**TABLE III** Comparison of Experimental Results of Six Algorithms

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | Index | CSO | WOA | CSA | MISCSA | SCACSA | PCSA |
|  | Best | 9.96E-51 | 5.94E-170 | 3.36E-02 | 1.24E-33 | 2.55E-172 | **0.00E+00** |
| Worst | 8.20E-40 | 6.11E-145 | 2.89E-01 | 6.20E-30 | 1.16E-133 | 0.00E+00 |
| Mean | 2.97E-41 | 2.04E-146 | 9.52E-02 | 8.69E-31 | 3.85E-135 | 0.00E+00 |
| Std | 1.50E-40 | 1.12E-145 | 5.40E-02 | 1.54E-30 | 2.11E-134 | 0.00E+00 |
| time(s) | 0.27614 | 0.08135 | 0.07729 | 0.09217 | 0.08727 | 0.09271 |
|  | Best | 3.76E-42 | 2.22E-116 | 5.00E-01 | 2.06E-17 | 3.58E-88 | **2.65E-285** |
| Worst | 2.47E-37 | 8.22E-101 | 5.17E+00 | 2.04E-15 | 1.49E-69 | 2.15E-274 |
| Mean | 1.03E-38 | 2.74E-102 | 2.18E+00 | 5.72E-16 | 5.05E-71 | 1.09E-275 |
| Std | 4.48E-38 | 1.50E-101 | 1.12E+00 | 5.38E-16 | 2.72E-70 | 0.00E+00 |
| time(s) | 0.27999 | 0.09253 | 0.08151 | 0.09308 | 0.09393 | 0.08205 |
|  | Best | 1.88E+02 | 2.29E+03 | 6.49E+00 | 9.67E-32 | 2.08E-175 | **0.00E+00** |
| Worst | 1.38E+04 | 4.14E+04 | 2.35E+02 | 6.60E-28 | 1.69E-130 | 0.00E+00 |
| Mean | 6.11E+03 | 1.87E+04 | 7.92E+01 | 3.93E-29 | 5.72E-132 | 0.00E+00 |
| Std | 2.86E+03 | 9.69E+03 | 5.43E+01 | 1.20E-28 | 3.08E-131 | 0.00E+00 |
| time(s) | 0.77918 | 0.45541 | 0.11227 | 0.12772 | 0.12274 | 0.24721 |
|  | Best | 1.71E-02 | 2.71E-02 | 1.93E+00 | 2.20E-17 | 6.20E-93 | **3.11E-28** |
| Worst | 3.99E+01 | 8.79E+01 | 7.86E+00 | 2.67E-15 | 1.49E-67 | 7.03E-271 |
| Mean | 1.68E+01 | 4.01E+01 | 4.48E+00 | 5.02E-16 | 5.28E-69 | 2.35E-272 |
| Std | 1.26E+01 | 2.53E+01 | 1.36E+00 | 6.38E-16 | 2.72E-68 | 0.00E+00 |
| time(s) | 0.27408 | 0.08350 | 0.08288 | 0.09938 | 0.09421 | 0.08813 |
|  | Best | 3.02E-03 | 2.85E-06 | 1.52E-02 | 2.90E-06 | **1.65E-06** | 2.35E-06 |
| Worst | 3.41E-01 | 8.02E-03 | 7.17E-02 | 2.63E-04 | 1.85E-04 | 1.66E-04 |
| Mean | 4.43E-02 | 1.68E-03 | 3.79E-02 | 7.57E-05 | 6.85E-05 | 5.80E-05 |
| Std | 7.10E-02 | 1.96E-03 | 1.62E-02 | 6.02E-05 | 5.20E-05 | 4.26E-05 |
| time(s) | 0.45180 | 0.24577 | 0.23028 | 0.25321 | 0.23849 | 0.22972 |
|  | Best | 2.88E-50 | 1.37E-171 | 6.96E+02 | 1.95E-30 | 2.15E-177 | **0.00E+00** |
| Worst | 3.33E-40 | 1.88E-149 | 4.64E+03 | 8.04E-26 | 2.09E-130 | 0.00E+00 |
| Mean | 1.20E-41 | 9.85E-151 | 2.59E+03 | 4.74E-27 | 6.97E-132 | 0.00E+00 |
| Std | 6.06E-41 | 3.53E-150 | 9.31E+02 | 1.48E-26 | 3.82E-131 | 0.00E+00 |
| time(s) | 0.27184 | 0.08026 | 0.08039 | 0.09568 | 0.09141 | 0.09088 |
|  | Best | 7.59E-54 | 4.18E-147 | 1.66E+04 | 6.56E-29 | 9.61E-160 | **0.00E+00** |
| Worst | 1.55E-41 | 2.29E-146 | 1.62E+05 | 5.09E-26 | 5.05E-135 | 0.00E+00 |
| Mean | 1.67E-42 | 7.72E-148 | 5.73E+04 | 6.69E-27 | 1.94E-136 | 0.00E+00 |
| Std | 3.96E-42 | 4.18E-147 | 3.20E+04 | 1.21E-26 | 9.20E-136 | 0.00E+00 |
| time(s) | 0.40889 | 0.21761 | 0.23176 | 0.25570 | 0.24653 | 0.23773 |
|  | Best | **0.00E+00** | **0.00E+00** | 1.59E+01 | **0.00E+00** | **0.00E+00** | **0.00E+00** |
| Worst | 5.14E+01 | 1.14E-13 | 5.47E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mean | 2.97E+00 | 7.58E-15 | 2.96E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Std | 1.05E+01 | 2.88E-14 | 9.13E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| time(s) | 0.30666 | 0.09256 | 0.10848 | 0.11773 | 0.09942 | 0.09184 |
|  | Best | 4.44E-15 | **8.88E-16** | 2.41E+00 | **8.88E-16** | **8.88E-16** | **8.88E-16** |
| Worst | 7.99E-15 | 7.99E-15 | 6.67E+00 | 8.88E-16 | 8.88E-16 | 8.88E-16 |
| Mean | 6.45E-15 | 3.97E-15 | 3.92E+00 | 8.88E-16 | 8.88E-16 | 8.88E-16 |
| Std | 1.79E-15 | 2.42E-15 | 1.17E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| time(s) | 0.32502 | 0.10055 | 0.11940 | 0.12705 | 0.09479 | 0.09479 |
|  | Best | **0.00E+00** | **0.00E+00** | 1.60E-01 | **0.00E+00** | **0.00E+00** | **0.00E+00** |
| Worst | 2.40E-01 | 9.90E-02 | 3.97E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mean | 1.24E-02 | 6.06E-03 | 2.68E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Std | 4.64E-02 | 2.32E-02 | 6.36E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| time(s) | 0.34186 | 0.13270 | 0.13356 | 0.14209 | 0.11222 | 0.10164 |
|  | Best | 2.07E-42 | 9.73E-119 | 1.50E-02 | 1.25E-18 | 2.64E-86 | **3.14E-28** |
| Worst | 8.13E-01 | 1.84E+01 | 1.71E+00 | 1.48E-16 | 2.75E-69 | 3.52E-274 |
| Mean | 3.32E-02 | 6.12E-01 | 4.86E-01 | 4.52E-17 | 1.04E-70 | 1.23E-275 |
| Std | 1.48E-01 | 3.35E+00 | 4.86E-01 | 3.76E-17 | 5.04E-70 | 0.00E+00 |
| time(s) | 0.31094 | 0.09479 | 0.11047 | 0.12545 | 0.10963 | 0.10587 |
|  | Best | 3.86E-05 | 1.57E-28 | 4.18E-01 | 4.14E-35 | 2.36E-167 | **0.00E+00** |
| Worst | 1.30E+01 | 5.88E-06 | 3.16E+00 | 7.40E-31 | 9.54E-127 | 0.00E+00 |
| Mean | 5.81E-01 | 8.64E-07 | 1.42E+00 | 8.33E-32 | 3.18E-128 | 0.00E+00 |
| Std | 2.43E+00 | 1.58E-06 | 6.96E-01 | 1.64E-31 | 1.74E-127 | 0.00E+00 |
| time(s) | 0.37175 | 0.16269 | 0.17107 | 0.18609 | 0.18846 | 0.15704 |
|  | Best | **0.00E+00** | **0.00E+00** | **0.00E+00** | **0.00E+00** | **0.00E+00** | **0.00E+00** |
| Worst | 0.00E+00 | 9.72E-03 | 9.72E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mean | 0.00E+00 | 4.21E-03 | 3.78E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Std | 0.00E+00 | 4.90E-03 | 4.74E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| time(s) | 0.27740 | 0.06521 | 0.08219 | 0.11864 | 0.09338 | 0.08699 |
|  | Best | **0.00E+00** | 1.77E-181 | 7.91E-28 | 3.59E-44 | 3.52E-187 | **0.00E+00** |
| Worst | 3.83E-320 | 1.88E-142 | 5.27E-24 | 1.56E-39 | 2.27E-155 | 0.00E+00 |
| Mean | 1.80E-321 | 6.26E-144 | 8.35E-25 | 1.66E-40 | 7.84E-157 | 0.00E+00 |
| Std | 0.00E+00 | 3.43E-143 | 1.38E-24 | 3.70E-40 | 4.15E-156 | 0.00E+00 |
| time(s) | 0.28687 | 0.07564 | 0.08717 | 0.10760 | 0.09171 | 0.08391 |
|  | Best | **0.00030** | 0.00031 | **0.00030** | 0.00032 | 0.00031 | **0.00030** |
| Worst | 1.44E-03 | 1.50E-03 | 1.22E-03 | 1.92E-03 | 5.93E-04 | 7.23E-04 |
| Mean | 7.84E-04 | 7.72E-04 | 3.42E-04 | 6.08E-04 | 3.98E-04 | 4.71E-04 |
| Std | 2.67E-04 | 4.13E-04 | 1.68E-04 | 4.06E-04 | 8.19E-05 | 1.36E-04 |
| time(s) | 0.28858 | 0.08215 | 0.08560 | 0.11194 | 0.10244 | 0.09211 |
|  | Best | **-10.1532** | -10.1530 | **-10.1532** | **-10.1532** | -10.1485 | **-10.1532** |
| Worst | -2.5451 | -0.8810 | -2.6827 | -2.6305 | -9.4385 | -9.8122 |
| Mean | -7.9585 | -8.5677 | -9.4865 | -8.9189 | -10.0027 | -5.0552 |
| Std | 3.0143 | 2.7737 | 2.0661 | 2.3491 | 0.1734 | 1.2931 |
| time(s) | 0.32372 | 0.13174 | 0.10453 | 0.12424 | 0.11532 | 0.10711 |
|  | Best | **-10.4029** | -10.4028 | **-10.4029** | **-10.4029** | -10.3974 | **-10.4029** |
| Worst | -2.5729 | -2.7652 | -2.7519 | -5.0629 | -9.9586 | -10.3582 |
| Mean | -7.6505 | -9.2596 | -9.9721 | -9.8696 | -10.2954 | -10.3997 |
| Std | 3.2988 | 2.3530 | 1.6690413 | 1.6272 | 0.10855 | 0.010089 |
| time(s) | 0.35400 | 0.14406 | 0.10811 | 0.12797 | 0.11882 | 0.11286 |
|  | Best | **-10.5364** | -10.5363 | **-10.5364** | **-10.5364** | -10.5316 | **-10.5364** |
| Worst | -2.3816 | -2.4217 | -4.0699 | -4.5284 | -9.4017 | -10.4136 |
| Mean | -8.6362 | -7.8370 | -10.3209 | -9.4141 | -10.3302 | -10.5300 |
| Std | 2.9711 | 3.4269 | 1.18063 | 2.2847 | 0.2497 | 0.0233 |
| time(s) | 0.47307 | 0.18881 | 0.12651 | 0.15039 | 0.13612 | 0.13808 |
|  | Best | **-3.86278** | **-3.86278** | **-3.86278** | **-3.86278** | **-3.86278** | **-3.86278** |
| Worst | -3.84982 | -3.85151 | -3.86278 | -3.86278 | -3.86261 | -3.86278 |
| Mean | -3.86191 | -3.85985 | -3.86278 | -3.86278 | -3.862713 | -3.86278 |
| Std | 0.00250 | 0.00345 | 3.15E-15 | 1.78E-14 | 5.06E-05 | 8.08E-09 |
| time(s) | 0.37199 | 0.10535 | 0.10179 | 0.12554 | 0.11857 | 0.10761 |
|  | Best | -3.32194 | -3.32196 | **-3.32237** | **-3.32237** | -3.32221 | **-3.32237** |
| Worst | -3.10175 | -2.84040 | -3.20316 | -3.15547 | -3.29373 | -3.20121 |
| Mean | -3.23330 | -3.22261 | -3.31839 | -3.27484 | -3.18678 | -3.31003 |
| Std | 0.06295 | 0.12362 | 0.02176 | 0.06415 | 0.04861 | 0.03646 |
| time(s) | 0.38439 | 0.10736 | 0.10838 | 0.13052 | 0.13757 | 0.12349 |

**TABLE IV** Location and Demand of Materials

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| City ID | (*Xi,Yi*) | Supply and demand(t) | City ID | (*Xi,Yi*) | Supply and demand (t) |
| 1 | (1304, 2312) | 20 | 16 | (3715, 1678) | 80 |
| 2 | (3639, 131·5) | 90 | 17 | (3918, 2179) | 90 |
| 3 | (4177, 2244) | 90 | 18 | (4061, 2370) | 70 |
| 4 | (3712, 1399) | 60 | 19 | (3780, 2212) | 100 |
| 5 | (3488, 1535) | 70 | 20 | (3676, 2578) | 50 |
| 6 | (3326, 1556) | 70 | 21 | (4029, 2838) | 50 |
| 7 | (3238, 1229) | 40 | 22 | (4263, 2931) | 50 |
| 8 | (4196, 1044) | 90 | 23 | (3429, 908) | 80 |
| 9 | (4312, 790) | 90 | 24 | (3507, 2376) | 70 |
| 10 | (4386, 570) | 70 | 25 | (3394, 2643) | 80 |
| 11 | (3007, 1970) | 60 | 26 | (3439, 201) | 40 |
| 12 | (2562, 1756) | 40 | 27 | (2935, 3240) | 40 |
| 13 | (2788, 1491) | 40 | 28 | (3140, 3550) | 60 |
| 14 | (2381, 1676) | 40 | 29 | (2545, 2357) | 70 |
| 15 | (1332, 695) | 20 | 30 | (2778, 2826) | 50 |

**TABLE V** Comparison of Location Performance of Four Algorithms

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Algorithm | Site selection scheme | Optimal fitness value | Average fitness value | Running time (S) |
| PCSA | [6,28,21,18,13,10] | 1.22E-25 | 6.26E-04 | 2.5 |
| CCA | [27,12,18,5,9,25] | 3.21E-06 | 0.3843 | 28.4 |
| HPSA | [24,9,12,27,5,18] | 4.26E-04 | 1.2267 | 30.2 |
| MOA | [5,27,9,20,17,12] | 5.14E-08 | 0.0432 | 7.3 |