**Table 4** Comparison results of CCMSCSA with ten conventional algorithms

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **F1** |  |  | **F2** | |  |  | **F3** |  | |
|  | Avg | Std |  | | Avg | Std |  | Avg | Std |
| CCMSCSA | 0.0000E+00 | 0.0000E+00 |  | | 0.0000E+00 | 0.0000E+00 |  | 0.0000E+00 | 0.0000E+00 |
| SMA | 0.0000E+00 | 0.0000E+00 |  | | 0.0000E+00 | 0.0000E+00 |  | 3.7694E-03 | 5.8038E-03 |
| HGS | 0.0000E+00 | 0.0000E+00 |  | | 0.0000E+00 | 0.0000E+00 |  | 0.0000E+00 | 0.0000E+00 |
| WOA | 0.0000E+00 | 0.0000E+00 |  | | 2.5837E+01 | 4.3056E+01 |  | 4.7107E+00 | 1.2589E+01 |
| GWO | 0.0000E+00 | 0.0000E+00 |  | | 5.5878E-181 | 0.0000E+00 |  | 6.5907E-151 | 2.7863E-150 |
| SCA | 1.0514E-59 | 3.3409E-59 |  | | 3.9383E+00 | 1.7967E+01 |  | 7.7140E-02 | 2.8961E-01 |
| PSO | 4.7437E+01 | 6.4603E+00 |  | | 1.8765E+02 | 2.2914E+01 |  | 3.8596E+00 | 2.3621E-01 |
| DE | 1.2057E-94 | 9.3672E-95 |  | | 1.3904E+03 | 5.1862E+02 |  | 4.6808E-15 | 7.5810E-15 |
|  | **F4** |  |  | **F5** | |  |  | **F6** |  | |
|  | Avg | Std |  | | Avg | Std |  | Avg | Std |
| CCMSCSA | 5.6427E+02 | 2.2107E+02 |  | | 6.1499E+02 | 2.9613E+00 |  | 8.2130E+02 | 8.1719E+00 |
| SMA | 3.2165E+04 | 7.5885E+03 |  | | 6.2437E+02 | 2.2788E+00 |  | 9.6456E+02 | 2.6675E+01 |
| HGS | 1.0391E+04 | 7.1230E+03 |  | | 6.1823E+02 | 3.7642E+00 |  | 8.0422E+02 | 4.8932E+00 |
| WOA | 3.5364E+04 | 2.3401E+04 |  | | 6.3559E+02 | 3.2879E+00 |  | 9.8440E+02 | 4.0958E+01 |
| GWO | 2.9663E+04 | 1.0159E+04 |  | | 6.1281E+02 | 2.9453E+00 |  | 8.7626E+02 | 1.8265E+01 |
| SCA | 3.7428E+04 | 5.0035E+03 |  | | 6.3387E+02 | 2.5367E+00 |  | 1.0426E+03 | 1.8790E+01 |
| PSO | 9.9276E+02 | 1.2677E+02 |  | | 6.2304E+02 | 3.5038E+00 |  | 9.7773E+02 | 2.0655E+01 |
| DE | 4.3255E+02 | 1.5073E+02 |  | | 6.1874E+02 | 1.9633E+00 |  | 8.0070E+02 | 6.8276E-01 |
|  | **F7** |  |  | **F8** | |  |  | **F9** |  | |
|  | Avg | Std |  | | Avg | Std |  | Avg | Std |
| CCMSCSA | 1.4918E+03 | 2.8916E+02 |  | | 1.4003E+03 | 4.6942E-02 |  | 1.6108E+03 | 7.4710E-01 |
| SMA | 4.5630E+03 | 5.6360E+02 |  | | 1.4045E+03 | 3.3803E+00 |  | 1.6118E+03 | 4.2879E-01 |
| HGS | 1.2118E+03 | 1.6227E+02 |  | | 1.4008E+03 | 3.1526E-01 |  | 1.6110E+03 | 7.3223E-01 |
| WOA | 4.9055E+03 | 6.5275E+02 |  | | 1.4003E+03 | 1.4729E-01 |  | 1.6127E+03 | 4.2714E-01 |
| GWO | 3.2241E+03 | 7.4388E+02 |  | | 1.4028E+03 | 4.9845E+00 |  | 1.6109E+03 | 6.8057E-01 |
| SCA | 6.9897E+03 | 5.4900E+02 |  | | 1.4449E+03 | 8.8649E+00 |  | 1.6128E+03 | 2.3686E-01 |
| PSO | 5.2329E+03 | 5.5266E+02 |  | | 1.4003E+03 | 8.9269E-02 |  | 1.6118E+03 | 4.5070E-01 |
| DE | 1.0169E+03 | 6.2904E+00 |  | | 1.4003E+03 | 6.4904E-02 |  | 1.6114E+03 | 3.1629E-01 |
|  | **F10** |  |  | **F11** | |  |  | **F12** |  | |
|  | Avg | Std |  | | Avg | Std |  | Avg | Std |
| CCMSCSA | 3.1422E+03 | 2.2953E+03 |  | | 2.6085E+03 | 5.5985E+02 |  | 2.5000E+03 | 0.0000E+00 |
| SMA | 1.6579E+05 | 1.7170E+05 |  | | 1.9657E+04 | 1.1621E+04 |  | 2.5000E+03 | 0.0000E+00 |
| HGS | 1.1733E+04 | 7.7923E+03 |  | | 6.0634E+03 | 3.1436E+03 |  | 2.5000E+03 | 0.0000E+00 |
| WOA | 1.4322E+04 | 3.4046E+04 |  | | 2.3394E+04 | 1.1933E+04 |  | 2.6265E+03 | 2.4479E+01 |
| GWO | 1.1452E+07 | 2.1835E+07 |  | | 1.6261E+04 | 6.6657E+03 |  | 2.6318E+03 | 7.2507E+00 |
| SCA | 1.3973E+08 | 7.7986E+07 |  | | 1.6640E+04 | 7.6115E+03 |  | 2.6688E+03 | 1.7418E+01 |
| PSO | 2.1671E+06 | 4.5393E+05 |  | | 2.3346E+03 | 8.2197E+01 |  | 2.6160E+03 | 4.3308E-01 |
| DE | 7.5484E+03 | 4.7535E+03 |  | | 4.8226E+03 | 1.3837E+03 |  | 2.6152E+03 | 1.3876E-12 |
|  | **F13** |  |  | **F14** | |  |  | **F15** |  | |
|  | Avg | Std |  | | Avg | Std |  | Avg | Std |
| CCMSCSA | 2.6000E+03 | 0.0000E+00 |  | | 3.2702E+03 | 5.6388E+02 |  | 4.7562E+03 | 4.3323E+03 |
| SMA | 2.6000E+03 | 0.0000E+00 |  | | 1.6217E+04 | 2.0544E+04 |  | 1.8416E+04 | 2.3792E+04 |
| HGS | 2.6000E+03 | 1.3282E-04 |  | | 3.8555E+03 | 2.3179E+03 |  | 3.2937E+03 | 5.1295E+02 |
| WOA | 2.6052E+03 | 3.9250E+00 |  | | 5.6848E+06 | 4.7230E+06 |  | 1.0346E+05 | 6.8623E+04 |
| GWO | 2.6000E+03 | 6.3833E-04 |  | | 5.3507E+05 | 1.2181E+06 |  | 4.0283E+04 | 2.1808E+04 |
| SCA | 2.6001E+03 | 3.9574E-02 |  | | 1.3699E+07 | 7.4902E+06 |  | 2.2782E+05 | 9.6717E+04 |
| PSO | 2.6289E+03 | 7.4924E+00 |  | | 7.3744E+04 | 1.0726E+05 |  | 1.3463E+04 | 5.3254E+03 |
| DE | 2.6263E+03 | 2.2850E+00 |  | | 6.7434E+03 | 9.9666E+03 |  | 6.2531E+03 | 1.5995E+03 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Overall Rank** | | | |  | | |  |  |  |
|  | Rank | +/=/- | AVG |  | |  | |  |  |  |
| CCMSCSA | 1 | ~ | 1.5333 | |  | |  |  |  |  |
| SMA | 4 | 11/4/0 | 4.3333 | |  | |  |  |  |  |
| HGS | 2 | 6/6/3 | 2.4000 | |  | |  |  |  |  |
| WOA | 7 | 13/2/0 | 6.0667 | |  | |  |  |  |  |
| GWO | 4 | 12/2/1 | 4.3333 | |  | |  |  |  |  |
| SCA | 8 | 15/0/0 | 7.2000 | |  | |  |  |  |  |
| PSO | 6 | 13/1/1 | 5.2667 | |  | |  |  |  |  |
| DE | 3 | 12/0/3 | 3.6667 | |  | |  |  |  |  |

**Table 5** The p-values of CCMSCSA versus other conventional algorithms

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | SMA | HGS | WOA | GWO | SCA | PSO | DE |
| F1 | 1.0000E+00 | 1.0000E+00 | 1.0000E+00 | 1.0000E+00 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 |
| F2 | 1.0000E+00 | 1.0000E+00 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 |
| F3 | 1.2207E-04 | 1.0000E+00 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 |
| F4 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 4.7292E-06 | 1.5658E-02 |
| F5 | 1.7344E-06 | 2.2551E-03 | 1.7344E-06 | 6.8359E-03 | 1.7344E-06 | 2.1266E-06 | 5.2165E-06 |
| F6 | 1.7344E-06 | 2.1266E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 |
| F7 | 1.7344E-06 | 1.4773E-04 | 1.7344E-06 | 1.9209E-06 | 1.7344E-06 | 1.7344E-06 | 1.9209E-06 |
| F8 | 1.7344E-06 | 2.3534E-06 | 1.2544E-01 | 5.3197E-03 | 1.7344E-06 | 2.9894E-01 | 4.8603E-05 |
| F9 | 1.0246E-05 | 1.9861E-01 | 1.7344E-06 | 4.5281E-01 | 1.7344E-06 | 5.7517E-06 | 2.8308E-04 |
| F10 | 1.7344E-06 | 2.8786E-06 | 3.7243E-05 | 3.5152E-06 | 1.7344E-06 | 1.7344E-06 | 1.7988E-05 |
| F11 | 1.7344E-06 | 3.1817E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 4.7162E-02 | 2.6033E-06 |
| F12 | 1.0000E+00 | 1.0000E+00 | 2.5631E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 4.3205E-08 |
| F13 | 1.0000E+00 | 7.8125E-03 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 |
| F14 | 2.4414E-03 | 3.1250E-01 | 1.7181E-06 | 1.7344E-06 | 1.7344E-06 | 3.4053E-05 | 2.3534E-06 |
| F15 | 3.5994E-03 | 3.1250E-02 | 1.7344E-06 | 1.7344E-06 | 1.7344E-06 | 1.4936E-05 | 6.8359E-03 |